OPTIMIZATION OF BALANCE OF PLANT BUILDINGS THROUGH A DATABASE OF BUILDING COMPONENTS

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Major Project

Submitted in partial fulfillment of the requirements
For the degree of

Master of Technology in Civil Engineering
(Computer Aided Structural Analysis & Design)

By

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May 2008

CERTIFICATE

This is to certify that the Major Project entitled "Optimization of Balance of Plant Buildings Through a Database of Building Components" submitted by Mr. Bagga Raja I.(06MCL001), towards the partial fulfillment of the requirements for the degree of Master of Technology in Civil Engineering (Computer Aided Structural Analysis and Design) of Nirma University of Science and Technology, Ahmedabad is the record of work carried out by him under my supervision and guidance. In my opinion, the submitted work has reached a level required for being accepted for examination. The results embodied in this major project, to the best of my knowledge, haven't been submitted to any other university or institution for award of any degree or diploma.

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ABSTRACT

Power plants have structures such as storage sheds, pipe rack, service building, diesel generator building, electrical building, compressor building, and fire water pump house building. Selection of buildings required to maintain the balance of power plant has been done for study, as they are necessary in all power plant buildings for their proper and efficient functioning.

Power plant layout is generalized and if another plant of same capacity is to be constructed at a different location, then attempt is made that same layout can be used. As layout of the plant remains the same, the only change exists in structural configuration i.e. roof level, foundation level, bay width, etc. of various balance of plant buildings. Also the variation in topography, affects the design in respect of variation in seismic zone. The majority of balance of plant buildings are moment resisting framed structures; the combination of seismic load with dead load is governing, so here an attempt has been made to study effect of brick infills in framed structures. Here a comparison of bare frames and buildings with brick infills has been done, so as to develop template to start with preliminary design. Also push over analysis on 1 to 2 buildings will be performed to study the behavior of Balance of Plant buildings.

This report includes introduction to power plants, which further explains classification of power pants, different loading and design considerations. To understand behavior of different power plant buildings, a hypothetical building with various structural configuration and different seismic zone has been considered and has been modeled using SAP software. The push over analysis on 1 to 2 buildings has been done and its results are tabulated. Analysis and Design for various members of the building has been carried out using Indian Standards.

In this piece of work, an attempt has been made to study the behavior of buildings with bare frames and with brick infills. The pushover analysis has been introduced in B.O.P. buildings. Also the results obtained by performing push over analysis have been presented.

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ABBREVIATION NOTATION AND NOMENCLATURE

ADRS	Acceleration-Displacement Response Spectra
A_h	Design Seismic horizontal Co-efficient
A_r	Opening area ratio
B.O.P.	Balance of Plant
C_A	Seismic co-efficient
C_V	Seismic co-efficient
C_{VX}	Vertical distribution factor
d	Base dimension of the building at the plinth level,
d	Diagonal length of infill
DL	Dead Load
d_{pi}	Maximum structural displacement
E_D	Energy dissipated by damping
E_{fe}	Expected modulus of elasticity of frame material
E_m	Modulus of elasticity of masonry
E_{me}	Expected modulus of elasticity of infill material
EQX	Earthquake Load in X-direction
EQY	Earthquake Load in Y-direction
E_{So}	Maximum strain energy
FEMA	Federal Emergency Management Agency
f_m	Compressive strength of masonry prism
h	Height of the building
h_{col}	Column height between centerlines of beams
h_{inf}	Column height between centerlines of beams
I	Importance factor
I_{col}	Moment of inertia of column
k	Exponent related to the structure period
L_{inf}	Length of infill panel
LL	Live Load
M.I.	Masonry Infill
N	Level which is the uppermost portion of the structure
PF_1	Modal participation factor
R	Response Reduction factor
R.C.	Reinforced Concrete

r_{inf}	Diagonal length of infill panel
S_a	Spectral acceleration
S_a/g	Average Response Acceleration Co-efficient
SAP	Structure Analysis Program
S_d	Spectral displacement
SR_A	Spectral acceleration factor
S_v	Spectral velocity
T	Time period
t_{inf}	Thickness of infill panel and equivalent strut
u.d.l.	Uniformly distributed load
V_b	Total design lateral force
W	Seismic Weight of the building
w_{do}	Width of equivalent diagonal strut for infill walls with openings
w_{ds}	Width of equivalent diagonal strut for solid walls without any openings
Z	Zone factor
α_1	Modal mass coefficient
β_{eff}	Effective viscous damping
Δ_{roof}	Roof displacement
θ	Angle whose tangent is the infill height to length aspect ratio
λ_1	Coefficient used to determine equivalent width of infill strut
ρ_w	Reduction factor
Φ_{i1}	Amplitude of mode 1 at level i along the considered direction of lateral force

1. INTRODUCTION

1.1 GENERAL

Energy is an important input in all sectors of any country's economy. Power plants utilize sources of energy to generate electricity. The availability of various sources of energy affects the choice of power plants. The power plants are built to supply electricity to cities and industries and thus they play important role in generating revenue of the country. The availability of materials, pollution and future extension affect the selection of site for power plants. Typical process flow diagram of a power plant has been shown below in Fig. 1.1.

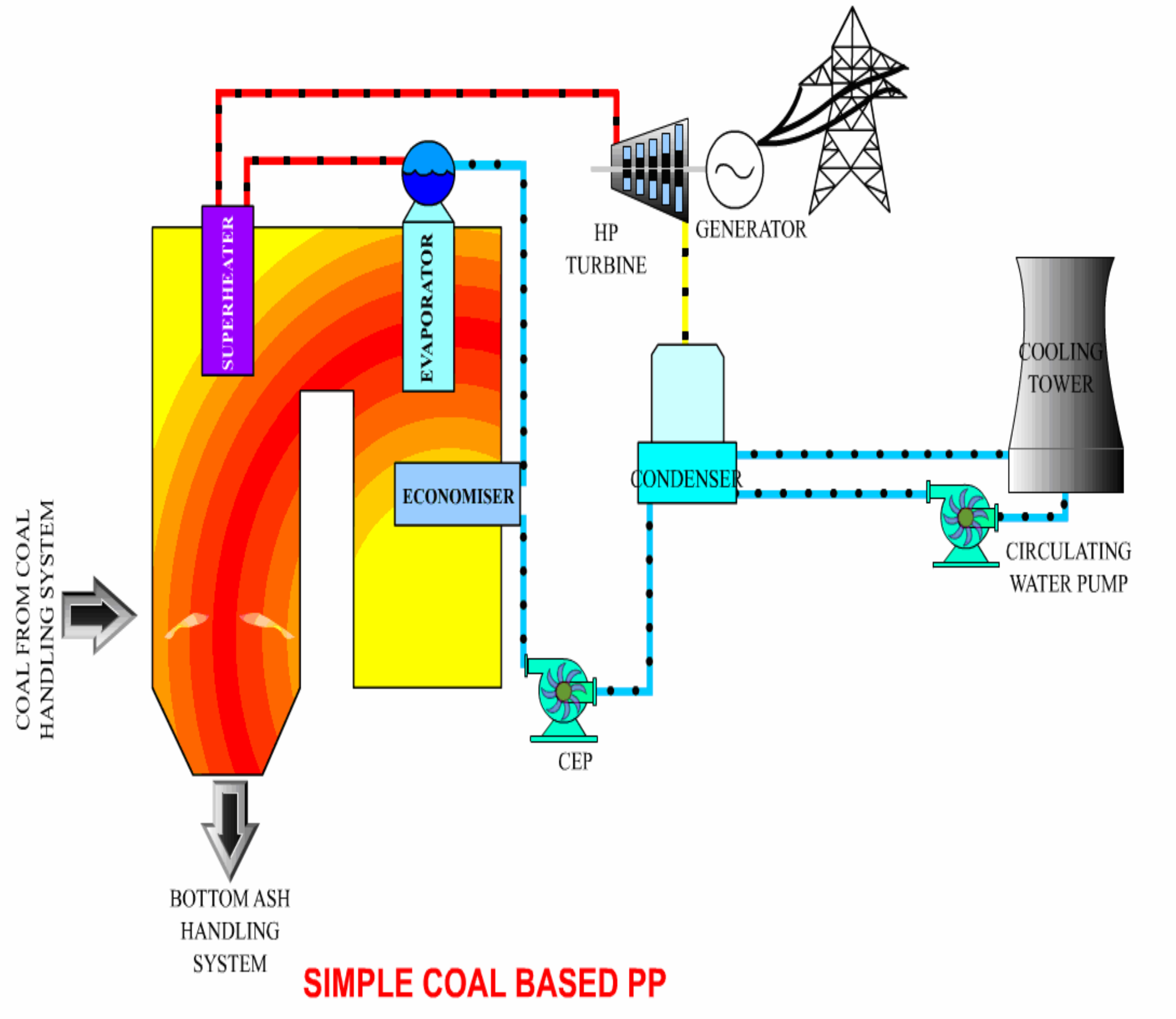


Fig.1.1 Typical Process Flow Diagram of Power Plant

A power plant is an assembly of systems or subsystems to generate electricity i.e. power with economy and requirements. The power plant itself must be useful economically and environmental friendly to the society. The power plant supplies electricity to industrial areas and helps them to grow financially, and generate revenues for the country. Power plant design and system planning require consideration of both engineering design and economics. The progress of any country is judged on the basis of its economic growth which depends on the availability of electricity. Cost effective power plant design is vital for the engineering design firm. Firms and engineers having the ability and reputation for designing reliable, low-cost power plants & systems are sought in the increasingly competitive environment. There exists enormous opportunities for the engineers and firms who are able to compete with the growing electric utility industry.

Various working groups of the steering committee on energy sector for the 10th five year plan projected an average primary commercial energy demand growth rate of 5.74% per year for the two forthcoming five year plans. In view of (a) the increased emphasis on energy efficiency and energy conservation, (b) an expected higher contribution of the service sector to the GDP in future and (c) the impact of information technology and e-commerce, the steering committee came up with a lower figure of 4.25% per year for the demand growth rate.

The Energy and Resources Institute (TERI) carried out an analysis of the Indian energy scenario and suggested strategies for sustainable development. In their base case scenario the primary energy growth rate was taken as 4.4% per year during the period 1997-2019 and 3.6% per year during the period 2020-2047. For electricity, the corresponding growth rates were 5.7% per year and 3.9% per year. In the alternative scenario, growth rates are smaller, 3.7% per year and 3.0% per year for the primary energy and 5.1% per year and 3.4% per year for electricity. Both of these scenarios assume a very large dependence on imports, which is projected to increase from about 20% in the year 1997 to about 70% in the year 2047 in the base scenario and 60% in the alternative scenario.

The International Energy Outlook 2002 (IEO) of the United States predicts for India a reference primary energy consumption growth rate of 3.6% per year during the period 1997 to 2020. The high and low growth scenarios correspond to 4.5% per year and 2.6% per year respectively. For the electricity consumption, the three corresponding growth rates for the above period are 3.8% per year, 4.5% per year and 2.6% per year.

Under the project "A Long-term Perspective on Environment and Development in the Asia-Pacific Region" of the Environment Agency of the Government of Japan the primary energy consumption growth rates, for India, were projected to be 3.9% per year till the year 2025, 2.6% per year till the year 2050 and 1.8% per year till the year 2100 under their high estimate category. Similar growth rates have been assumed for India in another study "US-Japan Energy Cooperation to Help Achieve Sustainable Development in Asia".

The primary and electricity energy growth rate forecasts made by the Institute of Energy Economics of Japan (IEEJ), for India, are 5.2% per year and 5.4% per year respectively for the forthcoming twenty years.

In India, Central Electricity Authority (CEA) undertakes periodic electric power surveys (EPS) to make projections of the energy requirements of the country. CEA released its report on the 16th electric power survey in January 2001 and projected electricity growth requirement, for the period 1997-2012, to be about 6.5% per year and 7.4% per year in its two scenarios.

1.1.1 Definition

"Power plant is an assembly of equipments that produces and delivers mechanical and electrical energy."

1.2 CLASSIFICATION OF POWER PLANT

Power plants are mainly classified depending on fuel used for power generation.

- Steam Power Plant

The steam power plants use solid fuel or coal in the pulverized form in burners or furnace oil in oil burners. The steam is produced in the boilers, and is expanded in steam turbines, which are coupled to electric generators, thus generating electricity.

- Diesel Power Plant

A diesel power plant is more efficient than any other heat engine of comparable size. These plants are cheap by way of initial cost, can be started and stopped quickly and can burn a wide range of fuels. The diesel engine is coupled directly to the generator and electricity is generated.

- Hydro-Electric Power Plant

Water is obstructed and stored behind a dam at an elevation in case of hydroelectric power stations. The potential energy of water is converted to mechanical energy by allowing the water to flow through water turbines. The generators are coupled to water turbines hence generating electricity.

- Nuclear Power Plant

The heat in the nuclear power plants is generated by the splitting of uranium atoms in the reactor. A cooling medium takes up this heat and delivers it to the reactor and heat exchanger, where the steam for the turbine is raised. The generators are coupled to turbines hence generating electricity.

- Gas Turbine Power Plant

In gas turbine power plants, the prime mover is the gas turbine and the working medium is the gas. The compressed air (with the help of compressor) is supplied in combustion chamber, where hot gases are generated, which is expanded in gas turbine to produce mechanical power. The gas turbine is connected to alternator to generate electric power.

1.3 POWER PLANT UNITS UNDER STUDY

The following units of power plant buildings will be covered under the study.

1.3.1 Storage Shed

The storage shed is used to store concrete material, spares, etc. and sometimes even coal which is required as a fuel in coal based power plants. The coal storage is essential as it prevents the complete shutdown of power plant occurring from failure of normal supplies and permits choice of the date of purchase allowing the management to take advantage of seasonal market conditions. The storage of coal protects the plant failure in case of coal strikes, failure of the transportation system and coal shortages. Coal storage is normally sized to have capacity of 1.25 million tons or 200 MW capacity plant. The coal is stored at a site located on solid ground, well drained, free of standing water, preferable on high ground not subjected to flooding. A moment resisting framed structure is designed to cover an area of 65 m $\times$ 12m and having an overall height of 6m approximately.

1.3.2 Electrostatic Precipitator Control Room

The ash particles are separated from the flue gases coming out of the boiler by the electrostatic precipitator. The precipitator has two sets of electrodes, which are insulated from each other and between which the 'flue gases' are made to pass. The dust particles are ionized as the gas passes through the electric field and are attracted by the collecting electrode, which is grounded. The dust falls off the electrode when it is given a shaking motion. The control room controls the functioning of the electrostatic precipitator control room. A moment resisting framed structure is designed to cover an area of 45 m $\times$ 10 m and having an overall height of 8 m approximately.

1.3.3 Fuel Oil Pumping And Heating Unit

The fuel oil is pumped in the combustion chamber so as to help in the ignition process. A structure is designed to accommodate the fuel oil pump and heating unit. A moment resisting framed structure is designed to cover an area of 20 m $\times$ 10 m and having an overall height of 6.5 m approximately. It is one of the important B.O.P. buildings.

1.3.4 Fuel Oil Transfer Pumphouse

The fuel oil from the fuel tanker is pumped into the fuel tank so as to help in the ignition process. A structure is designed to accommodate the fuel oil transfer pump house. The number of pumps and their individual capacity affects the size of shed required to support the pumphouse. A moment resisting framed structure is designed to cover an area of 20 m $\times$ 10 m and having an overall height of 6.5 m approximately.

1.3.5 Chlorination Tank

The chlorination of water is essential so as to facilitate the demineralization of water. A structure is designed to store the chlorination tank. A moment resisting framed structure is designed to cover an area of approximately 20 m $\times$ 28m and having an overall height of 6m. The chlorinated water is used for various requirements in the power plant and also prevents scaling of boiler.

1.3.6 Demineralized Tank And Pump House

The raw water obtained from the source is supposed to be demineralized so as to prevent the scaling of boilers. A moment resisting framed structure is designed to cover an area of 12 m × 6m and having an overall height of 6m approximately.

1.3.7 Service Building

The service building is provided for various utilities in the power plants like site visits, reception, etc. A moment resisting framed structure is designed to cover area of 35 m × 15 m and having an overall height of 8 m approximately.

1.3.8 Diesel Generator Building

Diesel is required to generate electricity in the building during startup and shutdown. Also during blackout, diesel is required for electricity generation. This diesel so required is stored in a tank so a structure is designed to accommodate the tank. A moment resisting framed structure is designed to cover an area of 15 m × 10 m and having an overall height of 7 m approximately.

1.3.9 Compressor House

A compressor should be able to handle a relatively large volume of air or working media and delivering it with the highest possible efficiencies. The compressor should be such that it can be coupled to the turbine shaft which runs at very high speed. The structure designed to accommodate the compressors is called as the compressor house. The compressor house serves as a shed for placing various mechanical equipments. A moment resisting framed structure is designed to cover an area of 20 m × 15 m and having an overall height of 7 m approximately.

1.3.10 Condensate Storage Tank And Pumphouse

The condensed water obtained after the condensation process from the turbine is stored in a tank and is pumped to the cooling tower with the help of pumps. A structure is designed to store the storage tank and pump house. The size of pump house depends on the capacity of power plant. A moment resisting framed structure is designed to cover an area of 5 m × 6 m and having an overall height of 8 m approximately.

1.3.11 Fire Water Pumphouse

The water required so as to prevent the accidents due to fire breakdown is stored in a tank and a pump is attached. A structure containing pumps is called fire water pump house. A moment resisting framed structure is designed to cover an area of 40 m $\times$ 20 m and having an overall height of 7.5 m approximately.

1.3.12 Raw Water Area –Electrical Building

The electrical equipment related to raw water handling is located in this building. A moment resisting framed structure is designed to cover an area of 35 m $\times$ 8 m and having an overall height of 7.5 m approximately.

It is observed that most of the buildings mentioned above are single storeyed moment resisting framed structures and so all the above structures are approximated as having fixed size of bays and the other building parameters like roof height, depth of foundation, width of building and width of bay are varied.

1.4 TYPICAL PROCESS FOR BALANCE OF PLANT BUILDINGS

A definite work process is followed for design of any Balance of Plant (will now be referred as B.O.P.) building so that a definite performance objective is achieved. The main purpose of the work process is to provide the basic guidelines for the deliverable items to be error free and is within the estimated cost so that the budget of the project is met. Also the scope of work and the specification should be accomplished within the target time. The following basic guidelines are required to be followed for successful completion of design as per scope of work.

- The depth of the beam is required to be checked for functional requirement as well as headroom clearance.
- The size of the column is required to be checked with respect to accessibility requirements as indicated in architectural drawings.
- All the interface issues are required to be solved before proceeding for detail analysis and design to avoid rework.
- The analysis and design methodology should be verified with the Lead engineer and necessary approval for preferential sections and material to be used during analysis and design should be obtained from the contractor.

- The loads are required to be verified before the loads are furnished to structural department for further design.
- Finally, it is required to check that the 3d models for the building structure are completed in all respect.
- The validated software should be used with its output verified rationally.

1.5 OBJECTIVE OF STUDY

Structures in B.O.P. area of power plants are generally designed as reinforced concrete moment resisting framed structures. The reason why only R.C. buildings have been taken for study is that labor cost in India for R.C. is less compared to steel. Also, based on study of drawings of recently executed projects, it has been observed that most of them are R.C. buildings with brick cladding. Here the above mentioned structures are selected for study, as they are required in each and every power plant. Power plant layout for particular capacity is generalized and if another plant of same capacity is to constructed at different location, then attempt is made that same layout can be used. As layout of plant is almost the same, the size of B.O.P. building remains same; the only change is in topography and capacity, which affect the design in respect of variation in seismic zone.

In this study, an attempt has been made to focus on introduction of brick infills and study its impact on cost implications as compared to bare frames which is generally used. Also, pushover analysis will be introduced in B.O.P. buildings and will be performed on 1 to 2 buildings to study its affect. With keeping others factors such as building geometry, importance factor fixed in order to provide a more consistent basis for comparison. Also by varying the parameters like depth of foundation, roof level, zone, bay with and width of foundation so that estimation of quantities, sizes can be done easily. Parametric study has been carried out to study behavior of various power plant buildings considering bare frames and buildings with infills walls and on the basis of analysis the optimum designs are worked out. Also, with the advance analysis tools and techniques, which are still not applied in many plant designs, a comparative analysis is attempted. Since seismic engineering is going more and more advanced, an attempt is made to study the cost impact on power plant structure. The plan of the building considered for modeling of brick infills and pushover analysis has been shown in Fig. 1.2.

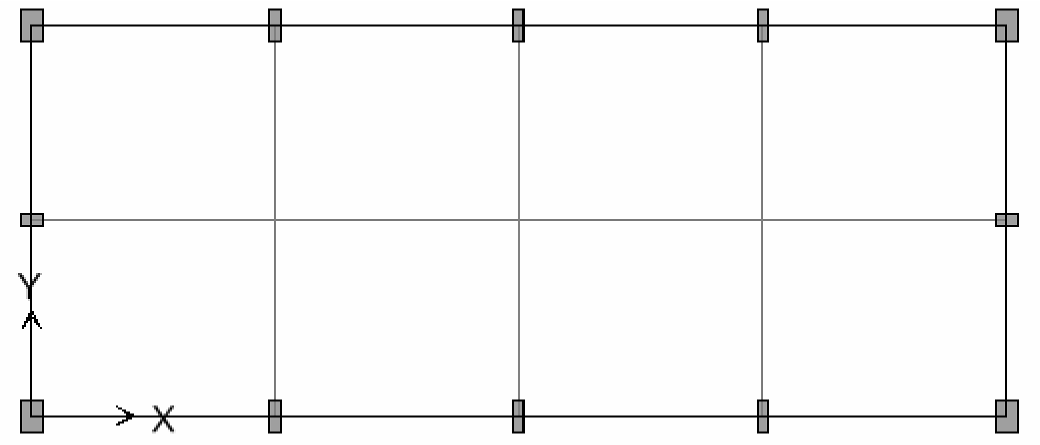


Fig. 1.2 Plan of the Building under Study

Based on the study conducted, it has been observed that in order to prepare the database for design of power plant buildings, it is required to create the buildings with the variations of depth of foundation, roof level, variation in design seismic force, bay width and width of building as mentioned in Table 1.1.

Table 1.1 Parameters Under Study

Bay width m	Width of building m	Foundation Level m	Height m	A_h %
5	6	3	5	10
6	8	4	6	15
8	10	5	8	20

The combination of the above mentioned parameters has been considered for the preparation of data base. For example, for bay width equal to 5 m, the width of the building has been taken as 6 m, 8m and 10m, the foundation level has been taken as 3m, 4m and 5m, the height of the building has been taken as 5m, 6m and 8m, while the percentage of design horizontal seismic coefficient has been taken as 10%, 15% and 20%. Thus, the total number of buildings required to be analyzed and designed is 150. The combinations have been discussed in detail in chapter 4. The results of the database shall be utilized for proposal engineering in order to estimate the quantity for various structural components.

As mentioned above, very high value of A_h has been assumed because it has been observed in earlier projects undertaken by L&T-S&L, that the value of time period using code formula as mentioned in Equation 1.1 with reference to Clause 7.6.2 of IS 1893 : (Part I)-2002[9] mostly lies between 0 to 0.8s.

$$T_a = \frac{.09h}{\sqrt{d}} \qquad ...(1.1)$$

Where,

h = height of the building in m

d = base dimension of the building at the plinth level, in m, along the considered direction of lateral force

As per the Clause 6.4.5, IS: 1893 (Part I)-2002[9], response spectra for 5% damping are presented in Fig. 1.3 for three subsurface soil profiles.

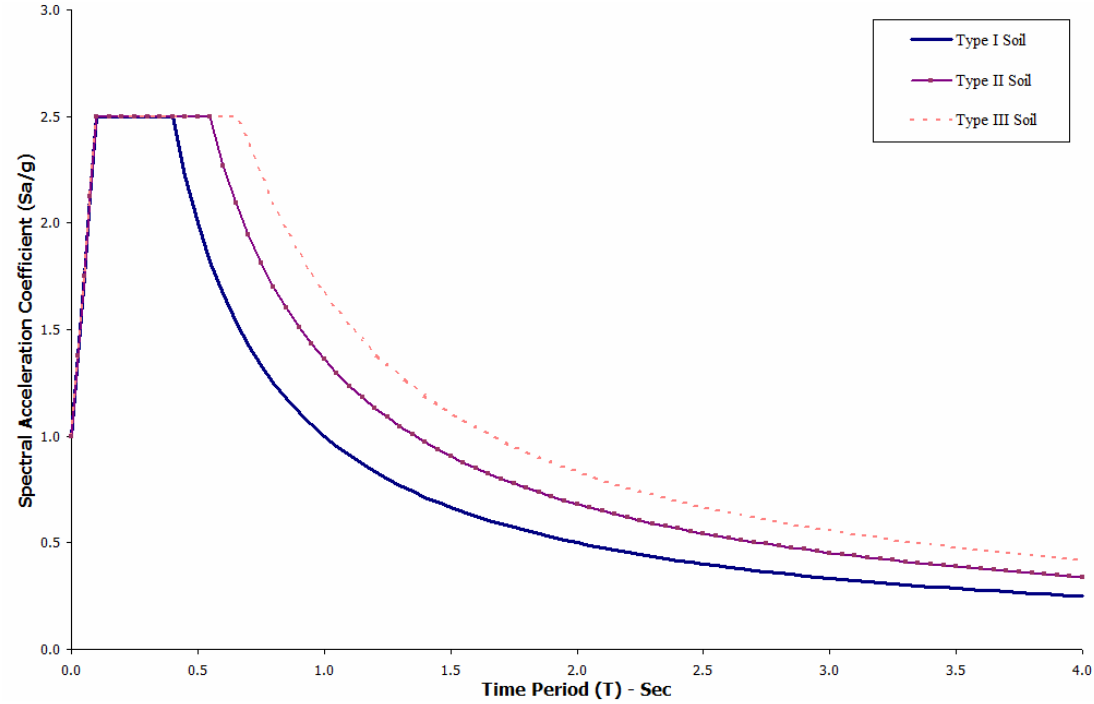


Fig. 1.3 Response Spectra for Rock, Medium and Soft Soil Sites for 5% Damping

The value of Spectral Acceleration Co-efficient for all types of soils gives a consistent value of 2.5. The design horizontal seismic coefficient A_h for a structure can be determined from the following Equation 1.2 with reference to Clause 6.4.2 of IS: 1893 (Part I)-2002.

$$A_h = \frac{ZIS_a}{2Rg} \qquad ...(1.2)$$

Where,

Z = Zone factor

I = Importance factor

S_a/g = Average response acceleration coefficient

R = Response reduction factor

The following values are assumed in order to evaluate the above Equation 1.2.

I = 1.5, S_a/g = 2.5, R = 5 and the value of Z has been taken as per the zone as mentioned in Table 1.2.

Table 1.2 Comparison of A_h Value

Seismic Zone	Zone Factor	A_h
II	.10	.0375
III	.16	.06
IV	.24	.09
V	.36	.135

Therefore as observed from Table 1.2, the value of design horizontal spectrum co-efficient varies between 10 to 15%. In certain specific buildings executed earlier by L&T-S&L, a high value of A_h has been taken, so a study with range of 10 to 20% is being conducted.

1.6 SCOPE OF WORK

The following scope of work has been decided as a part of Major Project.

- Developing a Visual Basic Tool for rapid generation of model.
- Analysis and design of Balance of Plant buildings.
- Preparing a database of building components for Balance of Plant buildings.
- Rapid estimation of concrete quantity and steel quantity for preliminary as well as detailed engineering.
- Study of equivalent diagonal strut approach suggested by FEMA-273[7] and Sudhir K Jain et al.[6].
- Introduction of brick infills in some Balance of Plant buildings to study its impact on cost.
- Parametric study of bare frames and infilled frames.
- Study of pushover analysis and its practical application to B.O.P. buildings and interpretation of results.

1.7 ORGANIZATION OF MAJOR PROJECT

Chapter-1, begins with the introduction of power plants and its classification. It also states the various components of power plants and its basic functioning. It highlights the various R.C. power plant buildings covered under the present study followed by a topic of utmost importance, i.e. scope and objectives of the present study.

Chapter-2, includes the literature available and study done in past on R.C. power plant buildings, especially on introduction of brick infills. It also includes certain literature available on pushover analysis on various R.C. power plant buildings.

Chapter-3, gives detail analysis and design of certain R.C. power plant buildings, which includes the modeling of power plant buildings in SAP 2000, load calculation, also the design of various structural components using I.S. codes.

Next chapter, i.e. **Chapter-4,** includes interpretation of results along with preparation of data base for power buildings by varying the structural parameters like width of building, width of bay, foundation level, roof top, etc. and size of various components is obtained on its basis and guidelines will be presented for quick estimation of structural quantities for proposals and detailed engineering.

Chapter-5, gives introduction of brick infills in power plant buildings along with its application considering variations in building parameters and its effect on sizes of components long with its comparison with bare frames. The chapter focuses on impact of modeling brick infills in power plant buildings from analysis point of view.

Chapter-6, includes introduction of pushover analysis and underlines various concepts of pushover analysis. It also deals with introduction of pushover analysis in 1 or 2 power plant buildings using SAP 2000 software and SAP 2000 output for analysis. The chapter deals with application of pushover analysis to power plant buildings and solution of a practical problem.

Finally **Chapter-7**, gives summary and conclusion of the present work, which is followed by future scope of work.

2. LITERATURE SURVEY

2.1 GENERAL

This section includes, brief review of various books, papers, journals on the behavior of R.C. buildings in power plants. The literature review is aimed to understand how buildings are idealized, modeled, analyzed and its design philosophies.

2.2 LITERATURE REVIEW

Black and Veatch [1] describe the basic concept of working of power plants and the working of different components of process plant and planning of power plants. The book explains the various mechanical processes which takes part in the power plants and also highlights the general requirements for structure layout. It covers the most common fundamentals of power plant engineering, maintenance and operational considerations. It also provides theoretical background of the various processes which occur in a power plant.

G.D. Rai [2] provides a wealth of information regarding concepts, theories and procedures of power plant engineering and the fuel handling systems and the usage of various types of fuels in power plants. It focuses on the classification of types of power plants.

In the experimental and analytical study carried out by **Diptesh Das et al. [3]** on brick masonry infills in reinforced concrete buildings, an attempt is made to understand the behavior of infilled walls under earthquake loading. They suggest the use of equivalent braced frame method and report that infill walls decrease storey drifts and increases stiffness and strength of structure. In the study, the bare frame analysis and design without assistance from infill walls and frame analysis with assistance from infill walls for a typical three-storey residential building, with five bays in the longitudinal direction and three in the transverse direction is considered. They also evaluate the available provisions in various codes with a view to identify design methodologies that exploit the benefits of infills in a rational manner, for improving the contribution of these infills and for reducing the detrimental effects.

Mohammad Aliaari et al. [4] presents details and results of an experimental study conducted to evaluate the performance of a proposed infill wall fuse system and suggest that infill walls act as sacrificial fuses in buildings; also the infill walls help in taking the forces initially. They conclude that in case of the tight fit construction, the presence of infill walls, increases the in plane stiffness of the structure, decreases its fundamental period, and leads to large earthquake forces.

Hemant B Kaushik et al. [5] review and compare the provisions for masonry infill reinforced concrete frames in various national codes. They suggest that masonry infill walls confined by reinforced concrete frames on all four sides play a vital role in resisting the lateral seismic loads on buildings. They find that most of the codes agree that M.I.-R.C. frame buildings require special requirement, and they specify clauses on several issues related to such buildings, but they differ greatly in specifications on the individual clauses. They suggest that M.I. walls which are normally very stiff initially attract most of the lateral forces, so the R.C. frames must have sufficient backup strength to avoid the collapse of the structure. They finally conclude that event though most of the codes agree that infill walls require special treatment, but they differ greatly in specification of individual cases, and they recommend a comprehensive design code for M.I.-R.C. frames, as a significantly large number of buildings belongs to this category.

Sudhir K Jain et al. [6] propose draft provisions and commentary on Indian Seismic Code IS 1893 (Part 1) as a part of ongoing project on building codes sponsored by Gujarat State Disaster Management Authority, Gandhinagar at Indian Institute of Technology Kanpur. They suggest the equivalent single diagonal strut approach for structural modeling of brick infills. They present an empirical relationship for evaluating the equivalent width of diagonal strut for soild walls and perforated walls.

FEMA-273 [7] provides information regarding the concepts, theories and procedures used to model brick infills in bare frames. The document suggests the use of equivalent diagonal strut approach to model brick infills. It also presents the empirical relation required to calculate the width of equivalent diagonal strut. It also discusses the behavior of bare frames and infilled frames under the influence of lateral earthquake loads. It illustrates the load transfer mechanism for bare frames and infilled frames with necessary sketches. It also provides technically sound and acceptable guidelines for the seismic rehabilitation of buildings. The document discusses the various performance levels in detail and also various concepts related to pushover analysis. It also provides necessary guidelines for the retrofitting of existing buildings.

FEMA-356 [8] provides information regarding the concepts of linear as well as non-linear analysis. The document also discusses the seismic rehabilitation process along with its objectives. It also presents general analysis requirements for non-linear methods along with its acceptance criteria. It also provides tables for various modeling parameters and acceptance criteria related to structural components for nonlinear procedures.

Ashraf Habibullah et al. [9] provides information on practical application of 3 dimensional nonlinear static Pushover Analysis to building frames using SAP 2000 graphical user interface. They discuss the various steps involved in performing push over analysis using SAP 2000.

ATC-40 [10] provides a wealth of information regarding concepts, theories and procedures of nonlinear static analysis. The document provides consolidated guideline for building owners, building officials, architects and engineers and incorporates two related concepts i.e. evaluation of building performance and use of non linear analysis techniques to address the seismic evaluation and retrofit of concrete buildings. The document emphasizes the use of nonlinear static procedures in general and focuses on the capacity spectrum method. The document also presents the step by step procedure to determine the capacity and demand. It discusses the application of pushover analysis in evaluating the performance of existing buildings and verifying the design of seismic retrofits. The chapter concludes by providing example of various procedures discussed in the chapter.

Apart from the literature review mentioned above, as this project is being done at a power plant engineering esteemed company like L&T-S&L, a thorough study of buildings for recently executed project was conducted. It was found that about

20 out of 30 buildings were BOP buildings. Also there exist certain similarities, like most of them were single storeyed RC moment resisting framed structures and were mostly designed to accommodate the equipment. While studying the geometry of building and its design parameters, certain variations in most of the structures were observed like depth of foundation, roof level, soil bearing capacity, variation in design seismic force, bay width and width of building. Also it was learnt that the B.O.P. buildings were modeled as bare frames without considering the strength and stiffness of the infills.

2.3 SUMMARY

In this chapter, review of relevant literature is carried out. In the literature review, concepts of brick infill modeling are presented. Also the literature relevant to non-linear pushover analysis is presented. These concepts are useful to understand the behavior of B.O.P. buildings during occurrence of seismic event.

3. ANALYSIS AND DESIGN OF SINGLE STOREYED BUILDINGS FOR POWER PLANTS

3.1 GENERAL

This chapter focuses on structural modeling, analysis and design of power plant buildings. The SAP 2000 text input file (*.$2k) file has been generated with the help of a program, using Microsoft Excel which has been linked with Visual Basic. The file thus generated has been imported in SAP 2000 to generate the relevant structural configuration, loading, etc. The analysis of power plant buildings has been carried out using SAP 2000 software and the design has been done according to relevant Indian standards.

3.2 INPUT-OUTPUT IN VISUAL BASIC

It was realized that it is difficult to create the building models with the earlier stated variation in a stipulated time, as the time required for modeling a single building along with necessary assignments like loading, member properties, etc would be more. Therefore a need aroused to develop tool which could model the building easily with minimum effort, thus saving time, which could otherwise be used for modeling of building. In order to accelerate the work and perform quick analysis and design, a Microsoft Excel Macro has been made. The Macro could generate 900 odd lines of SAP 2000 *.$2k file within split of second, based on the varied parameters like preliminary dimensions, preliminary sizes of various components entered in Microsoft Excel. Thus with bare minimum input, this macro could generate the complete Input file compatible to SAP 2000 *.$2k file including node definitions, member definitions and member properties, loading, analysis.

3.2.1 Generation of Frame Data

For developing a model in SAP 2000, it is necessary to generate the grid data for which Visual Basic is used. The Fig. 3.1 screenshot indicates the basic input like building dimensions, columns sizes and beams at different levels with reference to respective groups, slab thickness, thickness of masonry, density, etc.

In this chapter modeling, analysis and design of a single storey framed structure is presented. The entry of basic input data generates the x, y and z co-ordinate of each node in the output file generated in excel. The dead load has been calculated by the Visual Basic module. The preliminary dimensions have been assigned to each member and also the dead load and live load have been assigned to each member according to the group assigned to each member. The earthquake load has been assigned to each node through Visual Basic program pertaining to calculations as per IS: 1893 (Part I)-2002[13]. By simply clicking on the frame button the frame is generated with all the frame member and node definitions. The next step is to click on the SAP FILE button so as to generate the *.$2k file.

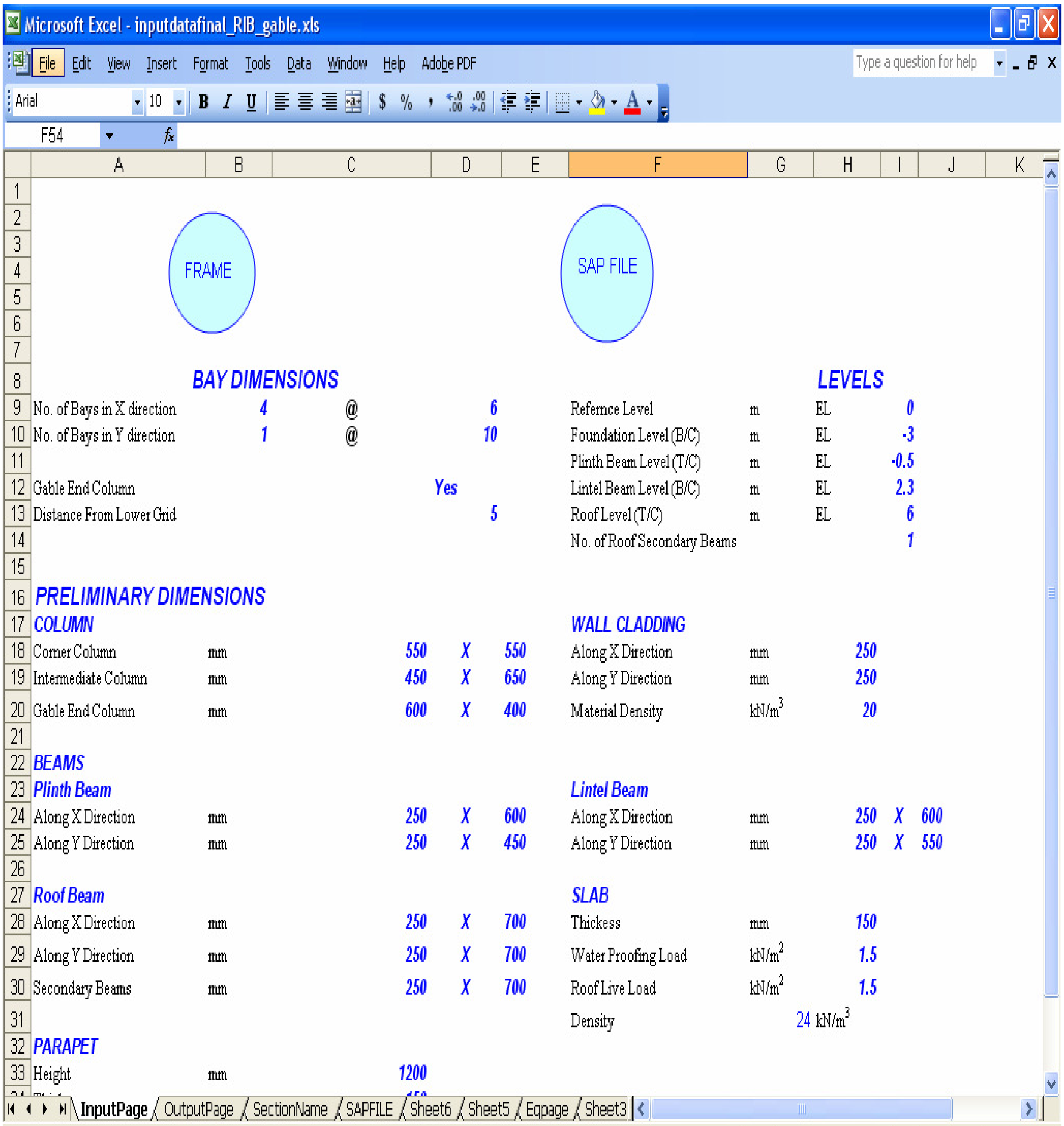
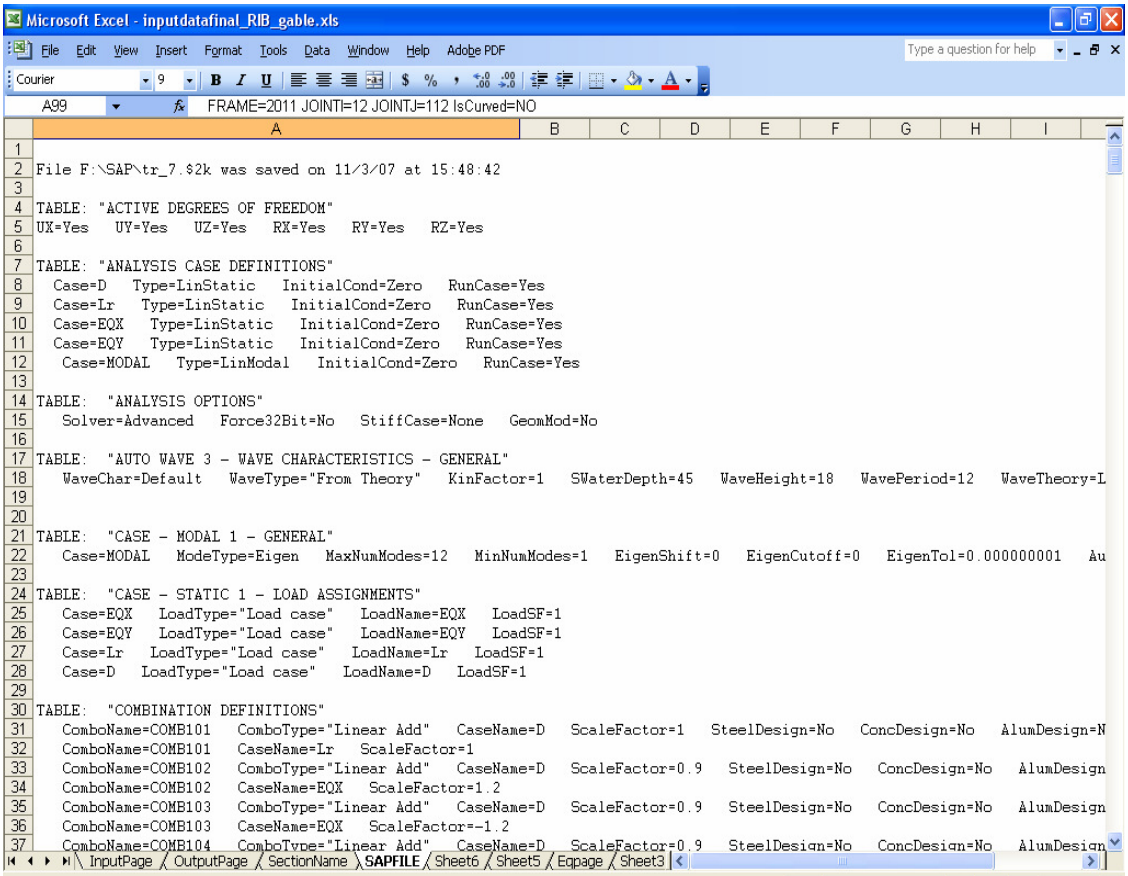


Fig.3.1 Initial Input to Generate the Frame Data

3.2.2 GENERATION OF SAP 2000 INPUT FILE

The Fig. 3.2 screenshot shows the text file generated as per SAP 2000 V11.01 format containing the data required to generate the building model. The text file contains member information, connectivity data, section property definition and assignments, diaphragm definition and assignment, frame releases and assignment, load case definition and load combination and material property definition as well as assignment, etc. pertaining to the model.



```
Microsoft Excel - inputdatafinal_RIB_gable.xls
A99   FRAME=2011 JOINTI=12 JOINTJ=112 IsCurved=NO

File F:\SAP\tr_7.$2k was saved on 11/3/07 at 15:48:42

TABLE:  "ACTIVE DEGREES OF FREEDOM"
UX=Yes   UY=Yes   UZ=Yes   RX=Yes   RY=Yes   RZ=Yes

TABLE:  "ANALYSIS CASE DEFINITIONS"
  Case=D   Type=LinStatic   InitialCond=Zero   RunCase=Yes
  Case=Lr   Type=LinStatic   InitialCond=Zero   RunCase=Yes
  Case=EQX   Type=LinStatic   InitialCond=Zero   RunCase=Yes
  Case=EQY   Type=LinStatic   InitialCond=Zero   RunCase=Yes
   Case=MODAL   Type=LinModal   InitialCond=Zero   RunCase=Yes

TABLE:  "ANALYSIS OPTIONS"
   Solver=Advanced   Force32Bit=No   StiffCase=None   GeomMod=No

TABLE:  "AUTO WAVE 3 - WAVE CHARACTERISTICS - GENERAL"
   WaveChar=Default   WaveType="From Theory"   KinFactor=1   SWaterDepth=45   WaveHeight=18   WavePeriod=12   WaveTheory=L


TABLE:  "CASE - MODAL 1 - GENERAL"
   Case=MODAL   ModeType=Eigen   MaxNumModes=12   MinNumModes=1   EigenShift=0   EigenCutoff=0   EigenTol=0.000000001   Au

TABLE:  "CASE - STATIC 1 - LOAD ASSIGNMENTS"
   Case=EQX   LoadType="Load case"   LoadName=EQX   LoadSF=1
   Case=EQY   LoadType="Load case"   LoadName=EQY   LoadSF=1
   Case=Lr   LoadType="Load case"   LoadName=Lr   LoadSF=1
   Case=D   LoadType="Load case"   LoadName=D   LoadSF=1

TABLE:  "COMBINATION DEFINITIONS"
   ComboName=COMB101   ComboType="Linear Add"   CaseName=D   ScaleFactor=1   SteelDesign=No   ConcDesign=No   AlumDesign=N
   ComboName=COMB101   CaseName=Lr   ScaleFactor=1
   ComboName=COMB102   ComboType="Linear Add"   CaseName=D   ScaleFactor=0.9   SteelDesign=No   ConcDesign=No   AlumDesign
   ComboName=COMB102   CaseName=EQX   ScaleFactor=1.2
   ComboName=COMB103   ComboType="Linear Add"   CaseName=D   ScaleFactor=0.9   SteelDesign=No   ConcDesign=No   AlumDesign
   ComboName=COMB103   CaseName=EQX   ScaleFactor=-1.2
   ComboName=COMB104   ComboType="Linear Add"   CaseName=D   ScaleFactor=0.9   SteelDesign=No   ConcDesign=No   AlumDesign

InputPage  OutputPage  SectionName  SAPFILE  Sheet6  Sheet5  Eqpage  Sheet3
```

Fig.3.2 The *.$2k File Generated as per SAP 2000 V 11.01 Format

3.3 ANALYSIS OF FRAMED STRUCTURE USING SAP 2000

SAP 2000, Structural Analysis Program 2000, is a user friendly, special purpose analysis software developed for various capabilities including static and dynamic analysis, linear and non-linear analysis, dynamic seismic analysis and push over analysis, etc. SAP 2000 Version 11.01 features powerful graphical interface with modeling, analytical and design procedures. SAP 2000 can handle building models with simpler configurations as well as buildings with complex behaviors like non linearity. Thus, SAP 2000 is utilized very popular software among structural engineers.

Some of the principal advantages of using SAP 2000 are listed below.

- The buildings with simpler configuration can be easily modeled with less effort.
- The grouping of members makes it simpler and easier for the user to define and assign properties to various members quickly.
- Import and export capabilities also exist for other popular drafting and design programs.
- Tabular data can be edited and displayed in the interface, or exported to Microsoft Excel spreadsheet file, or a simple text file. One can use the exported data to perform various calculations.
- In the present study SAP 2000 is mainly utilized:-
    - To import the *.$2k file.
    - To analyze the framed structure.

3.3.1 Importing the *.$2k File

The *.$2k file generated through Visual basic is imported using the import command from the File menu as shown in Fig. 3.3.

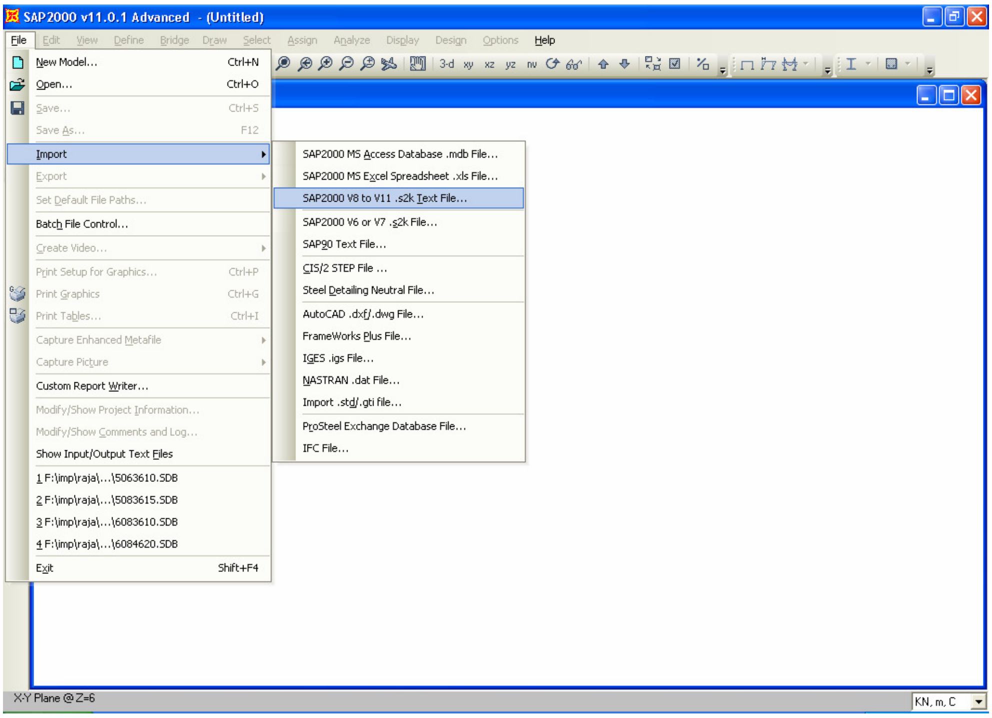


Fig.3.3 The *.$2k File is Imported in SAP 2000 V 11.01

The frame structure of the building appears with all the basic properties of the structure. The diaphragm rigidity, joint assignments at the base, dead and live load in the form of u.d.l. on predefined members, earthquake load in the form of nodal load at the predefined nodes is assigned to the structure. This completes the modeling part of the building. The Fig. 3.4 displays the 3-d view and plan view at the base of the building respectively.

The Fig. 3.5 shows the plan view at an elevation of -.5m and 6m respectively.

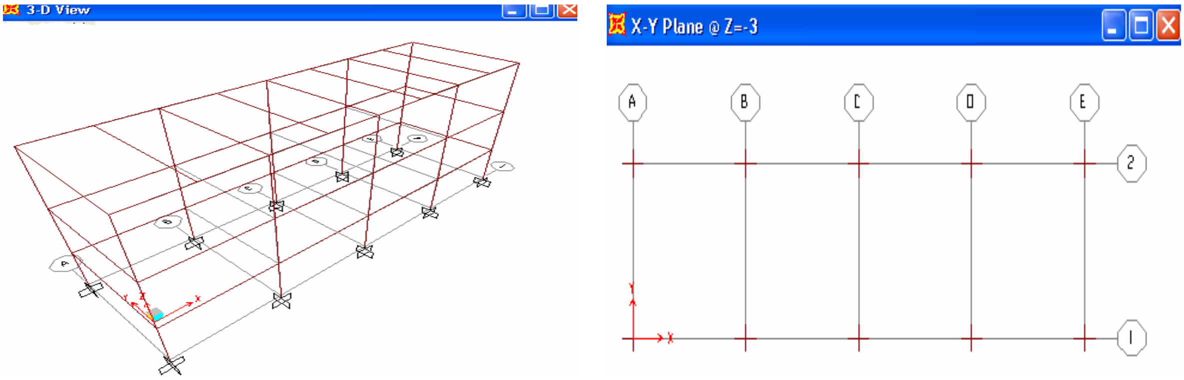


Fig.3.4 The 3-d View and Plan view at the base of the building

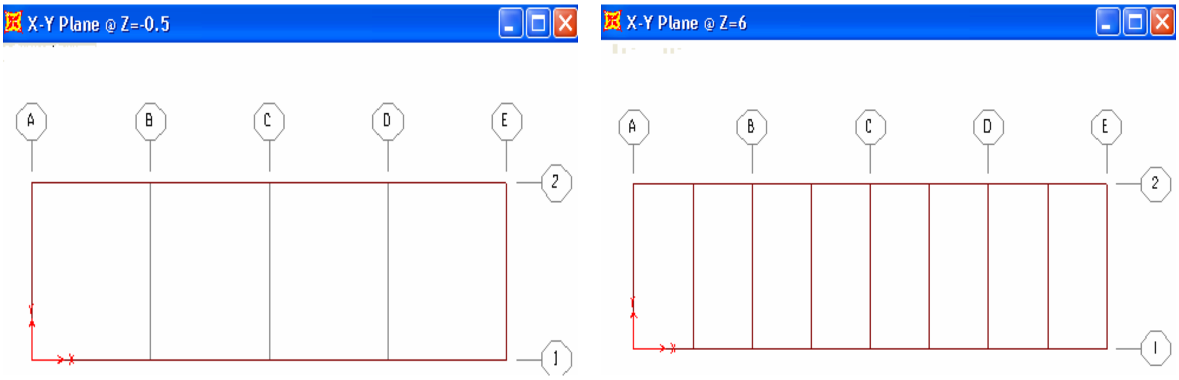


Fig.3.5 The Plan View of the building at an Elevation of -.5m and 6 m respectively

The Fig. 3.6 shows the plan view at an elevation of 2.55 m and side view of the building respectively.

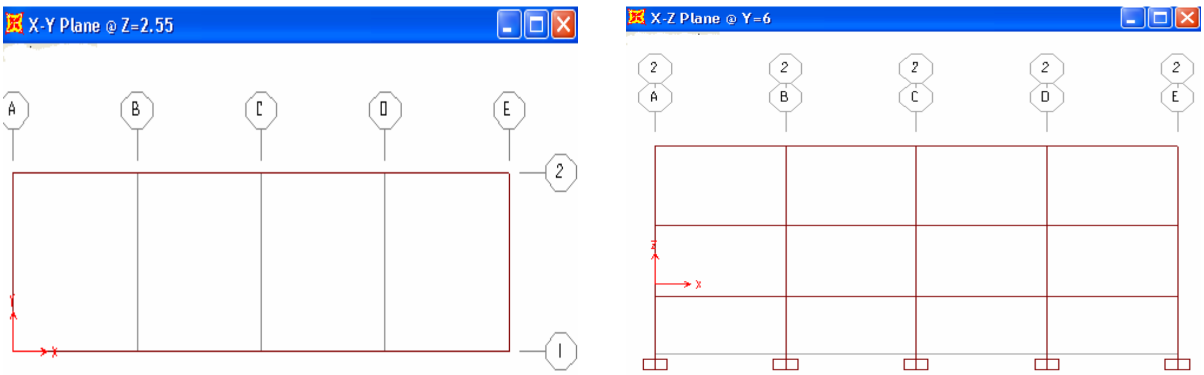


Fig.3.6 The Plan View of the building at an Elevation of 2.55 m and Side View of the building respectively

3.3.2 Analysis of Framed Structure

Analysis of framed structure involves definition of load cases, different load combinations, assigning the loads to the frame elements of the structures, and assigning the rigid diaphragms to the storey etc; all of which has been done earlier. The analysis of the frame structure is performed from the Run Analysis option of the Analyze menu as displayed in Fig. 3.7.

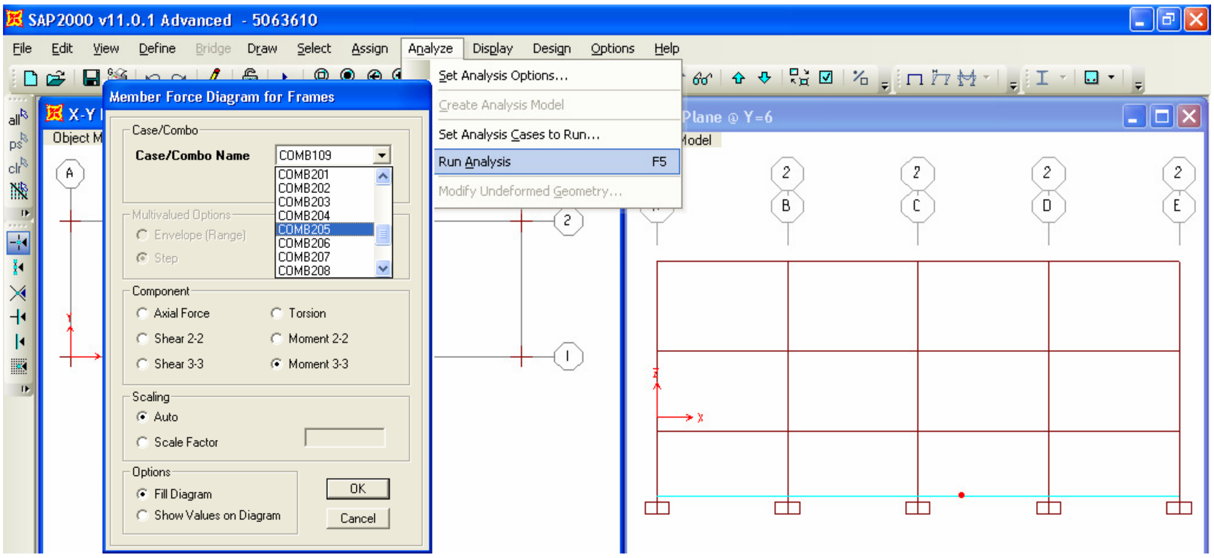


Fig. 3.7 Run Analysis Command

After the analysis is performed various results are displayed. The results are obtained in the form of shear forces, axial forces and bending moments for all the member elements of the frame structure. In order to view the forces in the members the Show Forces/Stresses command from the Display menu as shown in Fig. 3.8.

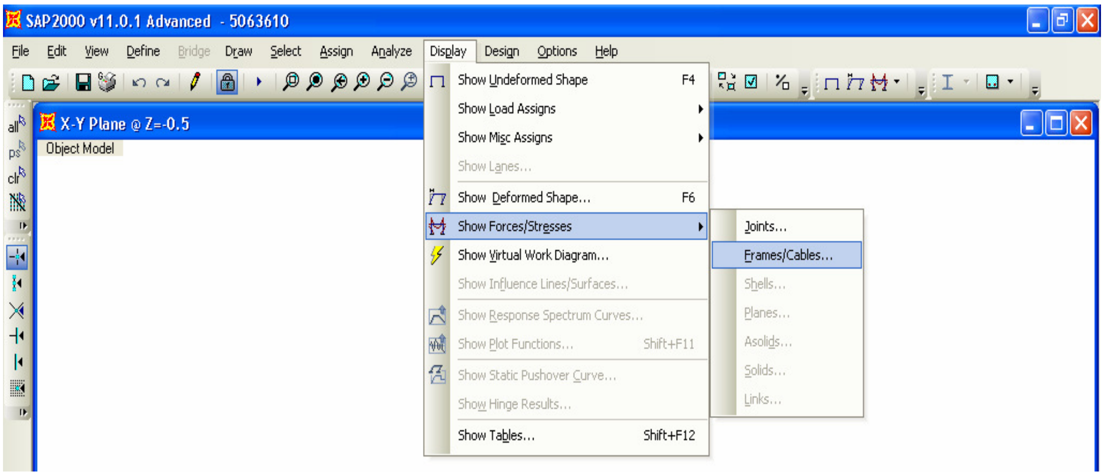


Fig. 3.8 Member Forces Data for Frame Structure

The Fig. 3.9 and Fig. 3.10 shows screen shots for viewing bending moments and shear forces for all beams and columns. Forces for all load combinations can be viewed and combination for maximum governing forces can be obtained. Thus maximum governing load combination is easily identified. The results of joint forces and element forces are imported to Microsoft Excel to interpret the data obtained and perform design for the predefined group of elements.

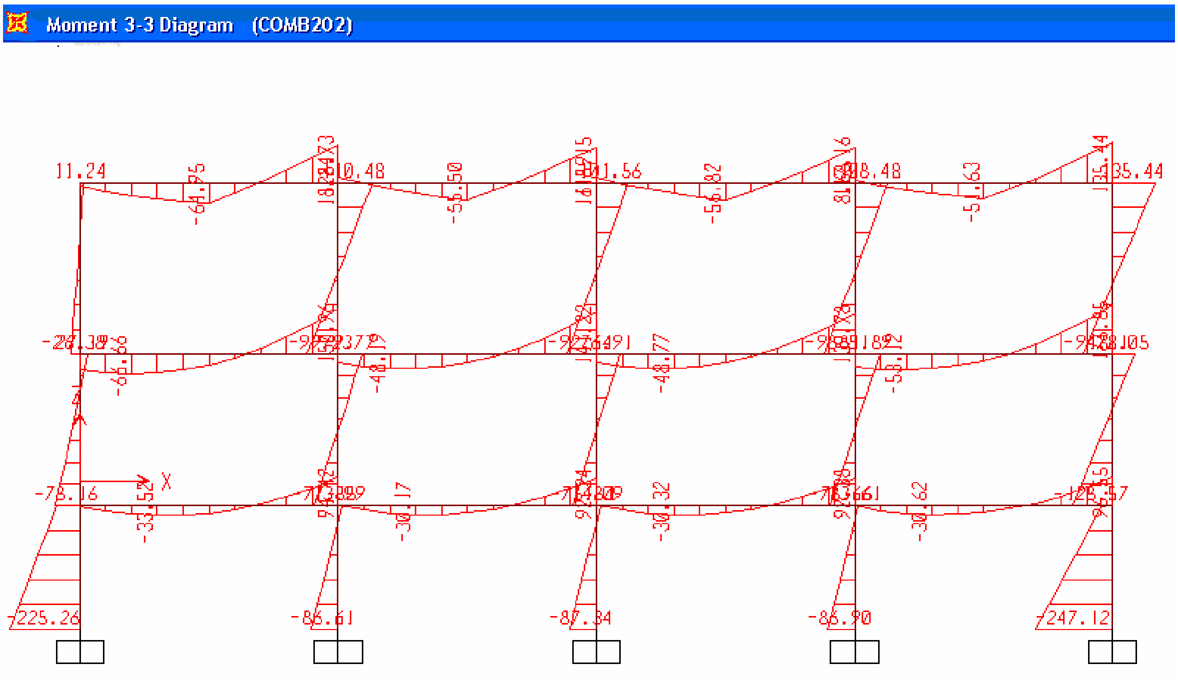


Fig. 3.9 Bending Moment Diagram

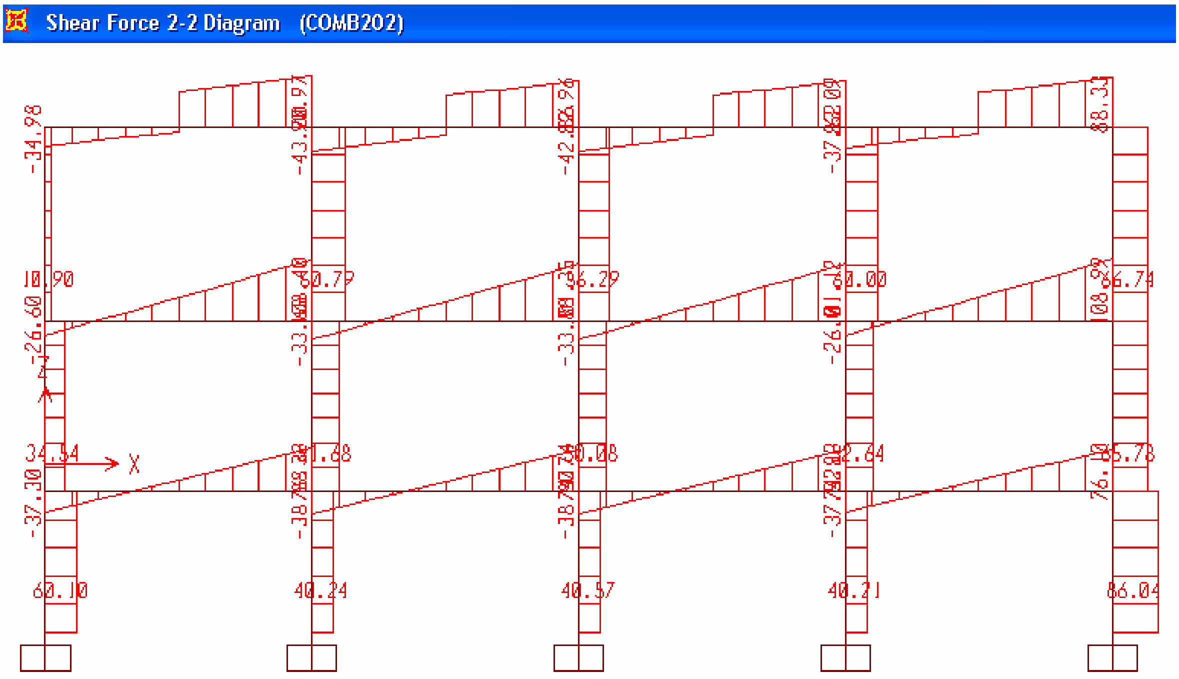


Fig. 3.10 Shear Force Diagram

3.4 DESIGN OF FRAMED STRUCTURE

Design of the frame structure has been done using Microsoft Excel worksheets which are in-house and validated. The design and detailing is carried out as per IS: 456-2000[12]. The screenshot shown below in Fig. 3.11 displays the in-house developed sheet for design of beams. The design of beams is carried out as per relevant Indian standards.

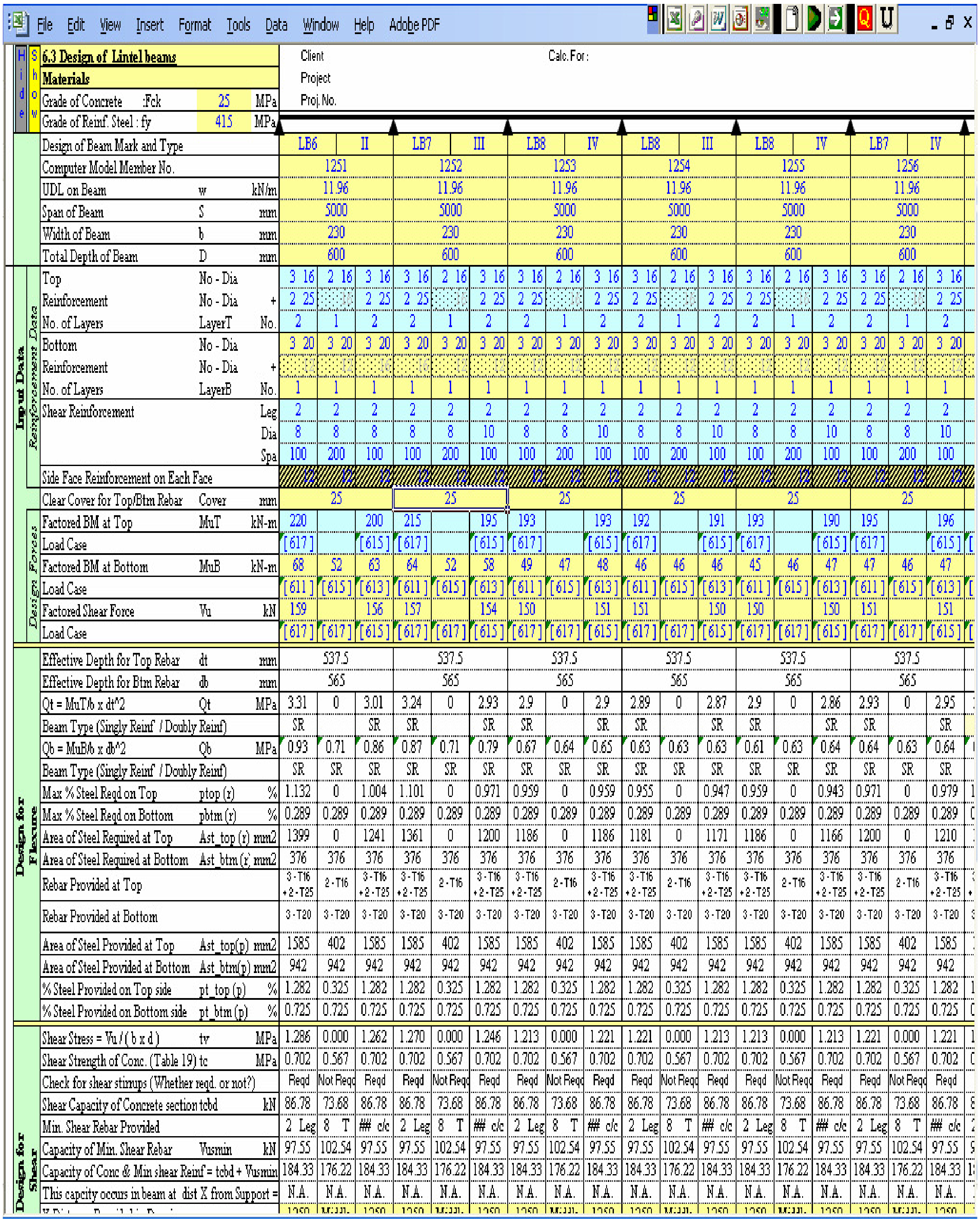


Fig. 3.11 Beam Design Sheet

The following screenshot displayed in Fig. 3.12 below shows the column design sheet as per IS: 456-2000[12]. The design sheets are developed in-house and are validated.

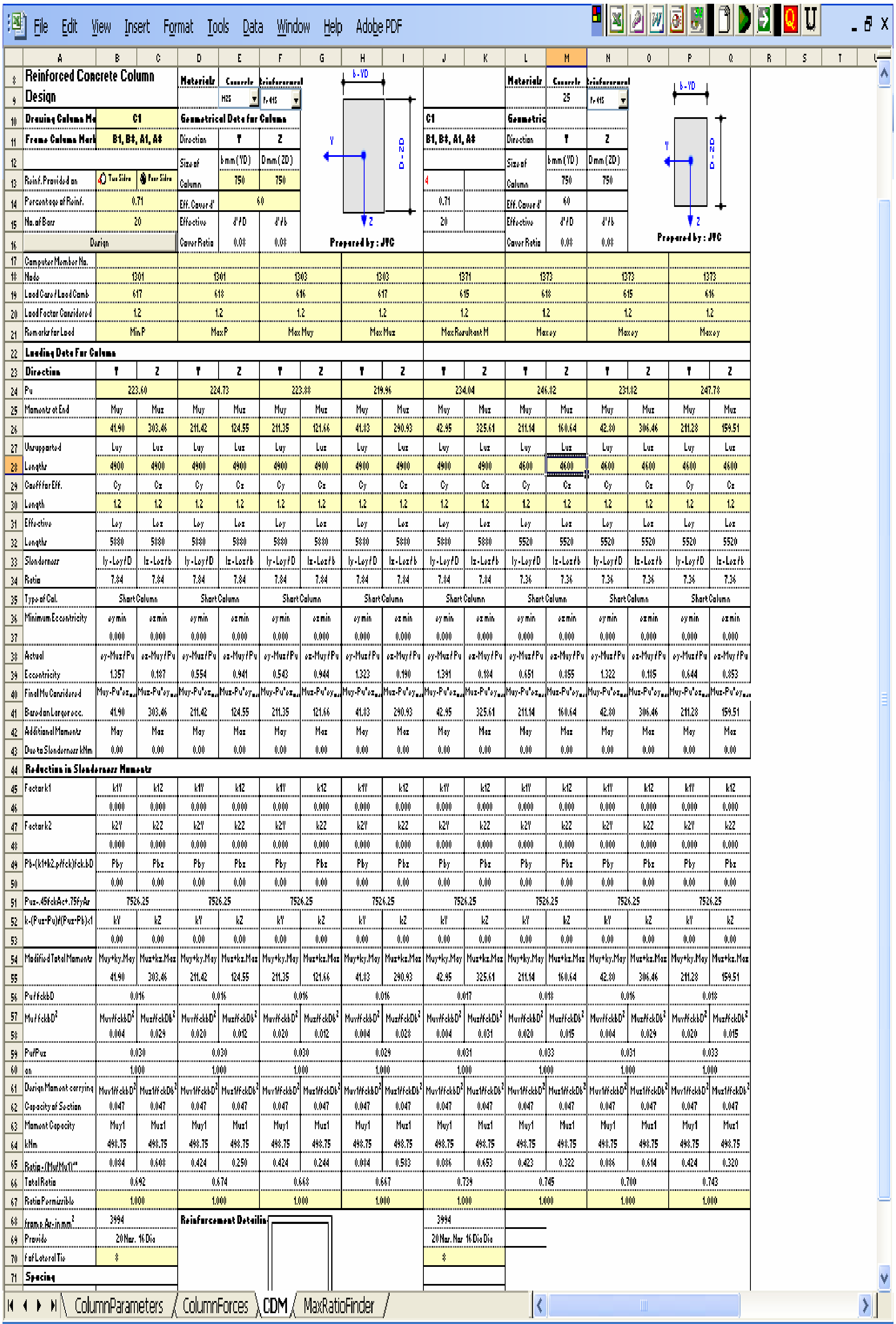
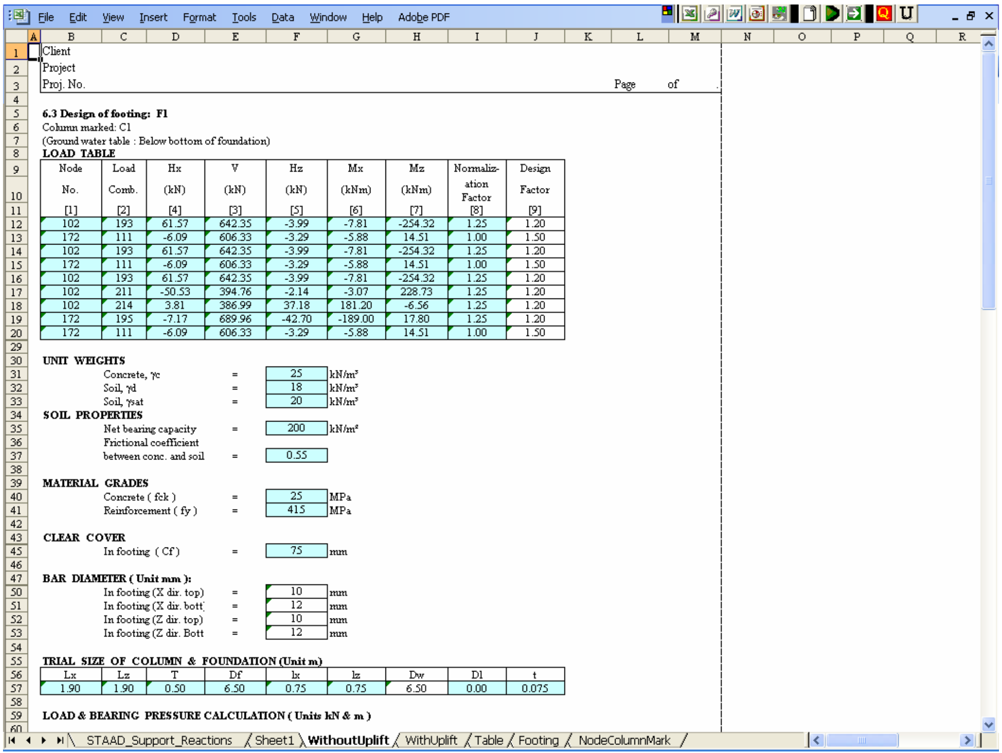


Fig. 3.12 Column Design Sheet

The following screenshot displayed in Fig. 3.13 below shows the footing design sheet as per relevant Indian Standard. The design sheets are developed in-house and are validated.



Client
Project
Proj. No. Page of

6.3 Design of footing: F1
Column marked: C1
(Ground water table : Below bottom of foundation)
LOAD TABLE

Node No. [1]	Load Comb. [2]	Hx (kN) [4]	V (kN) [3]	Hz (kN) [5]	Mx (kNm) [6]	Mz (kNm) [7]	Normalization Factor [8]	Design Factor [9]
102	193	61.57	642.35	-3.99	-7.81	-254.32	1.25	1.20
172	111	-6.09	606.33	-3.29	-5.88	14.51	1.00	1.50
102	193	61.57	642.35	-3.99	-7.81	-254.32	1.25	1.20
172	111	-6.09	606.33	-3.29	-5.88	14.51	1.00	1.50
102	193	61.57	642.35	-3.99	-7.81	-254.32	1.25	1.20
102	211	-50.53	394.76	-2.14	-3.07	228.73	1.25	1.20
102	214	3.81	386.99	37.18	181.20	-6.56	1.25	1.20
172	195	-7.17	689.96	-42.70	-189.00	17.80	1.25	1.20
172	111	-6.09	606.33	-3.29	-5.88	14.51	1.00	1.50

UNIT WEIGHTS
Concrete, γc = 25 kN/m³
Soil, γd = 18 kN/m³
Soil, γsat = 20 kN/m³
SOIL PROPERTIES
Net bearing capacity = 200 kN/m²
Frictional coefficient between conc. and soil = 0.55

MATERIAL GRADES
Concrete (fck) = 25 MPa
Reinforcement (fy) = 415 MPa

CLEAR COVER
In footing (Cf) = 75 mm

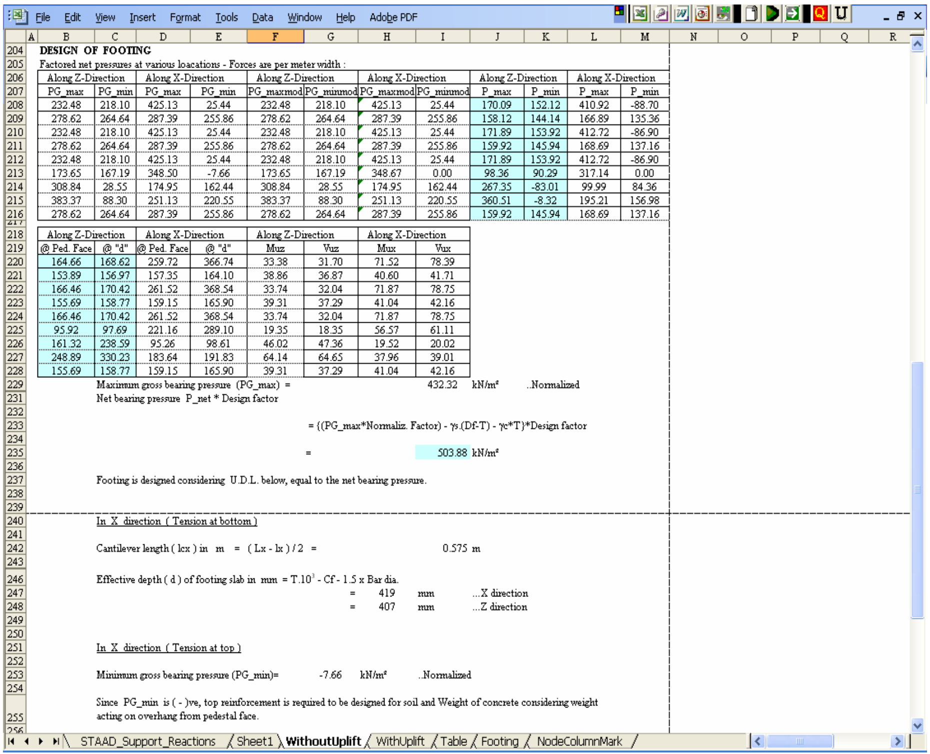
BAR DIAMETER (Unit mm):
In footing (X dir. top) = 10 mm
In footing (X dir. bott) = 12 mm
In footing (Z dir. top) = 10 mm
In footing (Z dir. Bott = 12 mm

TRIAL SIZE OF COLUMN & FOUNDATION (Unit m)

Lx	Lz	T	Df	lx	lz	Dw	Dl	t
1.90	1.90	0.50	6.50	0.75	0.75	6.50	0.00	0.075

LOAD & BEARING PRESSURE CALCULATION (Units kN & m)

(a)



DESIGN OF FOOTING
Factored net pressures at various loacations - Forces are per meter width :

Along Z-Direction		Along X-Direction		Along Z-Direction		Along X-Direction		Along Z-Direction		Along X-Direction	
PG_max	PG_min	PG_max	PG_min	PG_maxmod	PG_minmod	PG_maxmod	PG_minmod	P_max	P_min	P_max	P_min
232.48	218.10	425.13	25.44	232.48	218.10	425.13	25.44	170.09	152.12	410.92	-88.70
278.62	264.64	287.39	255.86	278.62	264.64	287.39	255.86	158.12	144.14	166.89	135.36
232.48	218.10	425.13	25.44	232.48	218.10	425.13	25.44	171.89	153.92	412.72	-86.90
278.62	264.64	287.39	255.86	278.62	264.64	287.39	255.86	159.92	145.94	168.69	137.16
232.48	218.10	425.13	25.44	232.48	218.10	425.13	25.44	171.89	153.92	412.72	-86.90
173.65	167.19	348.50	-7.66	173.65	167.19	348.67	0.00	98.36	90.29	317.14	0.00
308.84	28.55	174.95	162.44	308.84	28.55	174.95	162.44	267.35	-83.01	99.99	84.36
383.37	88.30	251.13	220.55	383.37	88.30	251.13	220.55	360.51	-8.32	195.21	156.98
278.62	264.64	287.39	255.86	278.62	264.64	287.39	255.86	159.92	145.94	168.69	137.16

Along Z-Direction		Along X-Direction		Along Z-Direction		Along X-Direction	
@ Ped. Face	@ "d"	@ Ped. Face	@ "d"	Muz	Vuz	Mux	Vux
164.66	168.62	259.72	366.74	33.38	31.70	71.52	78.39
153.89	156.97	157.35	164.10	38.86	36.87	40.60	41.71
166.46	170.42	261.52	368.54	33.74	32.04	71.87	78.75
155.69	158.77	159.15	165.90	39.31	37.29	41.04	42.16
166.46	170.42	261.52	368.54	33.74	32.04	71.87	78.75
95.92	97.69	221.16	289.10	19.35	18.35	56.57	61.11
161.32	238.59	95.26	98.61	46.02	47.36	19.52	20.02
248.89	330.23	183.64	191.83	64.14	64.65	37.96	39.01
155.69	158.77	159.15	165.90	39.31	37.29	41.04	42.16

Maximum gross bearing pressure (PG_max) = 432.32 kN/m² ..Normalized
Net bearing pressure P_net * Design factor

= {(PG_max*Normaliz. Factor) - γs.(Df-T) - γc*T}*Design factor

= 503.88 kN/m²

Footing is designed considering U.D.L. below, equal to the net bearing pressure.

In X direction (Tension at bottom)

Cantilever length (lcx) in m = (Lx - lx) / 2 = 0.575 m

Effective depth (d) of footing slab in mm = T.10³ - Cf - 1.5 x Bar dia.
= 419 mm ...X direction
= 407 mm ...Z direction

In X direction (Tension at top)

Minimum gross bearing pressure (PG_min)= -7.66 kN/m² ..Normalized

Since PG_min is (-)ve, top reinforcement is required to be designed for soil and Weight of concrete considering weight acting on overhang from pedestal face.

(b)

Fig. 3.13 Footing Design Sheet

3.5 EXAMPLE

The load calculation performed by the tool has been illustrated for a building having plan dimensions shown in Fig. 3.14.

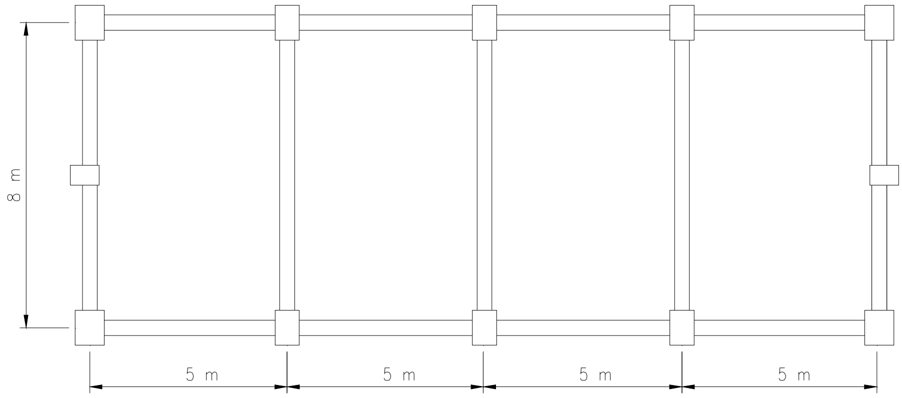


Fig. 3.14 Plan of the Building

Preliminary Data				
Building size	20	X	8	m
No. of Bays in X-direction	4	@ 5 m		
No. of Bays in Y-direction	1	@ 8 m		
Live Load	1.5	kN/m^2		
Preliminary Dimensions				
Density of Concrete			24	kN/m^3
Density of Wall			20	kN/m^3
Slab				
Thickness of Roof Slab			150	mm
Water Proofing load			1.5	kN/m^2
Beam				
Plinth beam				
X-direction	250	X	600	mm
Y-direction	250	X	450	mm
Lintel beam				
X-direction	250	X	600	mm
Y-direction	250	X	550	mm
Roof beam				
X-direction	250	X	700	mm
Y-direction	250	X	700	mm
Secondary beam				

X-direction	250	X	700	mm
Column	550	X	550	mm
Upto plinth			3	m
plinth to lintel			2.8	m
lintel to roof top			3.7	m
Walls				
X-direction			250	mm
Y-direction			250	mm
Thickness of Parapet wall			150	mm
Height of Parapet wall			1200	mm

Dead Load Calculations

Self weight of plinth beam		
X-direction	3.6	kN/m
Y-direction	2.7	kN/m
Self weight of lintel beam		
X-direction	3.6	kN/m
Y-direction	3.3	kN/m
Self weight of roof beam		
X-direction	4.2	kN/m
Y-direction	4.2	kN/m
Self weight of secondary beam	4.2	kN/m
Self weight of column	7.26	kN/m
Self weight of slab	3.6	kN/m^2
Self weight of wall	5	kN/m^2
plinth to lintel		
X-direction	11	kN/m
Y-direction	11.25	kN/m
Lintel to roof top		
X-direction	15	kN/m
Y-direction	15	kN/m
Self weight of parapet	4.32	kN/m

U.D.L. On Each Beam(DEAD)

Plinth beam		
Longitudinal intermediate	11	kN/m
Transverse gable	11	kN/m
Longitudinal gable	11	kN/m
Lintel beam		
Longitudinal gable	15	kN/m
Transverse gable	15	kN/m
Longitudinal intermediates	15	kN/m
Roof beam		
Longitudinal gable	4.32	kN/m
Transverse gable	17.07	kN/m
Longitudinal intermediate	4.32	kN/m
Transverse intermediate	25.5	kN/m
Secondary beam	12.75	kN/m
U.D.L. On Each Beam(LIVE)		
Transverse intermediate	7.5	kN/m
Secondary beam	0	kN/m
Transverse gable	3.75	kN/m

Earthquake Load Calculations as per IS: 1893 (Part I)-2002[13]

The total design lateral force is given by Equation 3.1.

$$V_b = A_h \times W \qquad \text{...(3.1)}$$

A_h = Design horizontal acceleration spectrum value = 10 %

W = Seismic Weight of the building = 3867 kN

V_b = The total design lateral force = 386 kN

The Table 3.3 shows the distribution of lateral forces at each node of the framed structure.

$$A_h = \frac{ZIS_a}{2Rg} \qquad \text{...(3.2)}$$

Where,

Z = Zone factor

I = Importance factor

R = Response Reduction factor

S_a/g = Average response acceleration coefficient

Here the value of design horizontal seismic co-efficient is assumed as 10% of weight of the structure, as per the reason specified earlier in Chapter 1.

The mass is lumped at plinth level and roof level. The calculation of roof and lintel level masses is attached in Table 3.1 and 3.2 .The nodal distribution of design seismic base shear has been displayed in Table 3.3.

Table 3.3 Nodal Distribution of Design Seismic Base Shear

Node No.	Height h_i m	Weight W_i kN	$W_i h_i^2$ kN/m^2	Shear Q_i kN
101	3.0	122.9	1106	1.89
121	3.0	112.9	1016	1.74
111	3.0	131.9	1187	2.30
102	3.0	131.9	1187	2.03
112	3.0	131.9	1187	2.03
103	3.0	131.9	1187	2.03
113	3.0	131.9	1187	2.03
104	3.0	131.9	1187	2.03
114	3.0	131.9	1187	2.03
105	3.0	122.9	1106	1.89
125	3.0	112.9	1016	1.74
115	3.0	122.9	1106	1.89
301	9.5	157.0	14169	24.28
321	9.5	150.2	13559	23.23
311	9.5	157.0	14169	24.28
302	9.5	236.8	21369	36.62
312	9.5	236.8	21369	36.62
303	9.5	236.8	21369	36.62
313	9.5	236.8	21369	36.62
304	9.5	236.8	21369	36.62
314	9.5	236.8	21369	36.62
305	9.5	157.0	14169	24.28
325	9.5	150.2	13559	23.23
315	9.5	157.0	14169	24.28
		3867	200000	

The following load combinations have been considered for design of structures as per clause 6.3.1.2 of IS: 1893 (Part I)-2002[12].

1) 1.5(DL+LL)
2) 1.2(DL+LL+EQX)
3) 1.2(DL+LL-EQX)
4) 1.2(DL+LL+EQY)
5) 1.2(DL+LL-EQY)
6) 1.5(DL+EQX)
7) 1.5(DL-EQX)
8) 1.5(DL+EQY)
9) 1.5(DL-EQY)
10) 0.9DL+1.5EQX
11) 0.9DL-1.5EQX
12) 0.9DL+1.5EQY
13) 0.9DL-1.5EQY

The structural details have been attached in appendix c.

3.5 SUMMARY

In the chapter, modeling, analysis and design of B.O.P. building according to relevant I.S. codes has been presented. For modeling the structure, a Microsoft Excel Macro has been made. For analysis, SAP 2000 software has been used. The design of structural components has been done using the in-house developed sheets. The modeling, analysis and design of all the selected framed structures have been carried out using the procedure specified in this chapter. The results computed for all B.O.P. buildings have been discussed in chapter 4.

Lumped Mass Calculations

Table 3.1 Calculation of Roof Level Masses

	Slab				Parapet		Beam				Column		Wall		
Node	Size		Area	Load		Load	Main	Ssecondary	Load	Load		Load			
	x	z		3.6		4.32	Beam	Beam	4.2	4.2		7.26		Load	Total
	m	m	m^2	kN/m^2	Length	kN/m	Length	Length	kN/m	kN/m	Height	kN/m	Length	11.6	Load
					m		m	m			m		m	kN/m	
				kN		kN			kN	kN		kN		kN	kN
301	2.78	2.28	6.31	22.73	5.60	24.19	4.50	2.00	18.90	8.40	3.25	23.60	4.50	52.20	156.99
321	2.78	4.00	11.10	39.96	4.00	17.28	4.00	0.00	16.80	0.00	3.25	23.60	4.00	46.40	150.24
311	2.78	2.28	6.31	22.73	5.60	24.19	4.50	2.00	18.90	8.40	3.25	23.60	4.50	52.20	156.99
302	5.00	4.00	20.00	72.00	5.00	21.60	9.00	4.00	37.80	16.80	3.25	23.60	5.00	58.00	236.77
312	5.00	4.00	20.00	72.00	5.00	21.60	9.00	4.00	37.80	16.80	3.25	23.60	5.00	58.00	236.77
303	5.00	4.00	20.00	72.00	5.00	21.60	9.00	4.00	37.80	16.80	3.25	23.60	5.00	58.00	236.77
313	5.00	4.00	20.00	72.00	5.00	21.60	9.00	4.00	37.80	16.80	3.25	23.60	5.00	58.00	236.77
304	5.00	4.00	20.00	72.00	5.00	21.60	9.00	4.00	37.80	16.80	3.25	23.60	5.00	58.00	236.77
314	5.00	4.00	20.00	72.00	5.00	21.60	9.00	4.00	37.80	16.80	3.25	23.60	5.00	58.00	236.77
305	2.78	2.28	6.31	22.72	5.60	24.19	4.50	2.00	18.90	8.40	3.25	23.60	4.50	52.20	156.98
325	2.78	4.00	11.10	39.96	4.00	17.28	4.00	0.00	16.80	0.00	3.25	23.60	4.00	46.40	150.24
315	2.78	2.28	6.31	22.73	5.60	24.19	4.50	2.00	18.90	8.40	3.25	23.60	4.50	52.20	156.99

Table 3.2 Calculation of Plinth Level Masses

	Slab				Parapet		Beam				Column		Wall		
Node	Size		Area	Load		Load	Main	Ssecondary	Load	Load		Load		Load	Total
	x	z		0		0	Beam	Beam	3.6	0	Height	7.26	Length	14.4	Load
	m	m	m^2	kN/m^2	Length	kN/m	Length	Length	kN/m	kN/m		kN/m		kN/m	
							m	m	kN		m		m	kN	
				kN		kN				kN		kN			kN
101							4.50	0.00	16.20	0.00	4.50	32.67	4.50	64.80	122.89
121							4.00	0.00	14.40	0.00	4.50	32.67	4.00	57.60	112.87
111							4.50	0.00	16.20	0.00	4.50	32.67	4.50	64.80	131.89
102							5.00	0.00	18.00	0.00	4.50	32.67	5.00	72.00	131.89
112							5.00	0.00	18.00	0.00	4.50	32.67	5.00	72.00	131.89
103							5.00	0.00	18.00	0.00	4.50	32.67	5.00	72.00	131.89
113							5.00	0.00	18.00	0.00	4.50	32.67	5.00	72.00	131.89
104							5.00	0.00	18.00	0.00	4.50	32.67	5.00	72.00	131.89
114							5.00	0.00	18.00	0.00	4.50	32.67	5.00	72.00	131.89
105							4.50	0.00	16.20	0.00	4.50	32.67	4.50	64.80	122.89
125							4.00	0.00	14.40	0.00	4.50	32.67	4.00	57.60	112.87
115							4.50	0.00	16.20	0.00	4.50	32.67	4.50	64.80	122.89

4. RESULTS OF DATABASE

4.1 GENERAL

In chapter 3, it has been discussed that in order to create a database for B.O.P. buildings, it is required to develop a tool which would help to perform quick analysis and finish the project in stipulated time. In order to accelerate the work and perform quick analysis and design, a Microsoft Excel Macro has been developed. Thus, the building could be modeled easily with minimum effort, thus saving time, which could otherwise be required for modeling of building. The saved effort can be utilized to optimize the presented building.

In the present work, the results of analysis and design have been presented in the form of charts and graphs. The charts so created help in quick estimation of the structural components of building and thus help significantly in proposal engineering. The graphical representation also helps to estimate the preliminary sizes of various components.

4.2 DEVELOPMENT OF DESIGN PARAMETERS

Based on the study conducted, it has been observed that in order to prepare the database for design of power plant buildings, it is required to create the buildings with the variations of depth of foundation, roof level, variation in design seismic force, bay width and width of building. The time period for a B.O.P. building generally varies from 0.2 to 0.4 sec , when the time period is calculated as per Clause 6.4.2 of IS: 1893 (Part I)-2002[12] for various soil conditions, as explained earlier in chapter 1.

Based on the study of previous projects till date it has been observed that the values of design seismic horizontal co-efficient vary from 10% to 20%. Since a huge number of buildings were required to be modeled, analyzed and designed, a need arose to assign certain names to each file or model so as to facilitate easy review of the models in a stipulated time. To illustrate this, an example of naming models is mentioned below. A name 5083610 has been assigned to one of the models, in which 1st digit stands for bay width, 2nd and 3rd digit stands for width of building, 4th digit stands for foundation level, 5th digit stands for height of the building and last 2 digits stand for percentage of A_h considered under study.

It has been observed that due to physical dimensions of buildings its floor area and volume may be similar for more than one building and would yield two values of ordinate for one typical value on abscissa. This duplication of one abscissa would not lead to proper representation or analysis. Hence, in order to succeed this challenge, a need aroused to determine a unique factor/parameter against which only one ordinate value can be represented.

Representative Volume = $(4 \times L \times B \times (B_f/T_f)^2 \times (B_f+T_f)^2)$ m^3.

As explained in Table 1.1, different building parameters required to be varied in this work. Table 4.1 depicts the models created by varying different building variables like L, B, B_f, T_f and A_h. Also the calculated value of representative Volume is presented in Table 4.1.

Table 4.1 Combination of Building Parameters

Sr. No.	Model No.	Bay Width (m)	Width of Building (m)	Foundation Level (m)	Top of Roof (m)	A_h %	Representative Volume (m3)
1	5083610	5	8	3	6	10	3240.00
2	5103610	5	10	3	6	10	4050.00
3	6083610	6	8	3	6	10	3888.00
4	6103610	6	10	3	6	10	4860.00
5	5103810	5	10	3	8	10	3403.12
6	5083810	5	8	3	8	10	2722.50
7	6083810	6	8	3	8	10	3267.00
8	6103810	6	10	3	8	10	4083.75
9	6103510	6	10	3	5	10	5529.60
10	5083510	5	8	3	5	10	3686.40
11	6083510	6	8	3	5	10	4423.68
12	5103510	5	10	3	5	10	4608.00
13	6105510	6	10	5	5	10	24000.00
14	5084610	5	8	4	6	10	7111.11
15	5104610	5	10	4	6	10	8888.88
16	6085510	6	8	5	5	10	19200.00
17	6084610	6	8	4	6	10	8533.33
18	6104610	6	10	4	6	10	10666.66

Sr. No.	Model No.	Bay Width (m)	Width of Building (m)	Foundation Level (m)	Top of Roof (m)	A_h %	Representative Volume (m3)
19	5084810	5	8	4	8	10	5760.00
20	6084810	6	8	4	8	10	6912.00
21	6104810	6	10	4	8	10	8640.00
22	5104810	5	10	4	8	10	7200.00
23	5084510	5	8	4	5	10	8294.40
24	5104510	5	10	4	5	10	10368.00
25	6084510	6	8	4	5	10	9953.28
26	6104510	6	10	4	5	10	12441.60
27	5105510	5	10	5	5	10	20000.00
28	5085510	5	8	5	5	10	16000.00
29	5085610	5	8	5	6	10	13444.44
30	5105610	5	10	5	6	10	16805.55
31	6085610	6	8	5	6	10	16133.33
32	6105610	6	10	5	6	10	20166.66
33	5085810	5	8	5	8	10	10562.50
34	5105810	5	10	5	8	10	13203.12
35	6085810	6	8	5	8	10	12675.00
36	6105810	6	10	5	8	10	15843.75
37	5083615	5	8	3	6	15	3240.00
.38	5103615	5	10	3	6	15	4050.00
39	6083615	6	8	3	6	15	3888.00
40	6103615	6	10	3	6	15	4860.00
41	5084615	5	8	4	6	15	7111.11
42	5104615	5	10	4	6	15	8888.88
43	5103815	5	10	3	8	15	3403.12
44	6083815	6	8	3	8	15	3267.00
45	6103815	6	10	3	8	15	4083.75
46	6103515	6	10	3	5	15	5529.60
47	5083515	5	8	3	5	15	3686.40
48	6083515	6	8	3	5	15	4423.68
49	5103515	5	10	3	5	15	4608.00
50	6084615	6	8	4	6	15	8533.33
51	5083815	5	8	3	8	15	2722.50

Sr. No.	Model No.	Bay Width (m)	Width of Building (m)	Foundation Level (m)	Top of Roof (m)	A_h %	Representative Volume (m3)
52	5085815	5	8	5	8	15	10562.50
53	5105815	5	10	5	8	15	13203.12
54	6085815	6	8	5	8	15	12675.00
55	6105815	6	10	5	8	15	15843.75
56	5084515	5	8	4	5	15	8294.40
57	5104515	5	10	4	5	15	10368.00
58	6084515	6	8	4	5	15	9953.28
59	6104515	6	10	4	5	15	12441.60
60	5085615	5	8	5	6	15	13444.44
61	6106615	6	10	5	5	15	24000.00
62	5105615	5	10	5	6	15	16805.55
63	6085615	6	8	5	6	15	16133.33
64	6105615	6	10	5	6	15	20166.66
65	5105515	5	10	5	5	15	20000.00
66	5085515	5	8	5	5	15	16000.00
67	6085515	6	8	5	5	15	19200.00
68	5084815	5	8	4	8	15	5760.00
69	5104815	5	10	4	8	15	7200.00
70	6084815	6	8	4	8	15	6912.00
71	6104815	6	10	4	8	15	8640.00
72	5083620	5	8	3	6	20	3240.00
73	5103620	5	10	3	6	20	4050.00
74	6083620	6	8	3	6	20	3888.00
75	6103620	6	10	3	6	20	4860.00
76	5104620	5	10	4	6	20	8888.88
77	6083820	6	8	3	8	20	3267.00
78	6103520	6	10	3	5	20	5529.60
79	5083520	5	8	3	5	20	3686.40
80	6083520	6	8	3	5	20	4423.68
81	5103520	5	10	3	5	20	4608.00
82	5083820	5	8	3	8	20	2722.50
83	6105520	6	10	5	5	20	24000.00
84	6085520	6	8	5	5	20	19200.00

Sr. No.	Model No.	Bay Width (m)	Width of Building (m)	Foundation Level (m)	Top of Roof (m)	A_h %	Representative Volume (m3)
85	5105520	5	10	5	5	20	20000.00
86	5084620	5	8	4	6	20	7111.11
87	5085520	5	8	5	5	20	16000.00
88	6084620	6	8	4	6	20	8533.33
89	6104620	6	10	4	6	20	10666.66
90	6084820	6	8	4	8	20	6912.00
91	5084520	5	8	4	5	20	8294.40
92	5104520	5	10	4	5	20	10368.00
93	6084520	6	8	4	5	20	9953.28
94	5104520	6	10	4	5	20	12441.60
95	5103820	5	10	3	8	20	3403.12
96	5104820	5	10	4	8	20	7200.00
97	5085620	5	8	5	6	20	13444.44
98	5105620	5	10	5	6	20	16805.55
99	6085620	6	8	5	6	20	16133.33
100	6105620	6	10	5	6	20	20166.66
101	6085820	6	8	5	8	20	12675.00
102	6103820	6	10	3	8	20	4083.75
103	5084820	5	8	4	8	20	5760.00
104	6104820	6	10	4	8	20	8640.00
105	5085820	5	8	5	8	20	10562.50
106	8083510	8	8	3	5	10	5898.24
107	8103510	8	10	3	5	10	7372.80
108	8083610	8	8	3	6	10	5184.00
109	8103610	8	10	3	6	10	6480.00
110	8084510	8	8	4	5	10	13271.04
111	8104510	8	10	4	5	10	16588.80
112	8105510	8	10	5	5	10	32000.00
113	8085510	8	8	5	5	10	25600.00
114	8085610	8	8	5	6	10	21511.11
115	8084610	8	8	4	6	10	11377.77
116	8104610	8	10	4	6	10	14222.22
117	8105610	8	10	5	6	10	26888.88

Sr. No.	Model No.	Bay Width (m)	Width of Building (m)	Foundation Level (m)	Top of Roof (m)	A_h %	Representative Volume (m3)
118	8083810	8	8	3	8	10	4356.00
119	8103810	8	10	3	8	10	5445.00
120	8084810	8	8	4	8	10	9216.00
121	8104810	8	10	4	8	10	11520.00
122	8085810	8	8	5	8	10	16900.00
123	8105810	8	10	5	8	10	21125.00
124	8083515	8	8	3	5	15	5898.24
125	8084515	8	8	4	5	15	13271.04
126	8085515	8	8	5	5	15	25600.00
127	8085615	8	8	5	6	15	21511.11
128	8084615	8	8	4	6	15	11377.77
129	8083615	8	8	3	6	15	5184.00
130	8103615	8	10	3	6	15	6480.00
131	8104615	8	10	4	6	15	14222.22
132	8105615	8	10	5	6	15	26888.88
133	8103515	8	10	3	5	15	7372.80
134	8104515	8	10	4	5	15	16588.80
135	8105515	8	10	5	5	15	32000.00
136	8083815	8	8	3	8	15	4356.00
137	8084815	8	8	4	8	15	9216.00
138	8085815	8	8	5	8	15	16900.00
139	8083520	8	8	3	5	20	5898.24
140	8084520	8	8	4	5	20	13271.04
141	8085520	8	8	5	5	20	25600.00
142	8083620	8	8	3	6	20	5184.00
143	8084620	8	8	4	6	20	11377.77
144	8103520	8	10	3	5	20	7372.80
145	8103620	8	10	3	6	20	6480.00
146	8104520	8	10	4	5	20	16588.80
147	8105520	8	10	5	5	20	32000.00
148	8083820	8	8	3	8	20	4356.00
149	8104620	8	10	4	6	20	14222.22
150	8085620	8	8	5	6	20	21511.11

Here, the number of bays has been kept fixed as shown in the Fig. 4.1 and 4.2 with all the basic parameters under study.

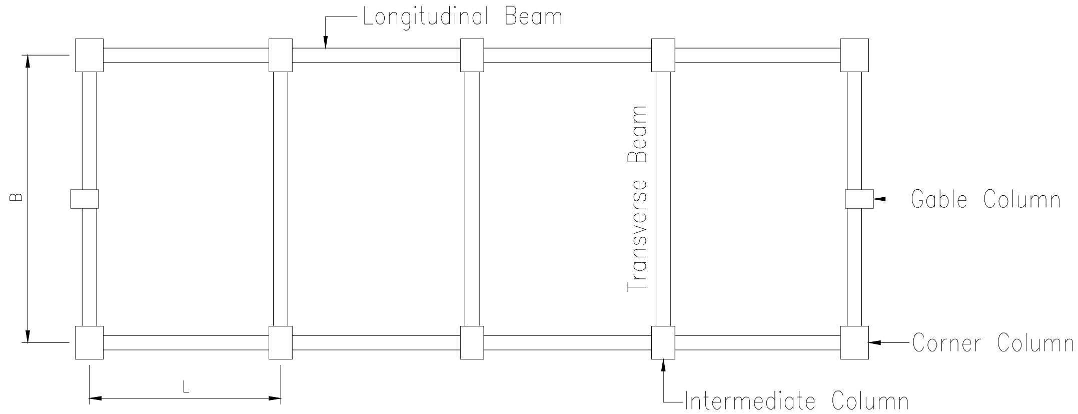


Fig. 4.1 Pictorial Representation of Plan with Various Parameters

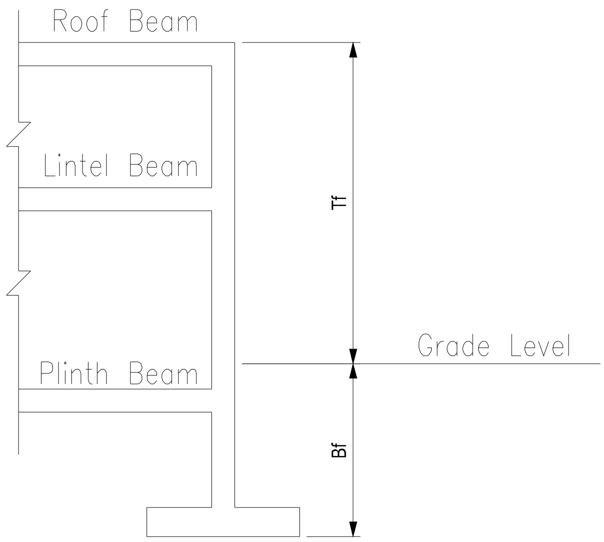
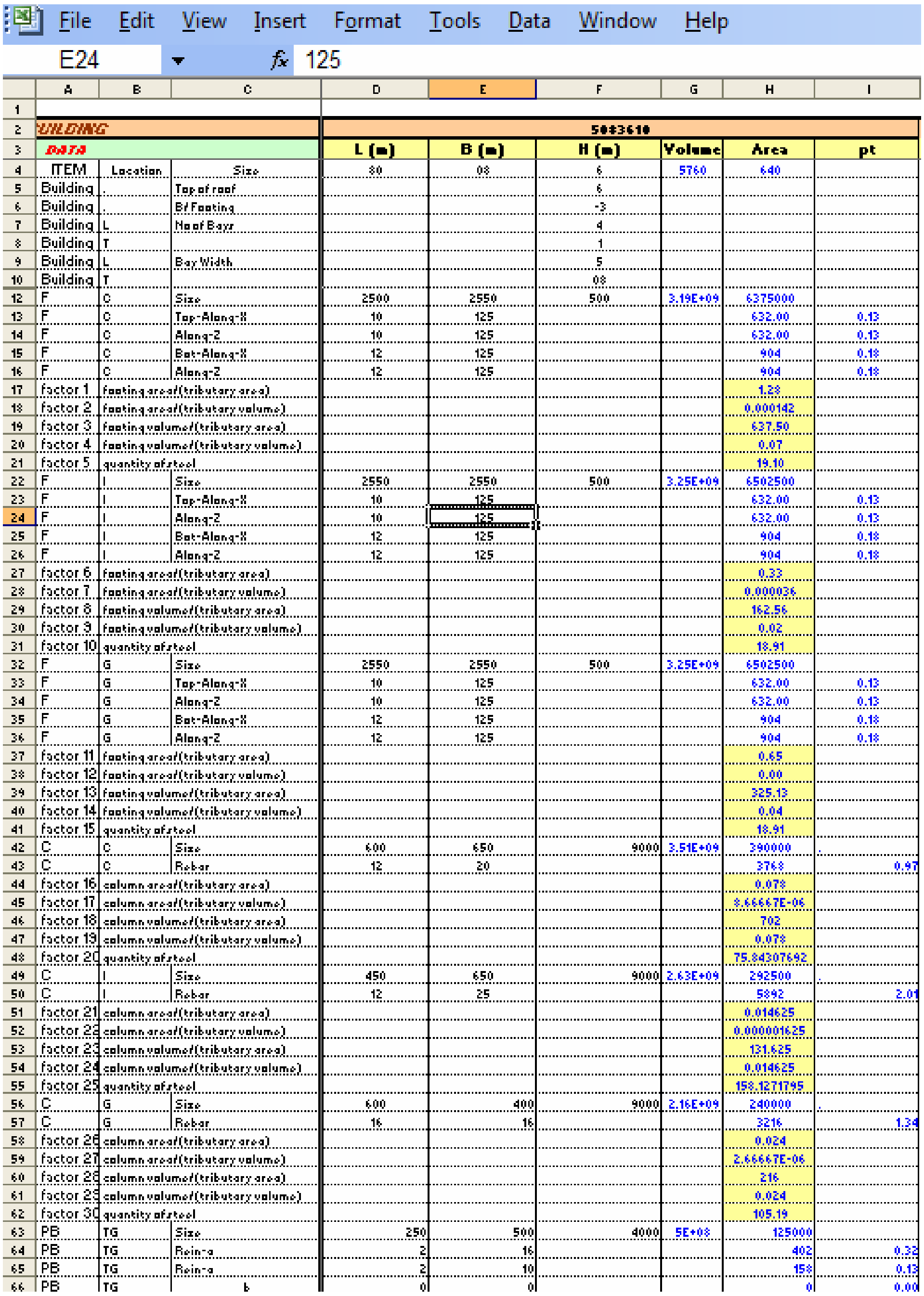


Fig. 4.2 Pictorial Representation of Sectional elevation with Various Parameters

Thus, total 67 factors have been considered. All the factors have been plotted against Representative Volume so as to obtain the required coefficient/factor. The factor has been estimated for corner, intermediate and gable foundations, and columns. Also, the graphs have been plotted so as to obtain the concrete quantity for the transverse and longitudinal beams at the plinth, lintel and roof level.

The buildings have been modeled, analyzed and designed. For each model, data has been collected and stored in a tabular format in order to derive some estimating parameters as shown in Fig. 4.3. A Macro has been written to consolidate the data and store the entire data at a particular location so as to facilitate quick plotting of graphs.



	A	B	C	D	E	F	G	H	I
1									
2	UILDING			50#3610					
3	DATA			L (m)	B (m)	H (m)	Volume	Area	pt
4	ITEM	Location	Size	80	08	6	5760	640	
5	Building	.	Top of roof			6			
6	Building	.	B/ Footing			-3			
7	Building	L	No of Bays			4			
8	Building	T				1			
9	Building	L	Bay Width			5			
10	Building	T				08			
12	F	C	Size	2500	2550	500	3.19E+09	6375000	
13	F	C	Top-Along-X	10	125			632.00	0.13
14	F	C	Along-Z	10	125			632.00	0.13
15	F	C	Bot-Along-X	12	125			904	0.18
16	F	C	Along-Z	12	125			904	0.18
17	factor 1	footing area/(tributary area)						1.28	
18	factor 2	footing area/(tributary volume)						0.000142	
19	factor 3	footing volume/(tributary area)						637.50	
20	factor 4	footing volume/(tributary volume)						0.07	
21	factor 5	quantity of steel						19.10	
22	F	I	Size	2550	2550	500	3.25E+09	6502500	
23	F	I	Top-Along-X	10	125			632.00	0.13
24	F	I	Along-Z	10	125			632.00	0.13
25	F	I	Bot-Along-X	12	125			904	0.18
26	F	I	Along-Z	12	125			904	0.18
27	factor 6	footing area/(tributary area)						0.33	
28	factor 7	footing area/(tributary volume)						0.000036	
29	factor 8	footing volume/(tributary area)						162.56	
30	factor 9	footing volume/(tributary volume)						0.02	
31	factor 10	quantity of steel						18.91	
32	F	G	Size	2550	2550	500	3.25E+09	6502500	
33	F	G	Top-Along-X	10	125			632.00	0.13
34	F	G	Along-Z	10	125			632.00	0.13
35	F	G	Bot-Along-X	12	125			904	0.18
36	F	G	Along-Z	12	125			904	0.18
37	factor 11	footing area/(tributary area)						0.65	
38	factor 12	footing area/(tributary volume)						0.00	
39	factor 13	footing volume/(tributary area)						325.13	
40	factor 14	footing volume/(tributary volume)						0.04	
41	factor 15	quantity of steel						18.91	
42	C	C	Size	600	650	9000	3.51E+09	390000	
43	C	C	Rebar	12	20			3768	0.97
44	factor 16	column area/(tributary area)						0.078	
45	factor 17	column area/(tributary volume)						8.66667E-06	
46	factor 18	column volume/(tributary area)						702	
47	factor 19	column volume/(tributary volume)						0.078	
48	factor 20	quantity of steel						75.84307692	
49	C	I	Size	450	650	9000	2.63E+09	292500	
50	C	I	Rebar	12	25			5892	2.01
51	factor 21	column area/(tributary area)						0.014625	
52	factor 22	column area/(tributary volume)						0.000001625	
53	factor 23	column volume/(tributary area)						131.625	
54	factor 24	column volume/(tributary volume)						0.014625	
55	factor 25	quantity of steel						158.1271795	
56	C	G	Size	600	400	9000	2.16E+09	240000	
57	C	G	Rebar	16	16			3216	1.34
58	factor 26	column area/(tributary area)						0.024	
59	factor 27	column area/(tributary volume)						2.66667E-06	
60	factor 28	column volume/(tributary area)						216	
61	factor 29	column volume/(tributary volume)						0.024	
62	factor 30	quantity of steel						105.19	
63	PB	TG	Size	250	500	4000	5E+08	125000	
64	PB	TG	Rein-a	2	16			402	0.32
65	PB	TG	Rein-a	2	10			158	0.13
66	PB	TG	b	0	0			0	0.00

Fig. 4.3 Data Capturing in Microsoft Excel Worksheet

4.3 RESULT INTERPRETATION

There exists variation in data because many parameters have been taken under study to prepare the database. Also the factor derived for each component is dependent on many parameters, so due to scattered data for a particular value of ordinate a unique value of abscissa has been difficult to obtain as illustrated in Fig. 4.4.

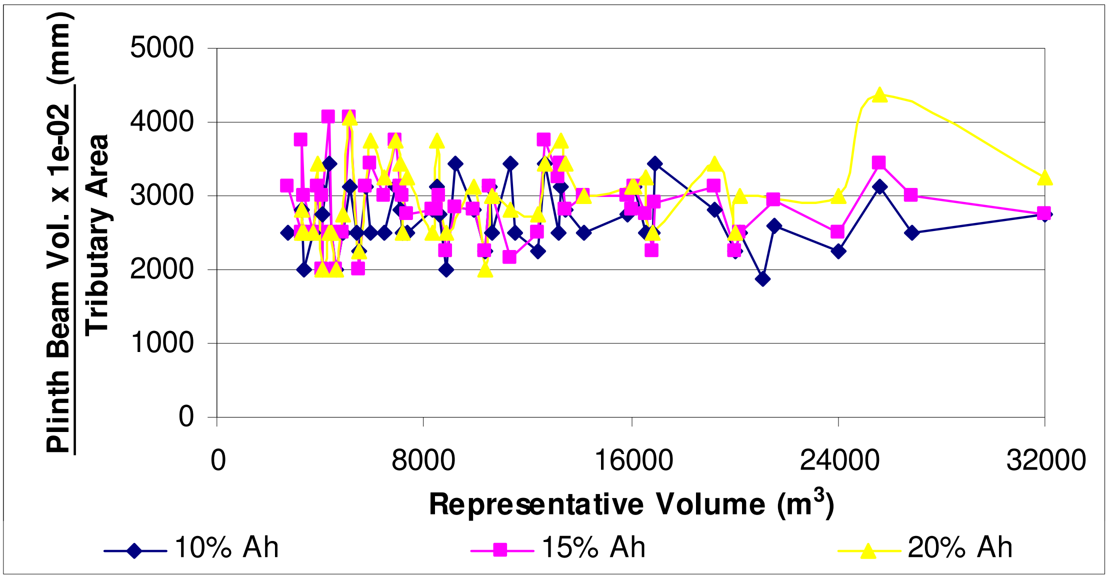


Fig. 4.4 Scattered Data

Since, the data has much variation the trend line charts have been plotted. The trend line gives fairly good estimate of values in such scattered data. The factors displayed in Table 4.2 have been considered in the present study.

Table 4.2 Factors

Sr No.	Component	Location	Factor Name
1	Footing	Corner	footing area/(tributary area)
2			footing area/(tributary volume)
3			footing volume/(tributary area)
4			footing volume/(tributary volume)
5		Intermediate	footing area/(tributary area)
6			footing area/(tributary volume)
7			footing volume/(tributary area)
8			footing volume/(tributary volume)
9		Gable	footing area/(tributary area)
10			footing area/(tributary volume)
11			footing volume/(tributary area)
12			footing volume/(tributary volume)
13	Column	Corner	column area/(tributary area)

Sr No.	Component	Location	Factor Name
14			column area/(tributary volume)
15			column volume/(tributary area)
16			column volume/(tributary volume)
17			quantity of Steel
18		Intermediate	column area/(tributary area)
19			column area/(tributary volume)
20			column volume/(tributary area)
21			column volume/(tributary volume)
22			quantity of Steel
23		Gable	column area/(tributary area)
24			column area/(tributary volume)
25			column volume/(tributary area)
26			column volume/(tributary volume)
27			quantity of Steel
28	Plinth Beam	Transverse	plinth beam area/(tributary area)
29			plinth beam area/(tributary volume)
30			plinth beam volume/(tributary area)
31			plinth beam volume/(tributary volume)
32			quantity of steel
33	Plinth Beam	Longitudinal	plinth beam area/(tributary area)
24			plinth beam area/(tributary volume)
35			plinth beam volume/(tributary area)
36			plinth beam volume/(tributary volume)
37			quantity of steel
38	Lintel	Transverse	lintel beam area/(tributary area)
39			lintel beam area/(tributary volume)
40			lintel beam volume/(tributary area)
41			lintel beam volume/(tributary volume)
42			quantity of steel
43		Longitudinal	lintel beam area/(tributary area)
44			lintel beam area/(tributary volume)
45			lintel beam volume/(tributary area)
46			lintel beam volume/(tributary volume)

Sr No.	Component	Location	Factor Name
47			quantity of steel
48	Roof Beam	Longitudinal	roof beam area/(tributary area)
49			roof beam area/(tributary volume)
50			roof beam volume/(tributary area)
51			roof beam volume/(tributary volume)
52			quantity of steel
53		Transverse Gable	roof beam area/(tributary area)
54			roof beam area/(tributary volume)
55			roof beam volume/(tributary area)
56			roof beam volume/(tributary volume)
57			quantity of steel
58		Transverse Intermediate	roof beam area/(tributary area)
59			roof beam area/(tributary volume)
60			roof beam volume/(tributary area)
61			roof beam volume/(tributary volume)
62			quantity of steel
63		Secondary Intermediate	roof beam area/(tributary area)
64			roof beam area/(tributary volume)
65			roof beam volume/(tributary area)
66			roof beam volume/(tributary volume)
67			quantity of steel

In order to estimate the concrete quantity, the tributary area and tributary volume is required for various footings, which are evaluated from the formula given in Table 4.3 depending on its location. The relations have been expressed in the form of length of building, breadth of building, height of building and roof level of the building.

Table 4.3 Tributary Parameter for Footing

Footing Location	Tributary Area	Tributary Volume
Corner	$0.125 \times L \times B$	$0.125 \times L \times (B_f + T_f)$
Intermediate	$0.5 \times L \times B$	$0.5 \times L \times (B_f + T_f)$
Gable	$0.25 \times L \times B$	$0.25 \times L \times (B_f + T_f)$

The Fig. 4.5 shows graphs (a), (b), (c) and (d) used to estimate the required factor. The concrete quantity for corner footing can be obtained by evaluating the tributary volume and tributary area as per equations given in Table 4.3. The trend lines presented in Fig. 4.5 shows logarithmic variation of factors for various percentage of A_h plotted against representative volume. The trend lines give fairly good judgment to estimate the preliminary sizes of footings for different values of A_h.

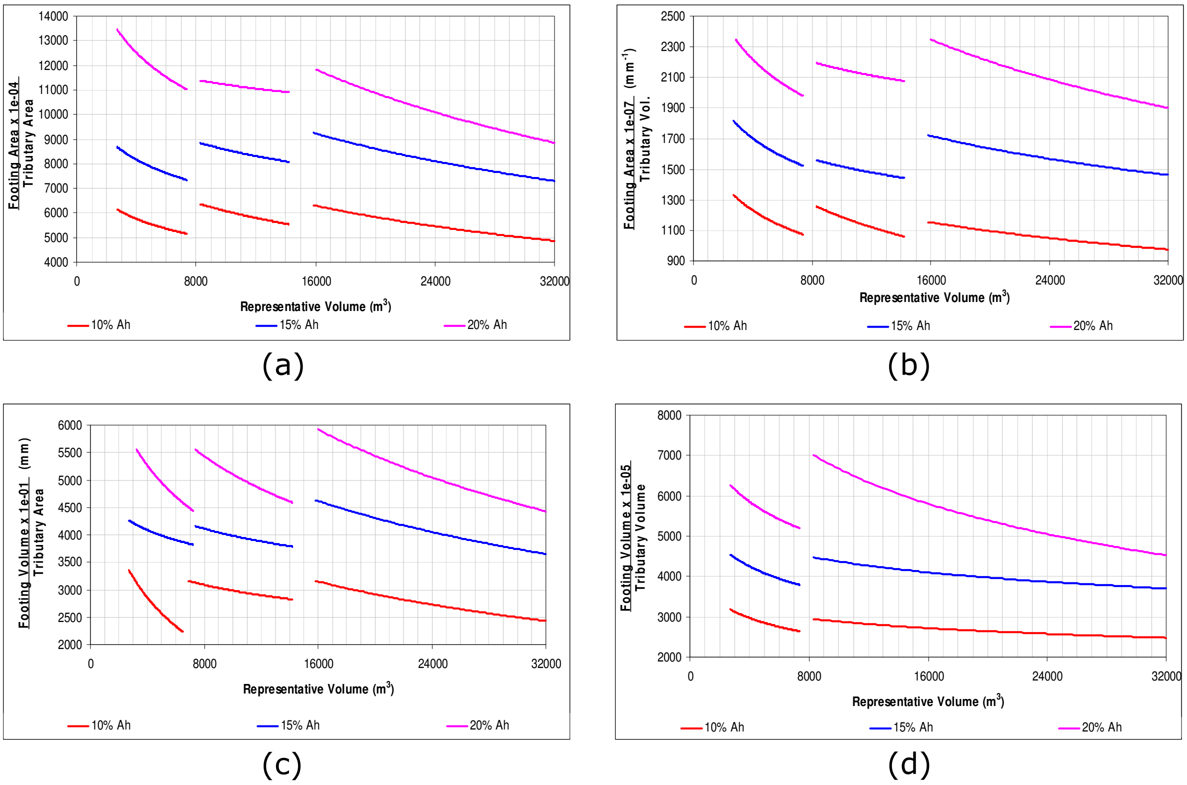


Fig. 4.5 Graphs for Estimation of Concrete Quantity for Corner Footing

The Fig. 4.6 shows graphs (a), (b), (c) and (d) used to estimate the required factor. The concrete quantity for intermediate footing can be obtained by evaluating the tributary volume and tributary area as per equations given in Table 4.3. The trend lines presented in Fig. 4.6 shows logarithmic variation of factors for various percentage of A_h plotted against representative volume.

The Fig. 4.7 shows graphs (a), (b), (c) and (d) used to estimate the required factor. The concrete quantity for gable footing can be obtained by evaluating the tributary volume and tributary area as per equations given in Table 4.3. The trend lines presented in Fig. 4.7 shows logarithmic variation of factors for various percentage of A_h plotted against representative volume.

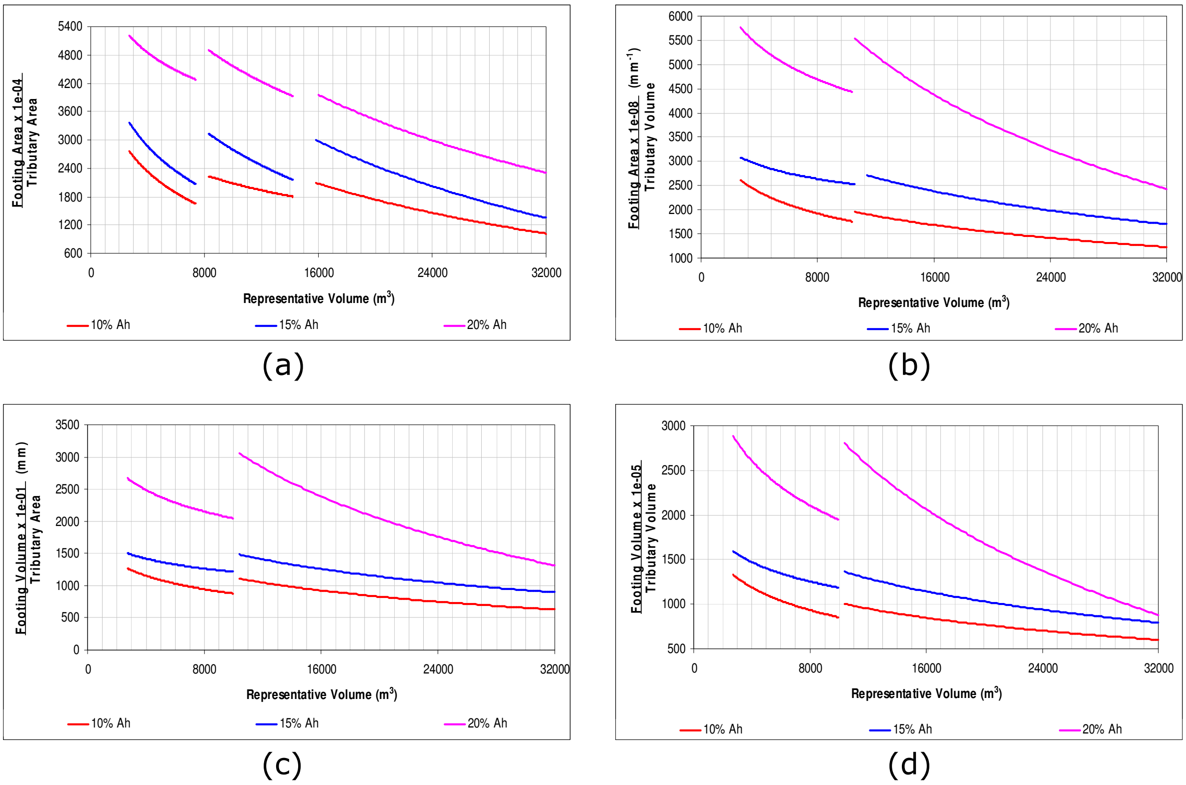


Fig. 4.6 Graphs for Estimation of Concrete Quantity for Intermediate Footing

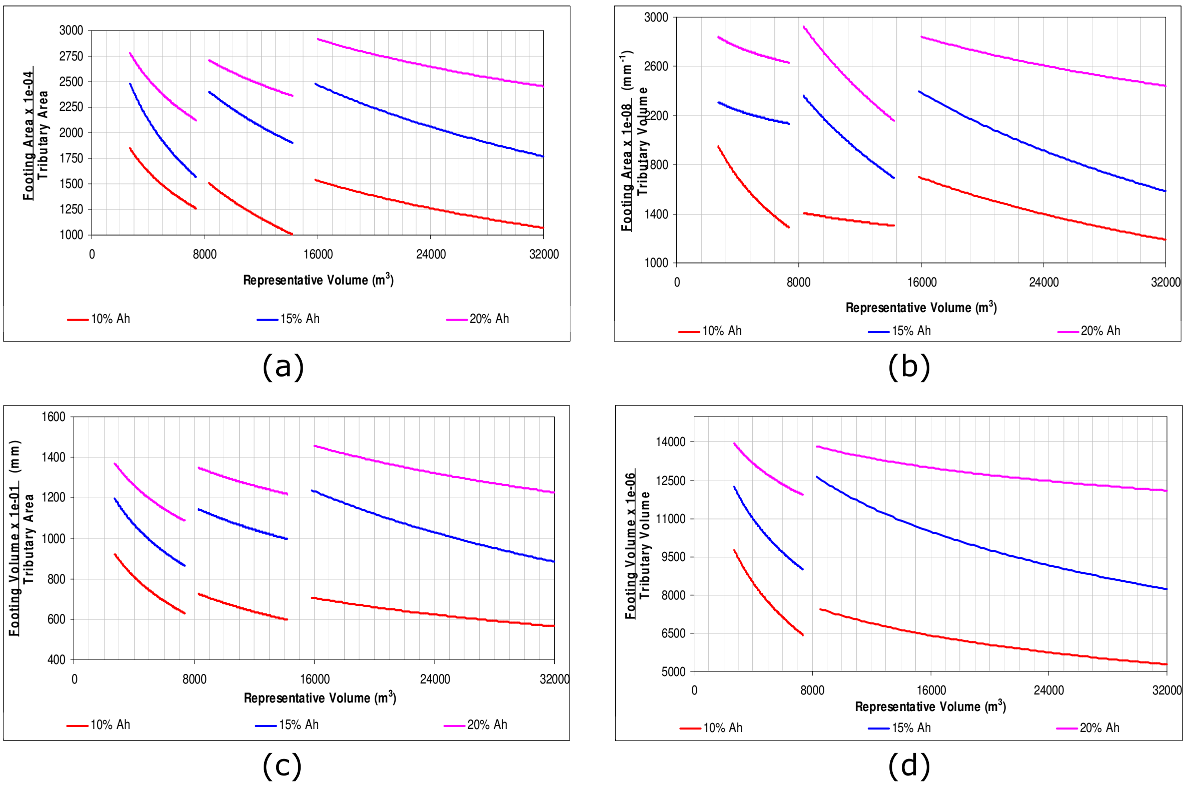


Fig. 4.7 Graphs for Estimation of Concrete Quantity for Gable Footing

Secondly, the concrete quantities for columns have been presented in the form of trend line charts. The tributary parameters have been expressed in the form of length of building, breadth of building, height of building and roof level of the building. The value of coefficient for intermediate value of design seismic horizontal coefficient can be interpolated from the graph. The estimation of preliminary sizes of various structural components can be easily made with the help of charts presented in the current section which will help to accelerate the design process.

The columns have been divided into 3 groups depending upon its location. The results for the governing load combinations have been tabulated and charts have been plotted for different values of A_h. In order to estimate the concrete quantity, the tributary area and tributary volume is required for various columns which are evaluated from the formula given in Table 4.4 depending on its location.

Table 4.4 Tributary Parameter for Column

Column Location	Tributary Area	Tributary Volume
Corner	$0.125 \times L \times B$	$0.125 \times L \times (B_f+T_f)$
Intermediate	$0.5 \times L \times B$	$0.5 \times L \times (B_f+T_f)$
Gable	$0.25 \times L \times B$	$0.25 \times L \times (B_f+T_f)$

The Fig. 4.8 shows graphs (a), (b), (c) and (d) used to estimate the required factor. The concrete quantity for corner column can be obtained by evaluating the tributary volume and tributary area as per equations given in Table 4.4. The trend lines presented in Fig. 4.8 shows logarithmic variation of factors for various percentage of A_h plotted against representative volume.

The Fig. 4.9 shows graphs (a), (b), (c) and (d) used to estimate the required factor. The concrete quantity for intermediate column can be obtained by evaluating the tributary volume and tributary area as per equations given in Table 4.4. The scattered data has been presented in the form of trend lines in order to obtain a relatively accurate value. The trend lines presented in Fig. 4.9 shows logarithmic variation of factors for various percentage of A_h plotted against representative volume.

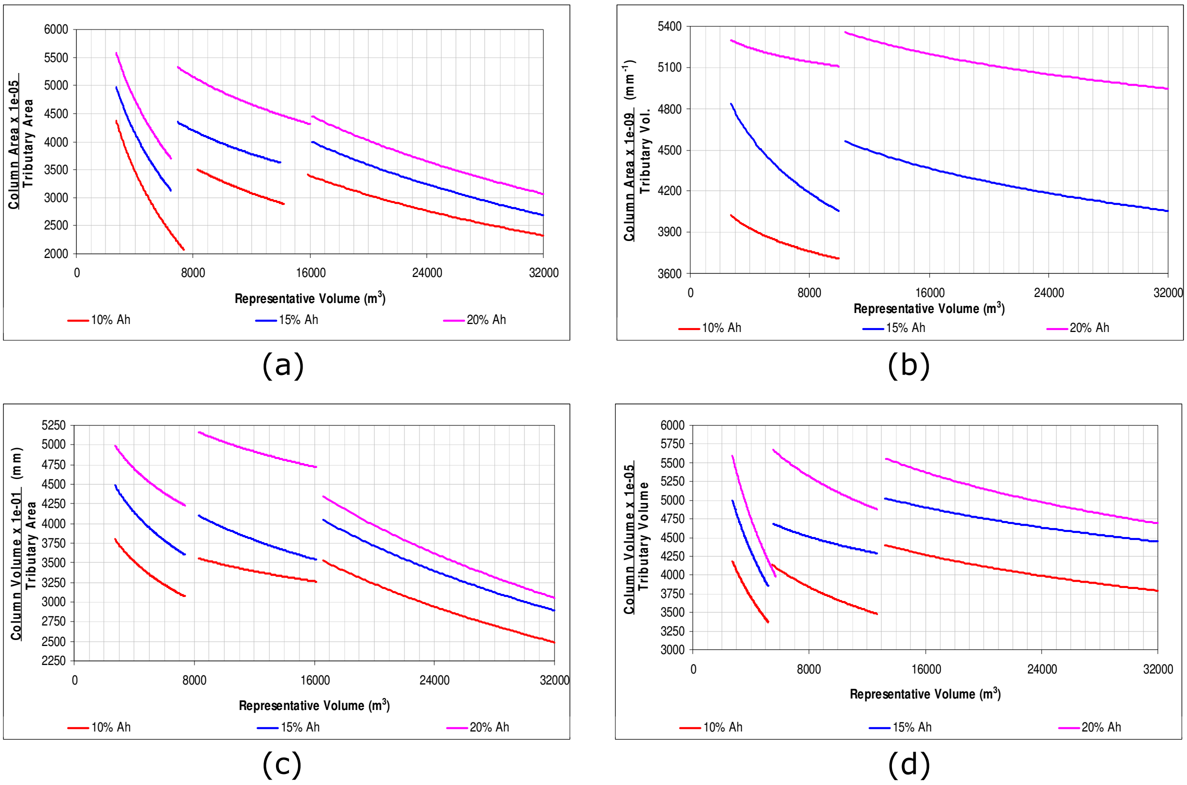


Fig. 4.8 Graphs for Estimation of Concrete Quantity for Corner Column

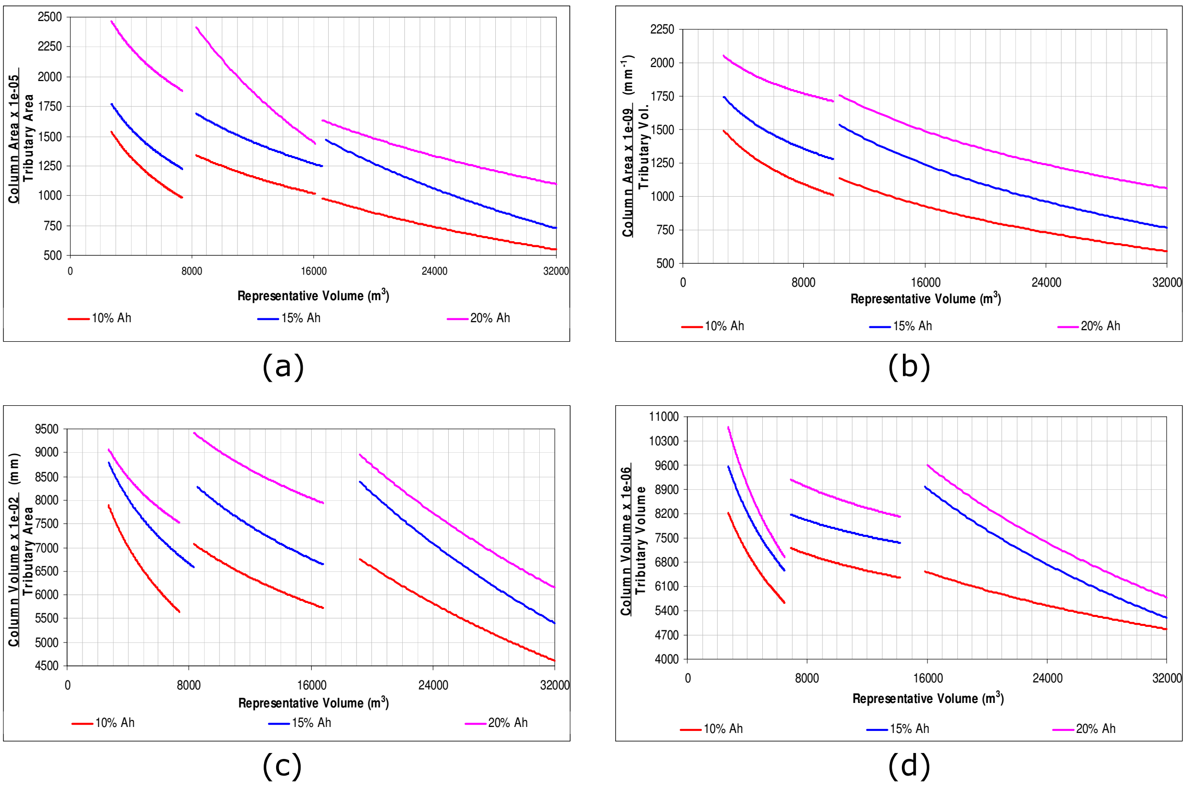


Fig. 4.9 Graphs for Estimation of Concrete Quantity for Intermediate Column

The Fig. 4.10 shows graphs (a), (b), (c) and (d) used to estimate the required factor. The concrete quantity for gable column can be obtained by evaluating the tributary volume and tributary area as per equations given in Table 4.4. The trend lines presented in Fig. 4.10 shows logarithmic variation of factors for various percentage of A_h plotted against representative volume.

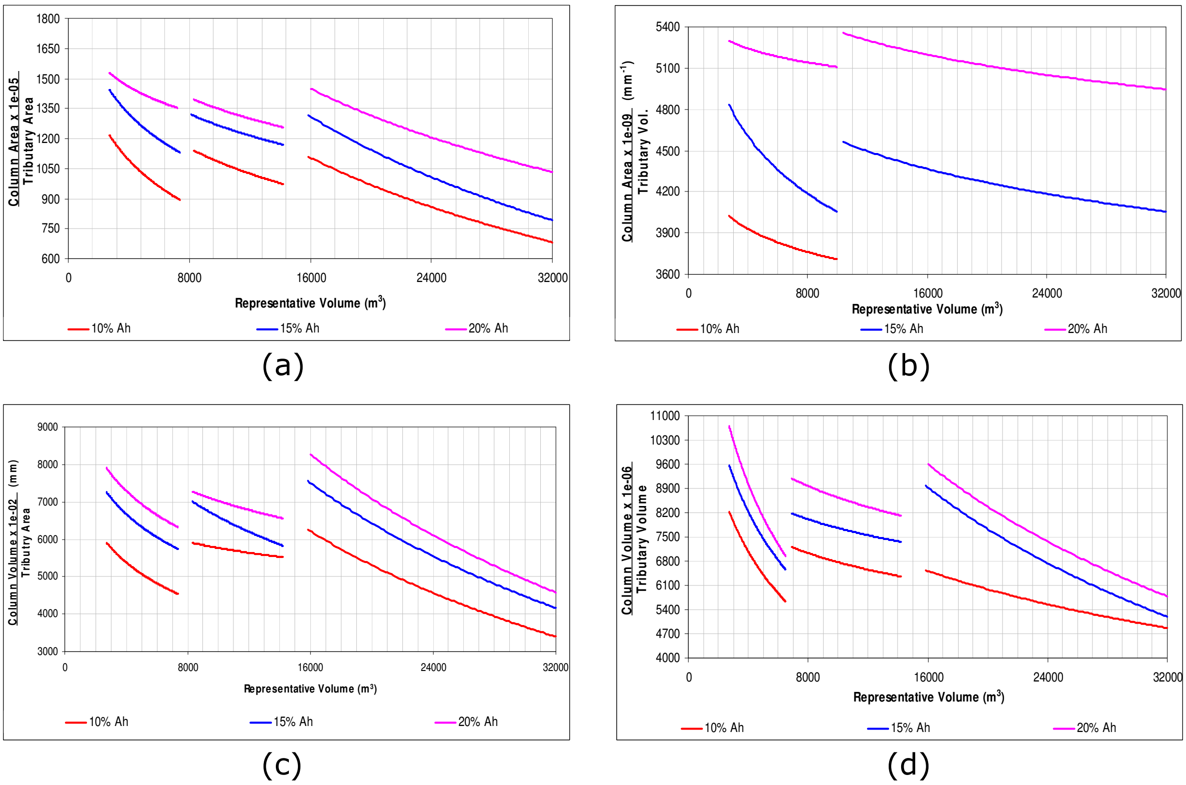


Fig. 4.10 Graphs for Estimation of Concrete Quantity for Gable Column

The tributary relations have been expressed in the form of length of building, breadth of building, height of building and roof level of the building and design seismic horizontal co-efficient. The value of coefficient for intermediate value of design seismic horizontal coefficient can be interpolated from the graph. The estimation of preliminary sizes of various structural components can be easily made with the help of charts presented in the current section which will help to accelerate the design process.

The beams have been divided into 3 groups depending upon its location. The results for the governing load combinations have been tabulated and charts have been plotted for different values of A_h. In order to concrete quantity, the tributary area and tributary volume is required for various beams which are evaluated from the formula given in Table 4.5 depending on its location.

Table 4.5 Tributary Parameter for Beam

Beam Location	Tributary Area	Tributary Volume
Transverse Plinth	0.5×L×B	0.5×L× (B_f+T_f)
Longitudinal Plinth	0.5×L×B	0.5×L× (B_f+T_f)
Transverse Lintel	0.5×L×B	0.5×L× (B_f+T_f)
Longitudinal Lintel	0.5×L×B	0.5×L× (B_f+T_f)
Transverse Gable Roof	0.5×L×B	0.5×L× (B_f+T_f)
Longitudinal Roof	0.5×L×B	0.5×L× (B_f+T_f)
Intermediate Roof	0.5×L×B	0.5×L× (B_f+T_f)
Secondary Roof	0.5×L×B	0.5×L× (B_f+T_f)

The Fig. 4.11 shows graphs (a), (b), (c) and (d) used to estimate the required factor. The concrete quantity for transverse plinth beam can be obtained by evaluating the tributary volume and tributary area as per equations given in Table 4.5. The scattered data has been presented in the form of trend lines in order to obtain a relatively accurate value. The trend lines presented in Fig. 4.11 shows logarithmic variation of factors for various percentage of A_h plotted against representative volume for transverse plinth beams.

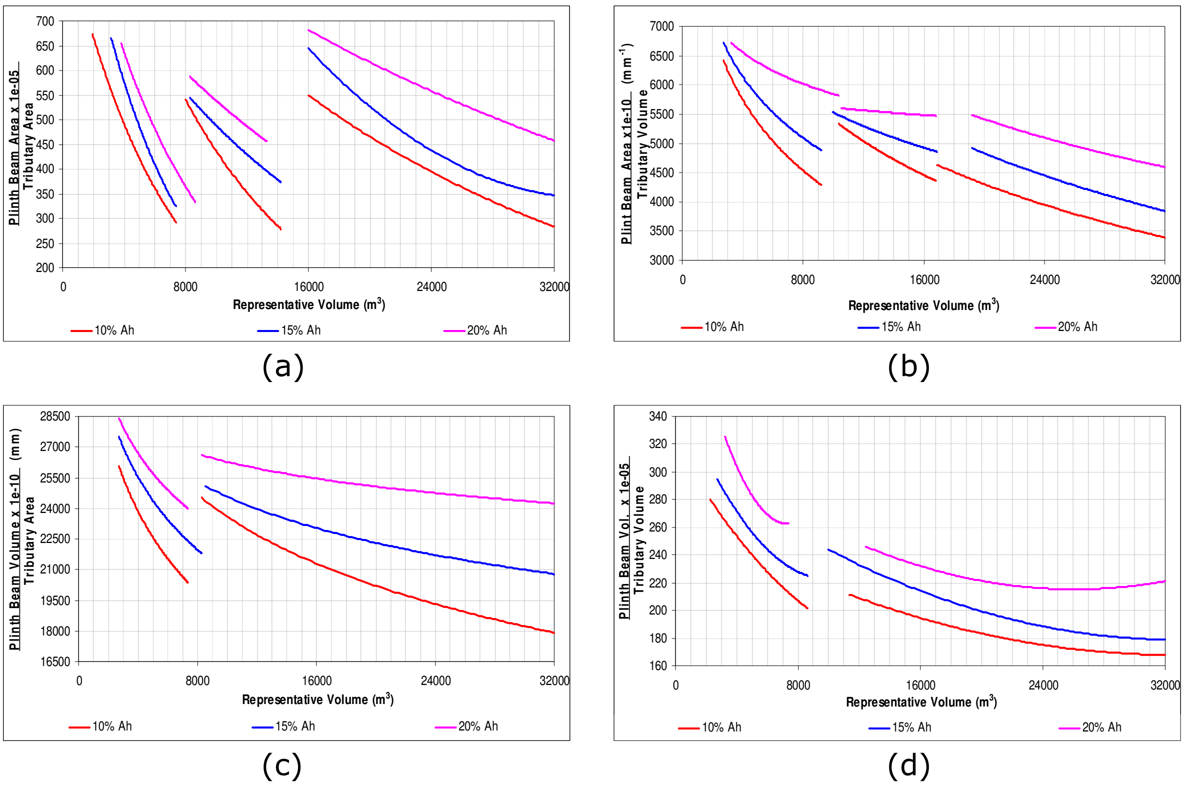


Fig. 4.11 Graphs for Estimation of Concrete Quantity for Transverse Plinth Beam

The Fig. 4.12 shows graphs (a), (b), (c) and (d) used to estimate the required factor. The concrete quantity for longitudinal plinth beam can be obtained by evaluating the tributary volume and tributary area as per equations given in Table 4.5. The trend lines presented in Fig. 4.12 shows logarithmic variation of factors for various percentage of A_h plotted against representative volume for longitudinal plinth beams.

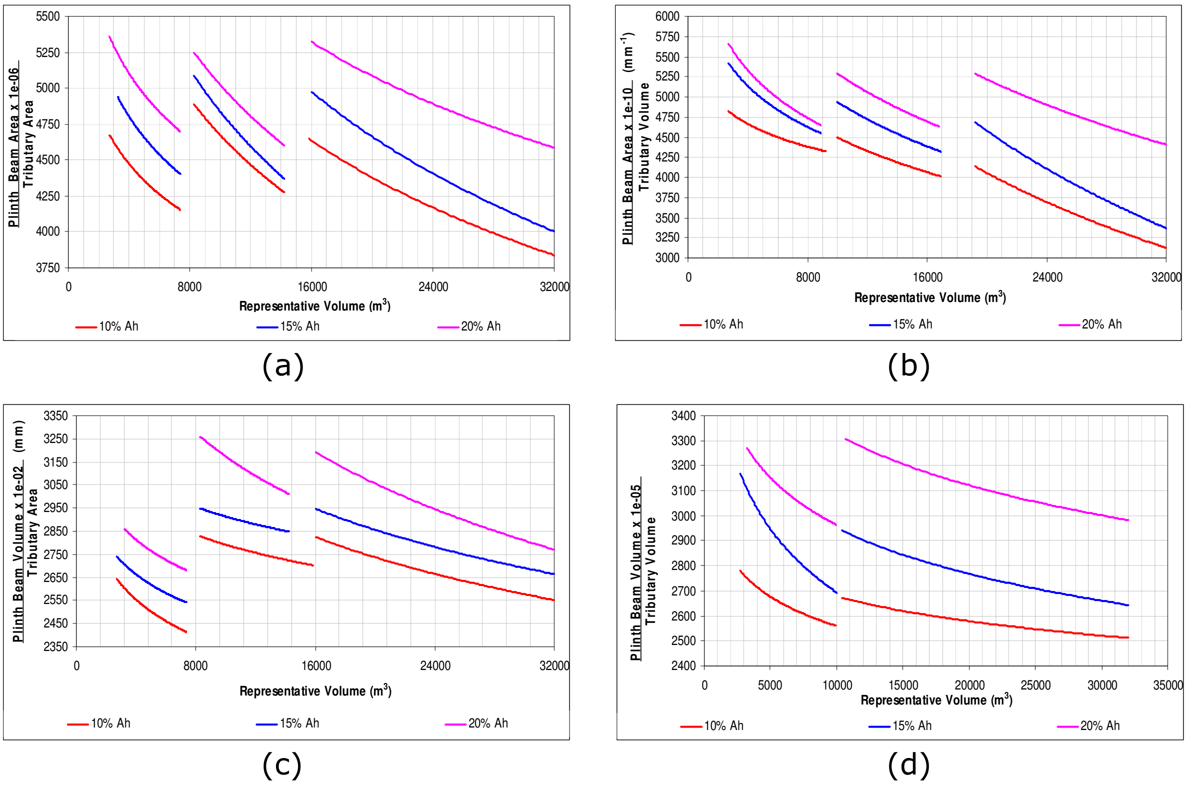
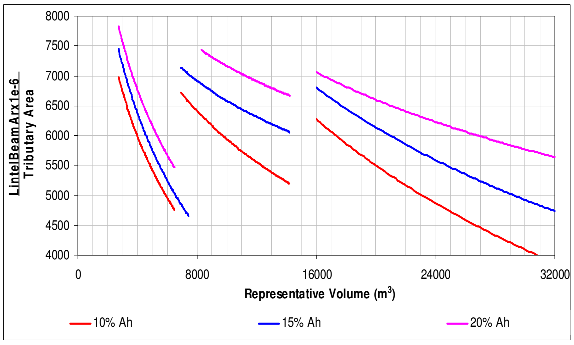


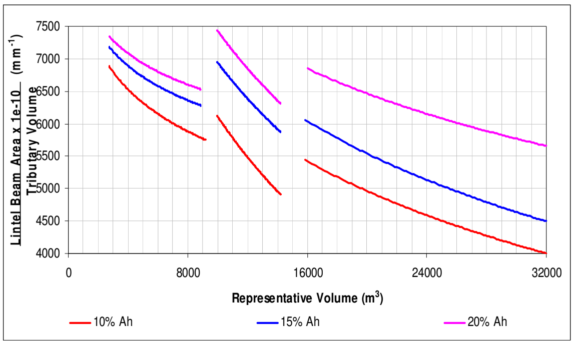
Fig. 4.12 Graphs for Estimation of Concrete Quantity for Longitudinal Plinth Beam

The Fig. 4.13 shows graphs (a), (b), (c) and (d) used to estimate the required factor. The concrete quantity for transverse lintel beam can be obtained by evaluating the tributary volume and tributary area as per equations given in Table 4.5. The trend lines presented in Fig. 4.13 shows logarithmic variation of factors for various percentage of A_h plotted against representative volume for transverse plinth beams.

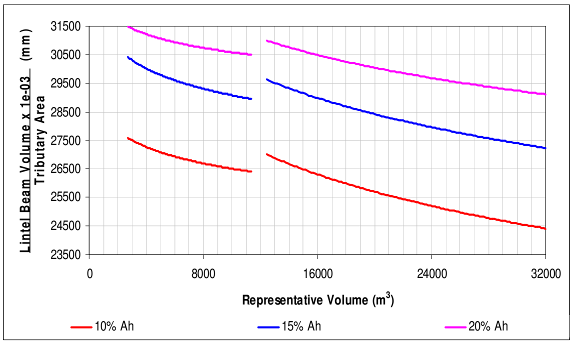
The Fig. 4.14 shows graphs (a), (b), (c) and (d) used to estimate the required factor. The concrete quantity for longitudinal lintel beam can be obtained by evaluating the tributary volume and tributary area as per equations given in Table 4.5. The trend lines presented in Fig. 4.14 shows logarithmic variation of factors for various percentage of A_h plotted against representative volume for longitudinal lintel beams.



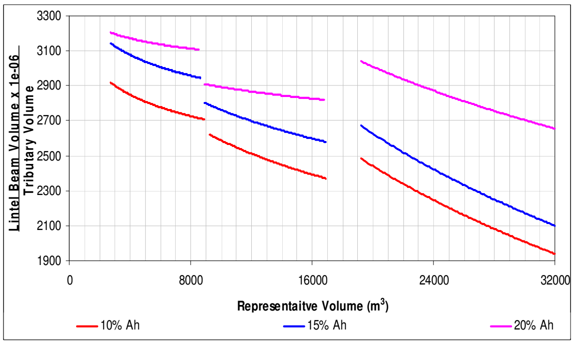
(a)



(c)

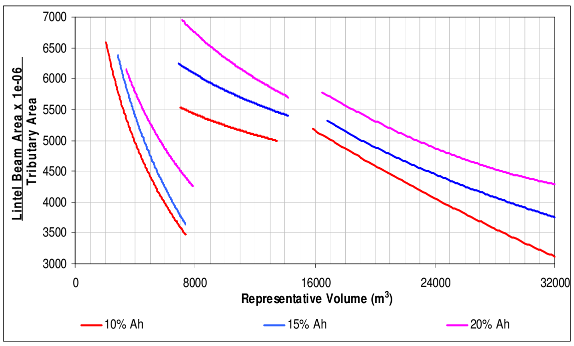


(c)

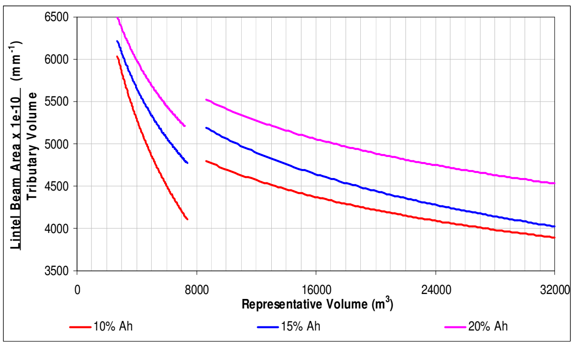


(d)

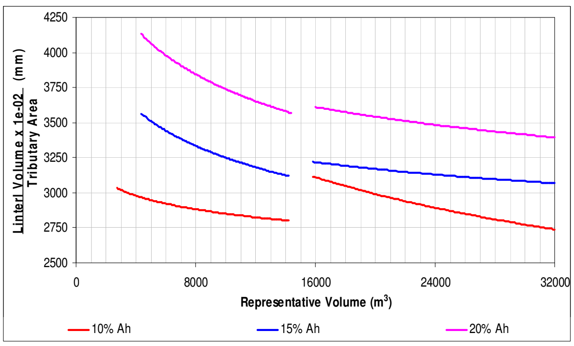
Fig. 4.13 Graphs for Estimation of Concrete Quantity for Transverse Lintel Beam



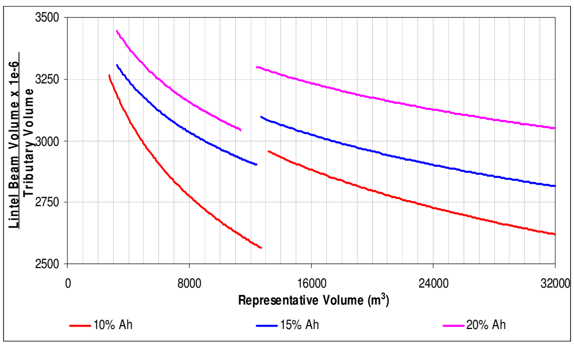
(a)



(b)



(c)



(d)

Fig. 4.14 Graphs for Estimation of Concrete Quantity for Longitudinal Lintel Beam

The Fig. 4.15 shows graphs (a), (b), (c) and (d) used to estimate the required factor. The concrete quantity gable roof beam can be obtained by evaluating the tributary volume and tributary area as per equations given in Table 4.5. The trend lines presented in Fig. 4.15 shows logarithmic variation of factors for various percentage of A_h plotted against representative volume.

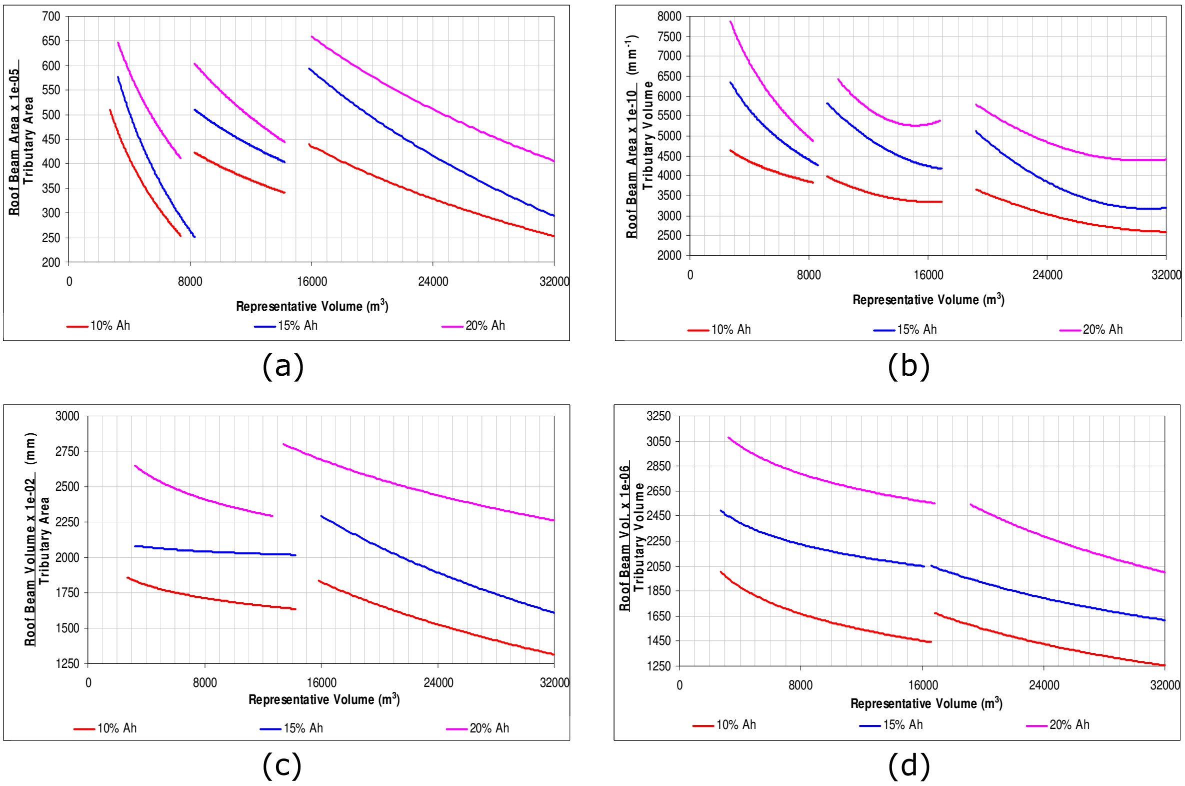


Fig. 4.15 Graphs for Estimation of Concrete Quantity for Gable Roof Beam

The Fig. 4.16 shows graphs (a), (b), (c) and (d) used to estimate the required factor. The concrete quantity longitudinal roof beam can be obtained by evaluating the tributary volume and tributary area as per equations given in Table 4.5. The trend lines presented in Fig. 4.16 shows logarithmic variation of factors for various percentage of A_h plotted against representative volume. The trend lines give a fairly good judgment of concrete quantity for different percentage of design seismic horizontal coefficient.

The Fig. 4.17 shows graphs (a), (b), (c) and (d) used to estimate the required factor. The concrete quantity transverse roof beam can be obtained by evaluating the tributary volume and tributary area as per equations given in Table 4.5. The trend lines presented in Fig. 4.17 shows logarithmic variation of factors for various percentage of A_h plotted against representative volume for transverse roof beams.

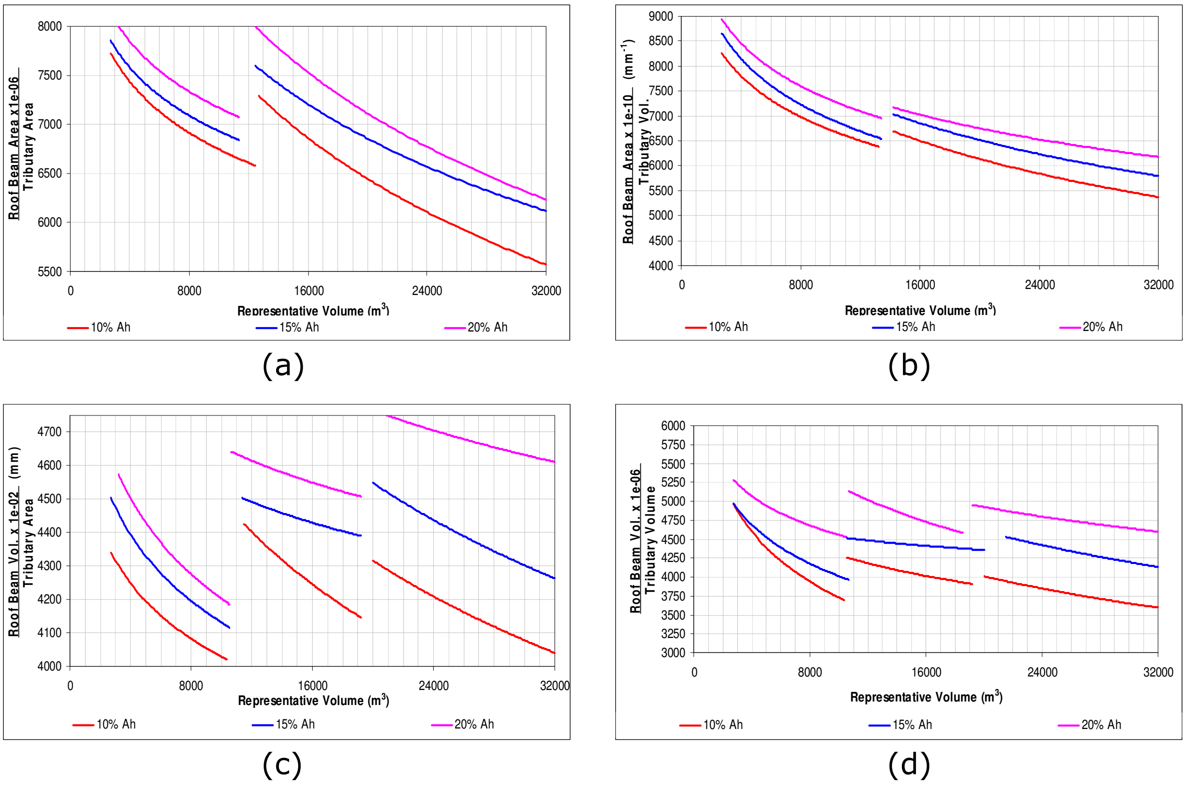


Fig. 4.16 Graphs for Estimation of Concrete Quantity for Longitudinal Roof Beam

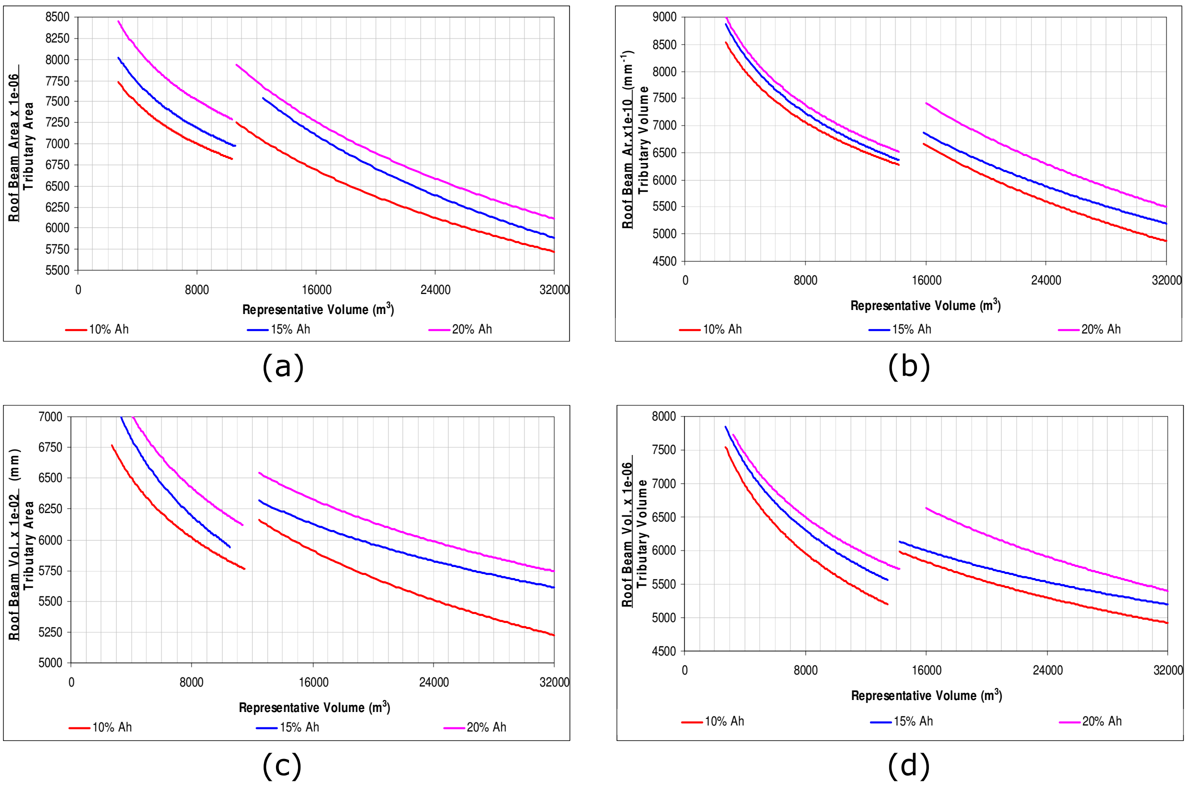


Fig. 4.17 Graphs for Estimation of Concrete Quantity for Transverse Roof Beam

The Fig. 4.18 shows graphs (a), (b), (c) and (d) used to estimate the required factor. The concrete quantity secondary roof beam can be obtained by evaluating the tributary volume and tributary area as per equations given in Table 4.5. The trend lines presented in Fig. 4.18 shows logarithmic variation of factors for various percentage of A_h plotted against representative volume. The trend lines give a fairly good judgment of concrete quantity for different percentage of design seismic horizontal coefficient.

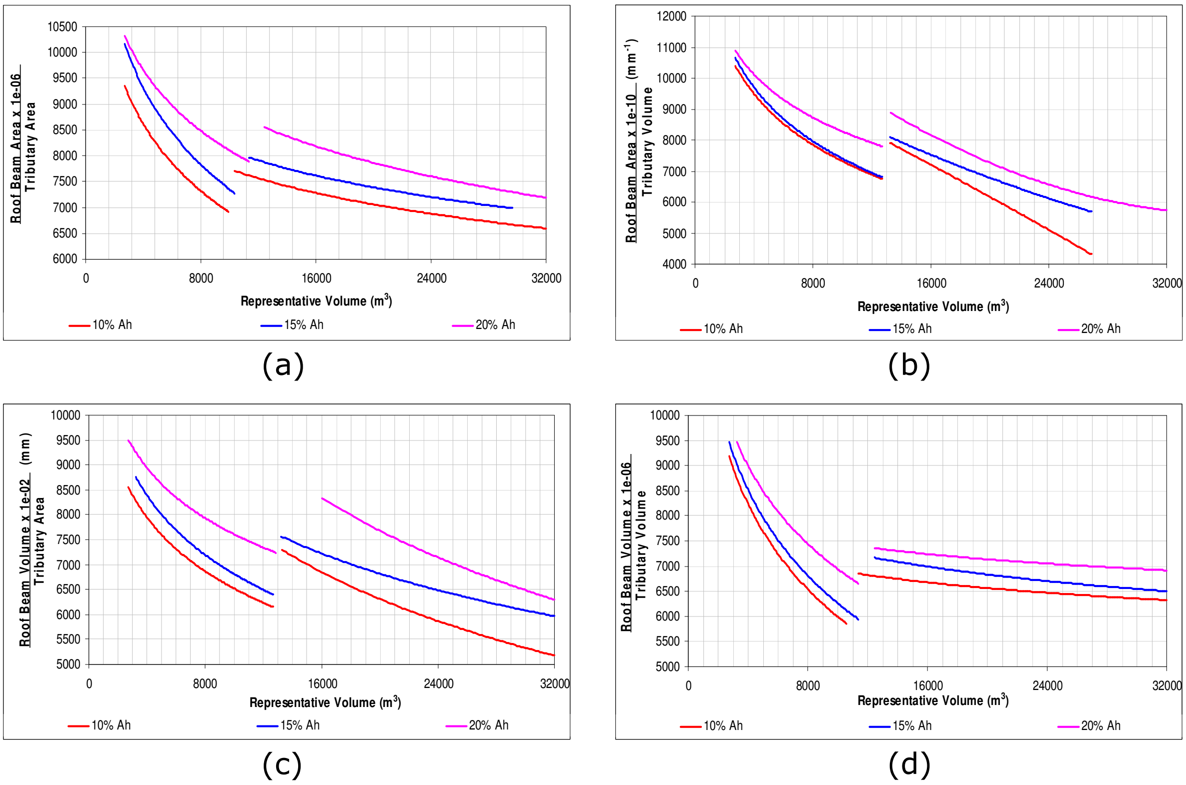


Fig. 4.18 Graphs for Estimation of Concrete Quantity for Secondary Roof Beam

The trend lines charts gives fairly good judgment to calculate the steel quantity for various structural components. Here, the logarithmic variation gives reliable results compared to linear variation. The trend line charts have been plotted to obtain the reinforcement quantity for corner, intermediate and gable end columns. Similarly, trend line charts have also been plotted to obtain the reinforcement quantity for plinth, lintel and roof beams. The scattered data has been presented in the form of trend lines in order to obtain a relatively accurate value. The trend lines presented in Fig. 4.19 shows logarithmic variation of reinforcement quantity for columns for various percentage of A_h plotted against representative volume.

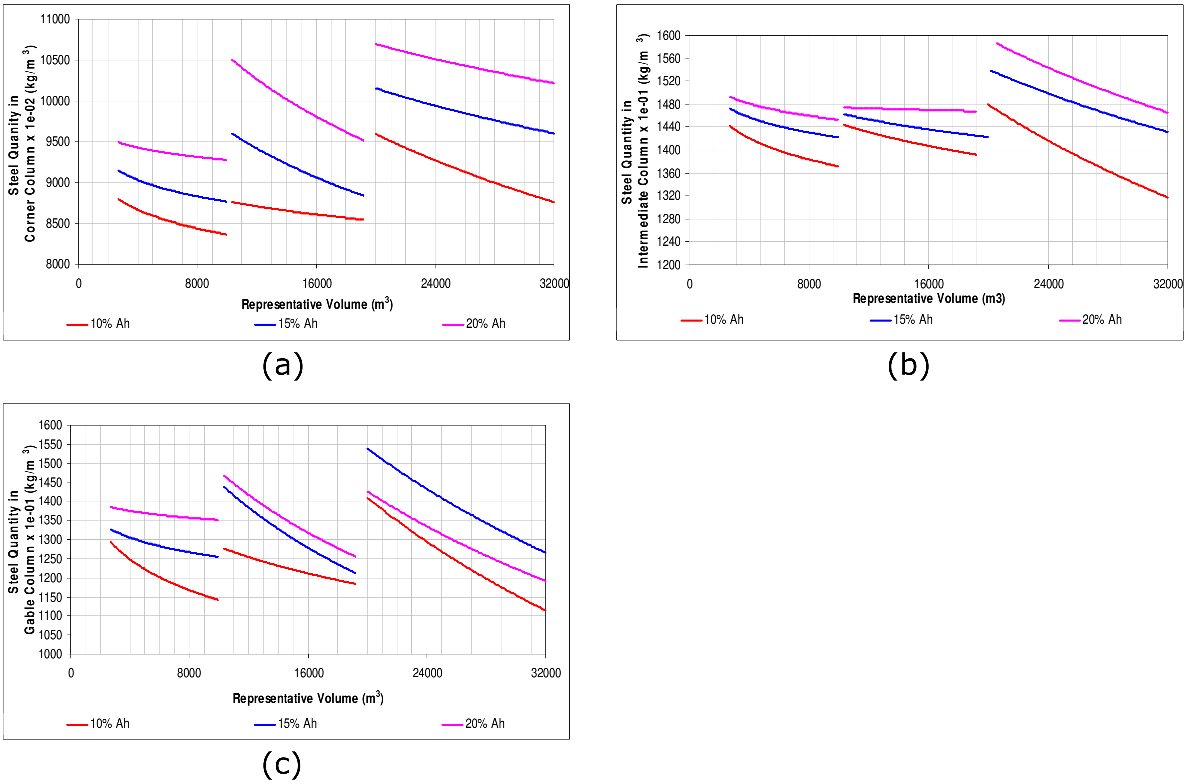


Fig. 4.19 Graphs for Estimation of Reinforcement Quantity for Columns

The trend lines presented in Fig. 4.20 shows logarithmic variation of reinforcement quantity for plinth beams for various percentage of A_h plotted against representative volume. The logarithmic trend lines have been selected for estimation because the logarithmic variation gives a relative accurate value as compared to the power or linear variation. For intermediate values of A_h the required values may be interpolated from the graphs.

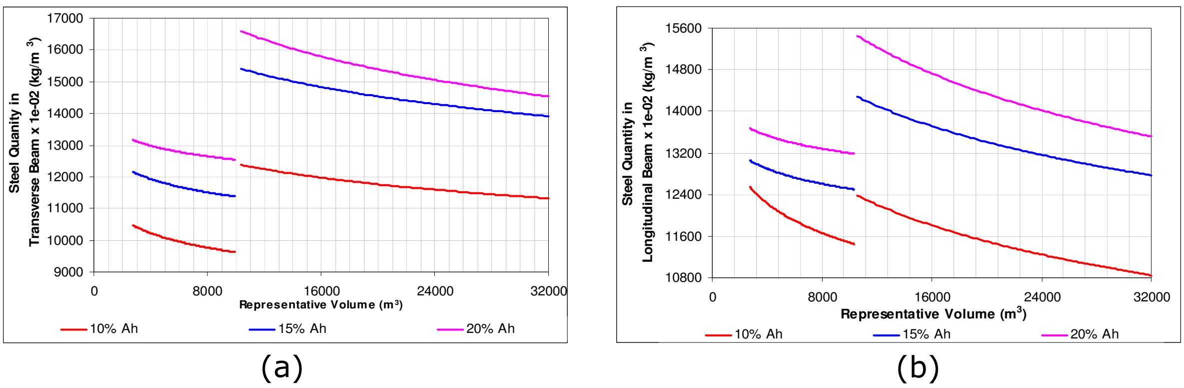


Fig. 4.20 Graphs for Estimation of Reinforcement Quantity for Plinth Beam

The trend lines presented in Fig. 4.21 shows logarithmic variation of reinforcement quantity for lintel beams for various percentage of A_h plotted against representative volume.

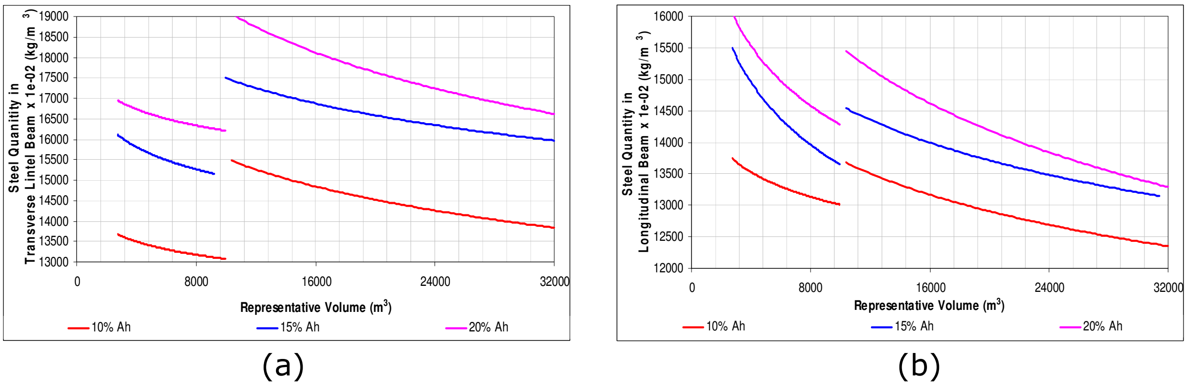


Fig. 4.21 Graphs for Estimation of Reinforcement Quantity for Lintel Beam

The trend lines presented in Fig. 4.22 shows logarithmic variation of reinforcement quantity for roof beams for various percentage of A_h plotted against representative volume.

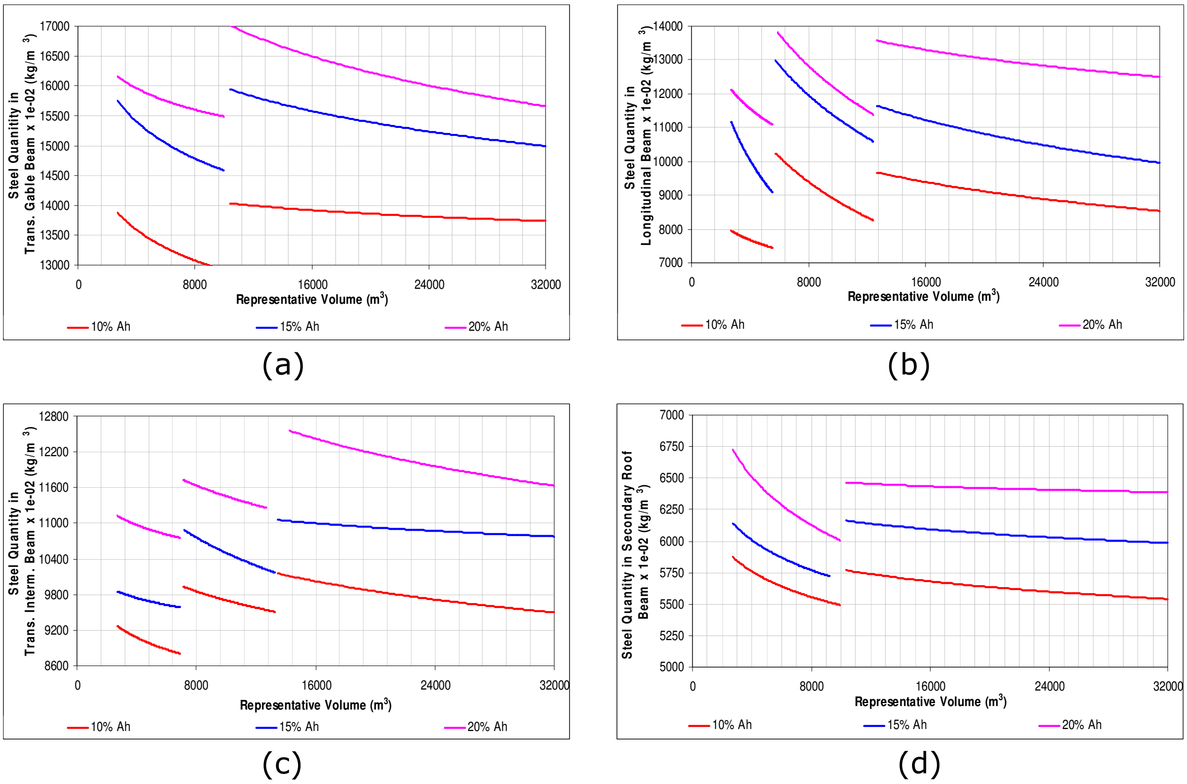


Fig. 4.22 Graphs for Estimation of Reinforcement Quantity for Roof Beam

For intermediate values of A_h, the required values may be interpolated so as to get a relatively accurate value. From the above graphs, following general observations can be made.

- The estimation of preliminary sizes of various structural components can be easily made with the help of charts given in the previous section. This database and graphs will result in saving of time in future and also help to complete the proposals for various projects within the stipulated time. For a large company like L&T-S&L, delivering design output in a stringent time schedule is one of the challenges. This will help in quick estimation of framing element sizes and accelerate the design process.

- Significant attention has been paid to establish a database which helps in estimating various structural quantities. Analysis and design of 150 odd buildings and deriving 67 factors to represent different structural quantities will help significantly in the quick estimate during proposal making and even during detailed engineering. Even a less skilled fresh learning engineer can quickly estimate the quantities with fairly good accuracy.
- This database will be kept in company's repository and will be enriched by adding data of buildings designed now onwards.

4.4 SUMMARY

In this chapter, the results of the database have been presented in the form of charts. The concrete quantities for the foundation, columns and beams can be estimated easily with the help of these graphs. These graphs can be used for preliminary as well as detailed engineering.

5. MODELING OF BRICK INFILLS IN POWER PLANT BUILDINGS

5.1 GENERAL

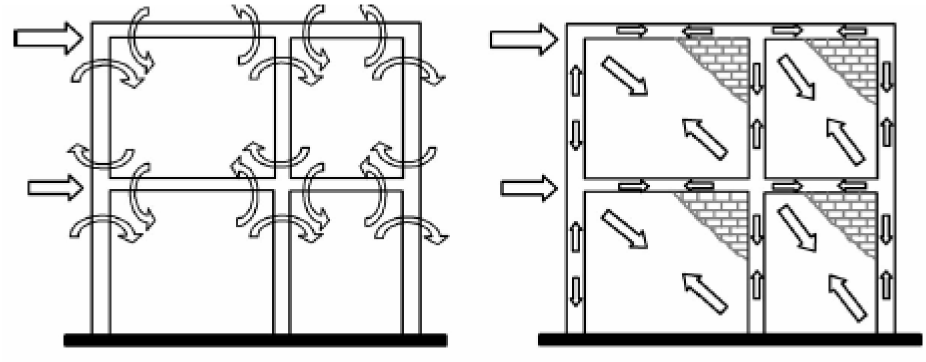
This chapter gives an introduction to different analytical methods for modeling of brick infills and also discusses the various approaches used to model the brick infills. This chapter focuses on structural modeling of brick infills in balance of plant buildings, analysis and design of power plant buildings. The infills have been modeled as equivalent compression struts using SAP 2000 software. The required B.O.P. building model has been generated with the help of a program, using Microsoft Excel which has been linked with Visual Basic. The required properties of infills have been assigned to the diagonal frame elements whose ends are pinned.

5.2 LOAD TRANSFER MECHANISM IN BARE FRAME AND INFILLED FRAME

Reinforced concrete framed buildings with infill walls are usually analyzed and designed as bare frames, without considering the strength and stiffness contributions of the infills. However, the infill walls contribute to the response of the structure and the behavior of infilled frame buildings is different from that predicted for bare frame structures, during earthquakes. Quality of infill material, workmanship and quality of frame-infill interface significantly affect the behavior of infilled frames.

In the framed structure, the main structural components are designed to carry the gravity loads and lateral loads. The bare frame with rigid joints predominantly behaves like a rigid frame, wherein the lateral forces are distributed according to the stiffness of each joint. The truss action is exhibited by the frame when the masonry infills are introduced in the bare frame.

When the columns receive the horizontal forces at floor levels, they try to move in the horizontal direction, but masonry walls tend to resist this movement and attract large horizontal forces due to their heavy weight and thickness. The truss action is responsible for reduction in bending moments and axial forces in the frame members. This leads to economy in design of various frame members as they are designed for lesser forces. In Fig. 5.1, the load transfer mechanism in bare frames and infillled frames has been shown.



(a) Predominant Frame Action (b) Predominant Truss Action

Fig. 5.1 Lateral Load Transfer Mechanism

5.3 NEED FOR MODELING OF BRICK INFILLS

Infilled frame construction has been in use for more than 200 years. The first study in the United States that investigated the lateral load behavior of infilled frames, was reported in the year 1958. Structural design plays an important role in mitigation of seismic hazards in case of strong earthquakes, which in turn depends on the estimation of earthquake forces on buildings. In the current design practice for reinforced concrete buildings, the skeleton frames are filled in their plane by brick or concrete block masonry walls to meet the architectural and functional requirements like partitioning, enclosing, etc. which are considered to be nonstructural. The analysis and design of buildings are done neglecting the strength and stiffness contributions of the infill which leads to incorrect idealization of the structure.

The composite behavior of an infill frame system combines the desirable characteristic of the separate wall and the frame. Individually the wall is stiff but brittle and the frame is ductile but relatively flexible. The combination, however as an infill frame is stiff, strong and tough. Therefore infill frame offers wide potential use in bracing of buildings and can be considered as an added safeguard against structural collapse under lateral forces.

The infill panel may be have reinforced concrete or brick masonry and bonded to the frame in a variety of ways. The bond characteristic is very important for the overall behavior of the structure. Many researchers have suggested the methods of analysis of the infilled frames, to make the concept of the infilled frames more realistic.

Mainly such structures can be analyzed by the following methods:-

- A more accurate Finite Element Approach
- An approximate Equivalent Single Strut Approach.

The finite element approach is more general approach to understand the behavior of infilled frame under various load conditions.

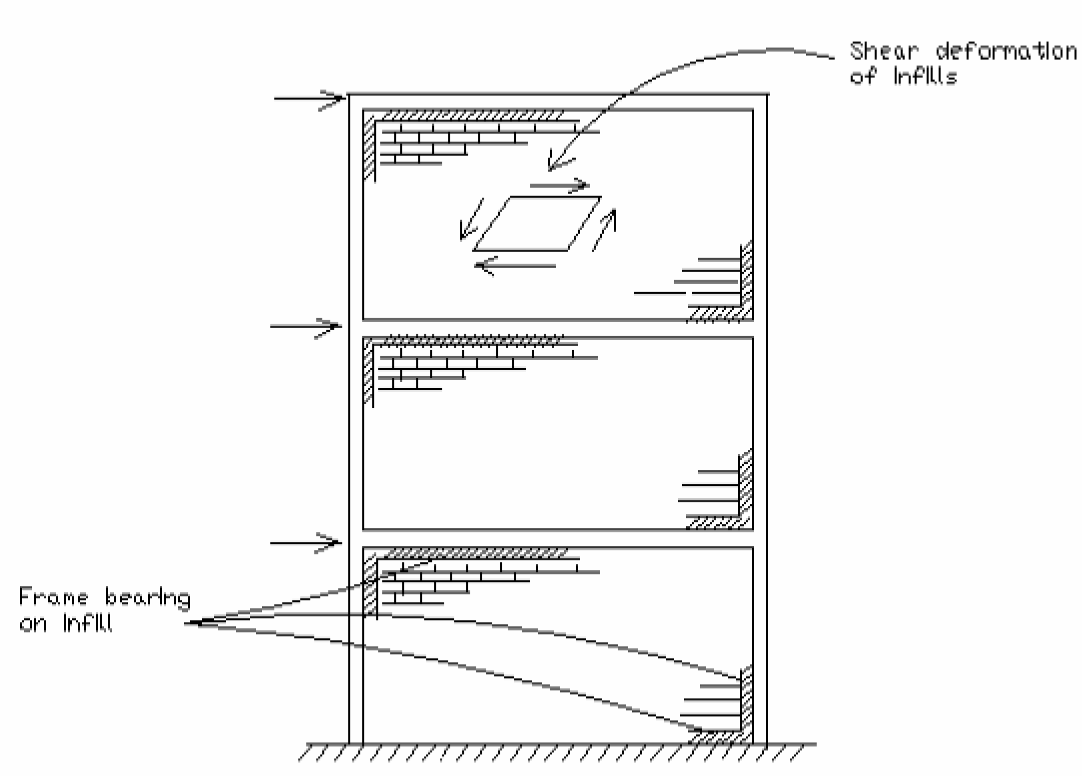
The Equivalent Single Strut Approach is an approximate approach to understand the strength and stiffness contribution of the infilled walls.

Different types of analytical macro-models, based on the physical understanding of the overall behavior of an infill panel are developed to mimic the behavior of infilled frames. Of the available models, the single strut model is the most widely used models and is reported in this literature. Thus, R.C. frames with unreinforced masonry walls are modeled as equivalent braced frames with infilled walls replaced by "equivalent struts".

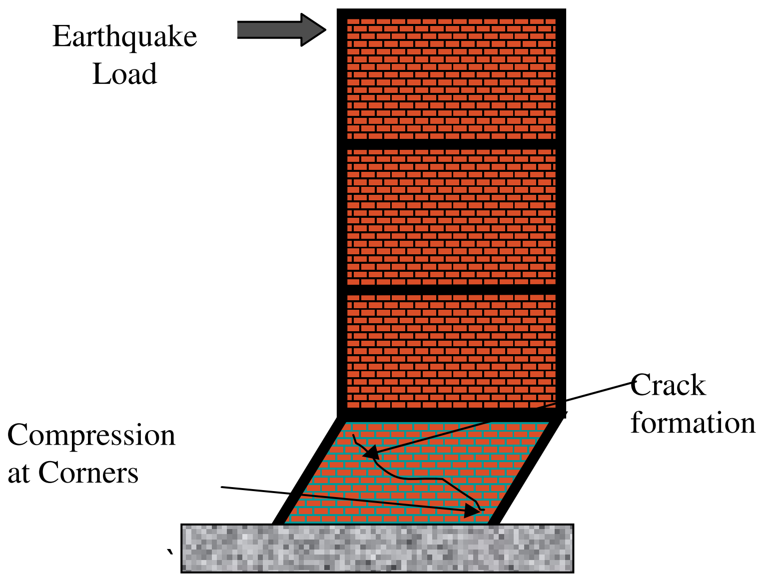
5.4 EQUIVALENT SINGLE DIAGONAL STRUT APPROACH

Masonry Infill in R.C. frame acts as a diaphragm in vertical plane and imparts significant lateral strength and stiffness to R.C. frames under lateral loads. Infilled frames are less deformable and are substantially stronger than otherwise identical bare frames. In symmetric buildings with vertical continuous infilled frames, the increased strength and stiffness may protect a building from damage associated with excessive lateral drift or inadequate strength. Therefore it is essential for the structural engineers to consider the action of infills in the design of R.C. buildings.

The in-plane lateral stiffness of an infilled frame system is not the same as the sum of the frame and infill stifnesses, because of the interaction of the infill with the surrounding frame. Experiments have shown that under lateral forces, the frame tends to separate from the infill near windward lower and leeward upper corners of the infill panels, causing compressive contact stresses to develop between the frame and the infill at other diagonally opposite corners, as observed in Fig. 5.2.



(a)



(b)

Fig.5.2 Frame-Infill Interaction

The contact stresses so developed may lead to (1) tension failure of the tension column due to overturning moments, (2) flexural or shear failure of the column, (3) diagonal tension cracking of the panel, (4) sliding shear failure of the masonry along the horizontal mortar beds. The engineering formulas are available for the capacity values corresponding to failure modes for the purpose of design in the relevant literature. Recognizing this behavior, the stiffness contribution of the infill is represented with an equivalent compression strut connecting windward upper and leeward lower corners of the infilled frames. In such analytical model, if the thickness and modulus of elasticity of the strut are assumed to be the same as those of the infill, the problem is reduced to determining the effective width of the compressive strut. Solid infilled frames may be modeled with a single compression strut as shown in Fig. 5.3. The equivalent diagonal struts are modeled as frame elements with pinned ends. The width of the strut depends on the method followed to model the brick infills. The ends of the diagonal strut shall be pin-jointed to the R.C. frame such that the moment transfer does not take place from R.C. frame to struts, as illustrated in Fig. 5.3.

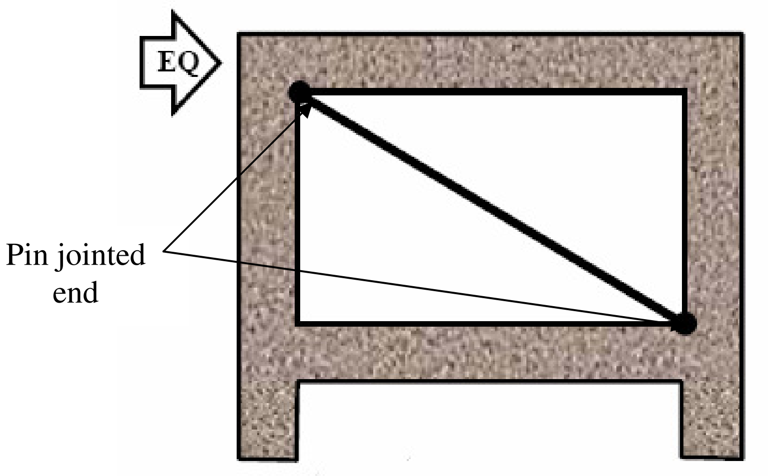
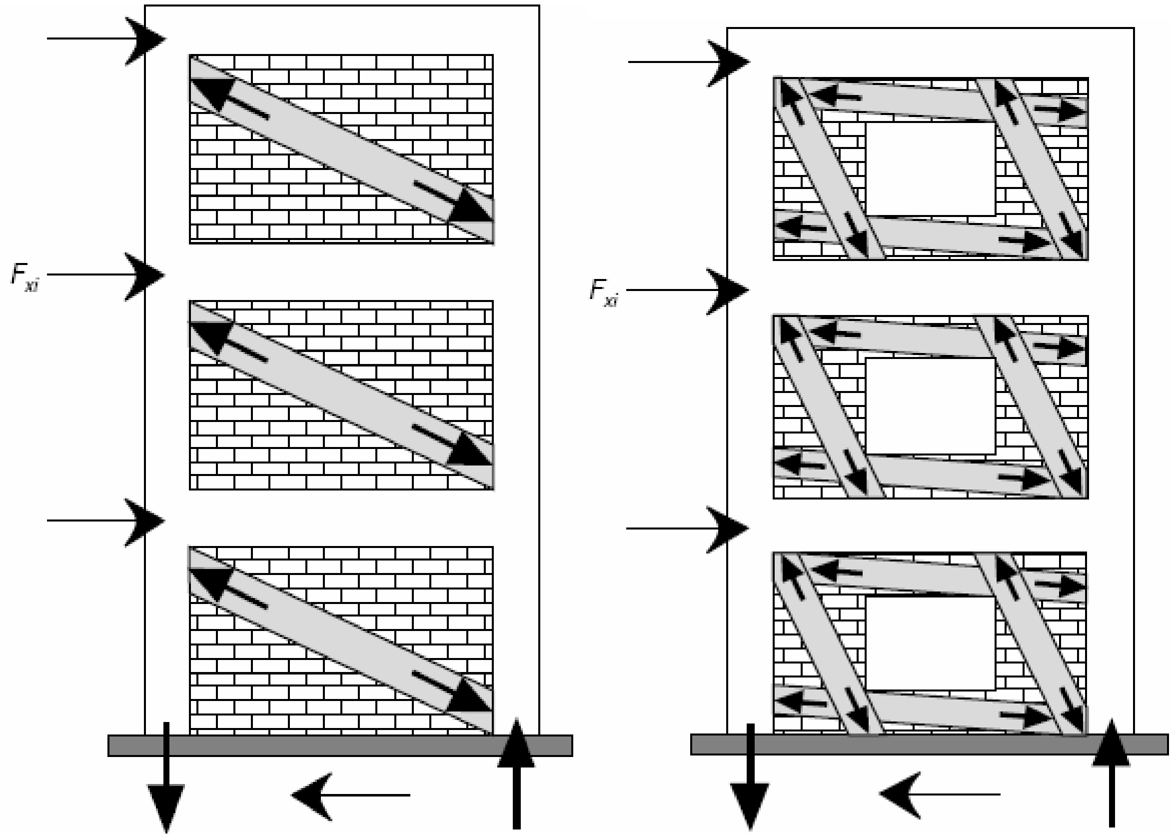


Fig. 5.3 Equivalent Diagonal Strut Model

The diagonally concentric equivalent struts can be used to incorporate infill panel stiffnesses into analytical models for the perforated infill panels, provided that the equivalent stifnesses of the infill is determined using appropriate analysis methods in a consistent fashion with a global analytical model. The various possible stress fields that can possibly develop within the infill can be represented with multiple compression struts. The required theoretical work and experimental data for determining multiple strut placement and strut properties however are not sufficient to establish reliable guidelines; thus the approach requires exercise of judgment on a case-by-case basis. The stiff masonry infill may attract more lateral force than a frame can resist, so the frames must be checked to see if they are capable of resisting infill forces in the ductile manner. The Fig. 5.4 shows compression strut analogy for bare frames and frames with brick infills.



(a) Brick Infills without Openings (b) Brick Infills with Openings

Fig. 5.4 Compression Strut Analogy

Masonry infill walls are remarkable in increasing the initial stiffness of reinforced concrete frames, and being the stiffer component, attract most of the lateral seismic shear forces on buildings, thereby reducing the forces resisted by R.C. frame members. The behavior of M.I. is difficult to predict because of its brittle nature and significant variation in material properties. Here, basically two methods are used to determine the width of the equivalent diagonal strut. The following literature is referred in this regard.

5.4.1 Proposed Draft Provisions And Commentary On Indian Seismic Code IS: 1893 (Part I)[6]

The Proposed Draft code is still in development stage as part of ongoing project on building codes sponsored by Gujarat State Disaster Management Authority, Gandhinagar at Indian Institute of Technology Kanpur. The Proposed Draft code suggests the methods to determine the effective width of strut. Thickness of the strut shall be taken as the actual thickness of the wall. The modulus of elasticity of masonry is evaluated from the empirical expression given in Proposed Draft provisions and Commentary on Indian Seismic Code IS: 1893 (Part I)[6] and is expressed in Equation 5.1.

$$E_m = 550 f_m \qquad \text{...(5.1)}$$

Where,

E_m = modulus of elasticity of masonry in MPa.

f_m = compressive strength of masonry prism in MPa.

The width of equivalent diagonal strut for brick infills without openings is evaluated from the empirical expression given in Proposed Draft provisions and Commentary on Indian Seismic Code IS: 1893 (Part I)[6] and is expressed in Equation 5.2.

$$w_{ds} = \frac{d}{3} \qquad \text{...(5.2)}$$

Where,

w_{ds} = width of equivalent diagonal strut in m, for solid walls without any openings

d = diagonal length of infill in m

The width of equivalent diagonal strut for brick infills with openings is evaluated from the empirical expression given in Proposed Draft provisions and Commentary on Indian Seismic Code IS: 1893 (Part I)[6] and is expressed in Equation 5.3.

$$w_{do} = \rho_w w_{ds} \qquad \text{...(5.3)}$$

Where,

$\rho_w = 1 - 2.5 A_r$

w_{do} = width of equivalent diagonal strut for infill walls with openings in m

ρ_w = reduction factor

A_r = opening area ratio

Here if the opening area ratio is less than 0.05, i.e. the area of opening is less than 5% of the area of infill panel, no reduction in the width of diagonal strut need to be made and the infill panel can be modeled as a solid panel, whereas if the opening are ratio is greater than 0.4, i.e. the area of opening exceeds 40% of the area of infill panel, the strut reduction factor shall be set to zero and the effect of infill shall be ignored in that panel.

The dimensions of equivalent diagonal strut as per proposed draft provisions and commentary on Indian Seismic Code IS: 1893 (Part I)[6] for brick infills without openings is illustrated in the following Fig. 5.5.

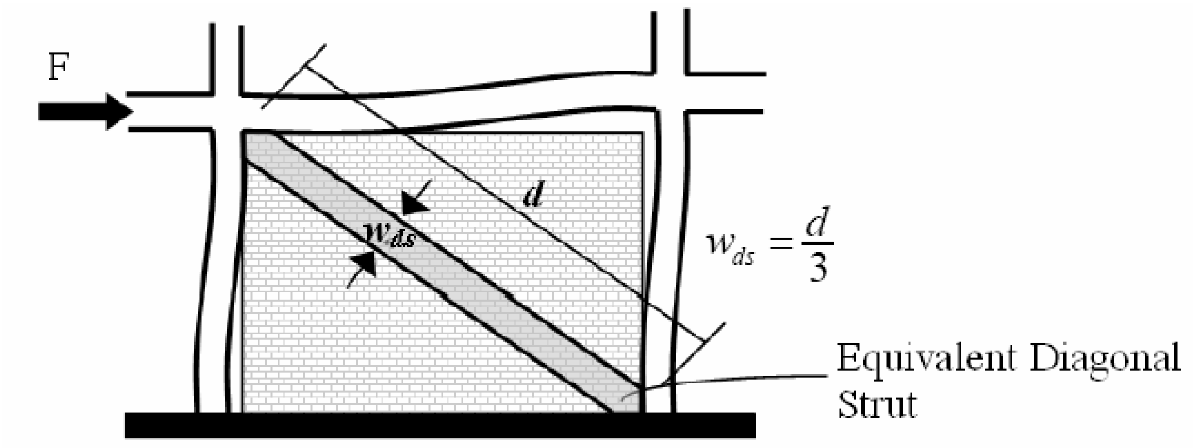


Fig. 5.5 Estimation of Dimensions for Equivalent Diagonal Strut as per Proposed Draft Provisions and Commentary on Indian Seismic Code IS: 1893 (Part I) for Infilled Frames Without Openings

5.4.2 Federal Emergency Management Agency-273[7]

The primary purpose of this document is to provide sound technical guidelines for the seismic rehabilitation of buildings. It is intended to serve as a ready tool for design professionals and a foundation for future development and implementation of building code provisions and standards. The chapter 7 of the guidelines discusses the masonry elements that are considered to resist lateral seismic forces as structural members. According to the guidelines given in chapter 7 of Federal Emergency Management Agency–273[7], the width of equivalent diagonal strut for brick infills without openings is evaluated from the following empirical expression given by Equation 5.4

$$a = 0.175(\lambda_1 h_{col})^{-0.4} r_{\inf} \qquad \ldots(5.4)$$

where $\lambda_1 = \left[\dfrac{E_{me} t_{\inf} \sin 2\theta}{4 E_{fe} I_{col} h_{\inf}}\right]^{\frac{1}{4}}$

λ_1 = coefficient to determine equivalent width of infill strut

h_{col} = column height between centerlines of beams, in.

h_{inf} = column height between centerlines of beams, in.

E_{fe} = expected modulus of elasticity of frame material, psi

E_{me} = expected modulus of elasticity of infill material, psi

I_{col} = moment of inertia of column, in.^{4}

L_{inf} = length of infill panel, in

r_{inf} = diagonal length of infill panel, in.

t_{inf} = thickness of infill panel and equivalent strut,in.

θ = angle whose tangent is the infill height to length aspect ratio, radians.

The dimension of equivalent diagonal strut as per FEMA-273[7] for brick infills without openings has been illustrated in the following Fig. 5.5.

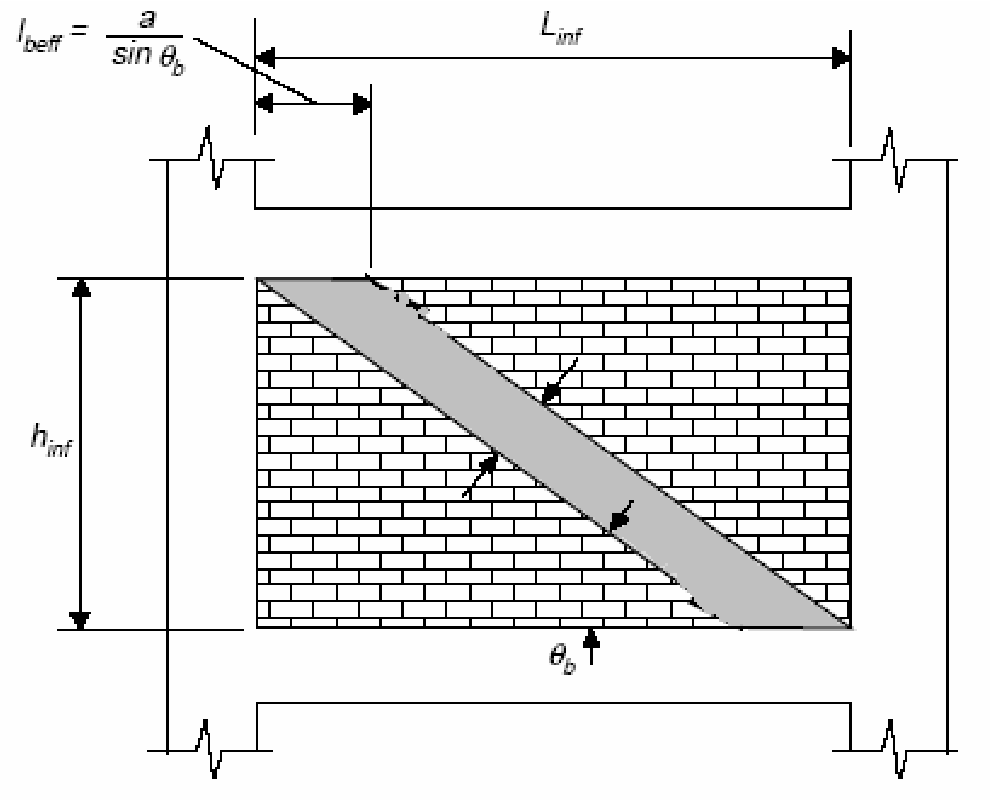


Fig. 5.6 Estimation of Dimensions for Equivalent Diagonal Strut as per FEMA-273 for Infilled Frames Without Openings

5.5 MODELING OF BRICK INFILLS IN B.O.P. BUILDINGS USING SAP 2000

The steps for modeling brick infills remains the same for IS: 1893 (Part I) Proposed Draft[6] as well as FEMA-273[7]. For modeling brick infills in B.O.P. buildings, the first step is to define a new material using the Define menu. The material properties required to model the equivalent diagonal strut are weight per unit volume, modulus of elasticity, poisson's ratio, co-efficient of thermal expansion and shear modulus. The above mentioned parameters are entered for masonry as shown in Fig. 5.7.

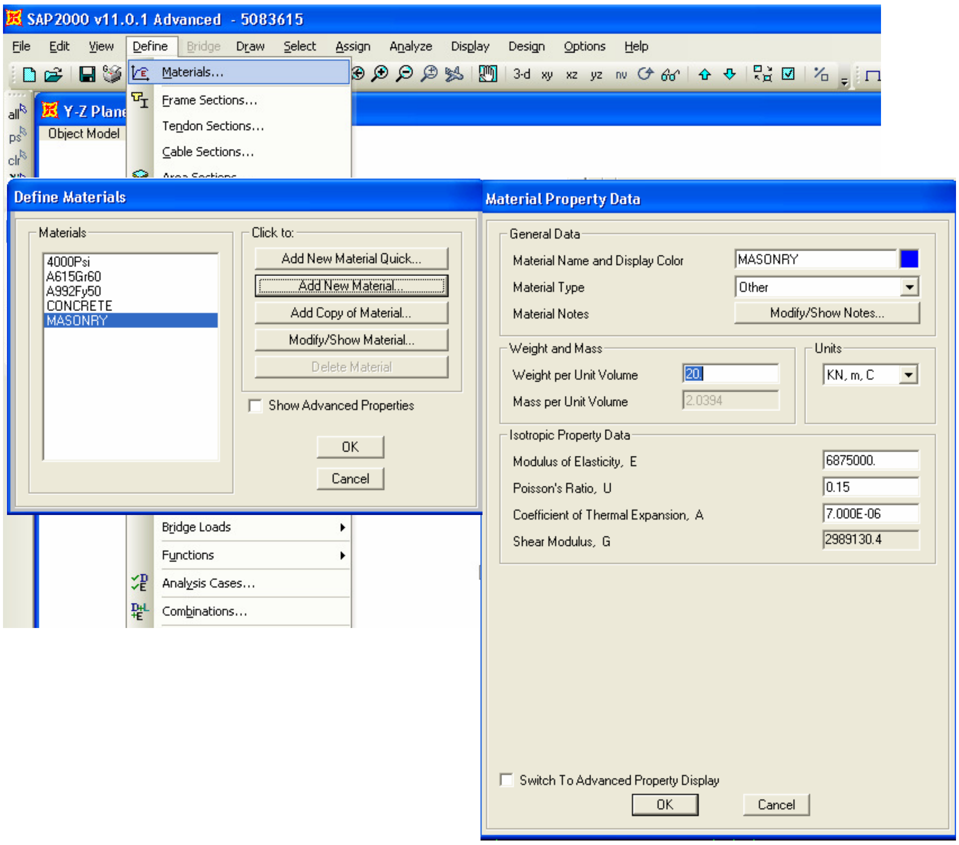


Fig. 5.7 Material Property Definition for Masonry

The next step is defining frame sections for modeling of diagonal strut using the Frame Sections command from the Define menu. The frames sections are defined for bare frames in both the orthogonal directions. Also the frame sections are defined for portion above lintel and portion below lintel. The first method to calculate the width of the strut is the one proposed by Sudhir K. Jain et al.[6] in Proposed Draft Provisions and Commentary on Indian Seismic Code (Part I), for B.O.P. buildings with and without infills. The second method used to evaluate the width of strut is that given in guidelines issued by Federal Emergency Management Agency-273[7].

The brick infills are modeled as rectangular sections and the thickness of the frame sections is taken same as the thickness of the masonry infill wall, while the width of sections depends on the method adopted to calculate the width of strut. The screenshot shown in the following Fig. 5.8 displays the frame section definition. The property of the infill is modified and the weight of the infills is taken as zero. The main reason for neglecting the weight of infill is to prevent the infill from resisting any moments due to self weight and carry only axial loads.

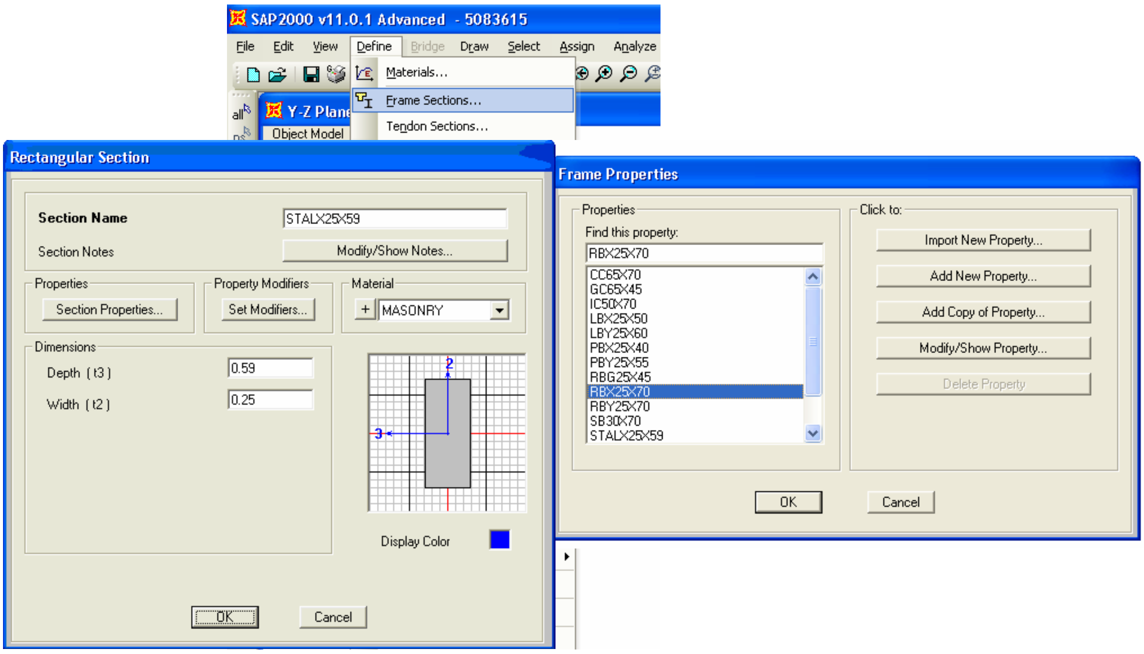


Fig. 5.8 Frame Property Definition for Masonry

After the frame section property is defined, the respective properties are assigned to the pinned struts as shown below in Fig. 5.9 using Assign Command from the Assign menu. This completes the modeling of the infills.

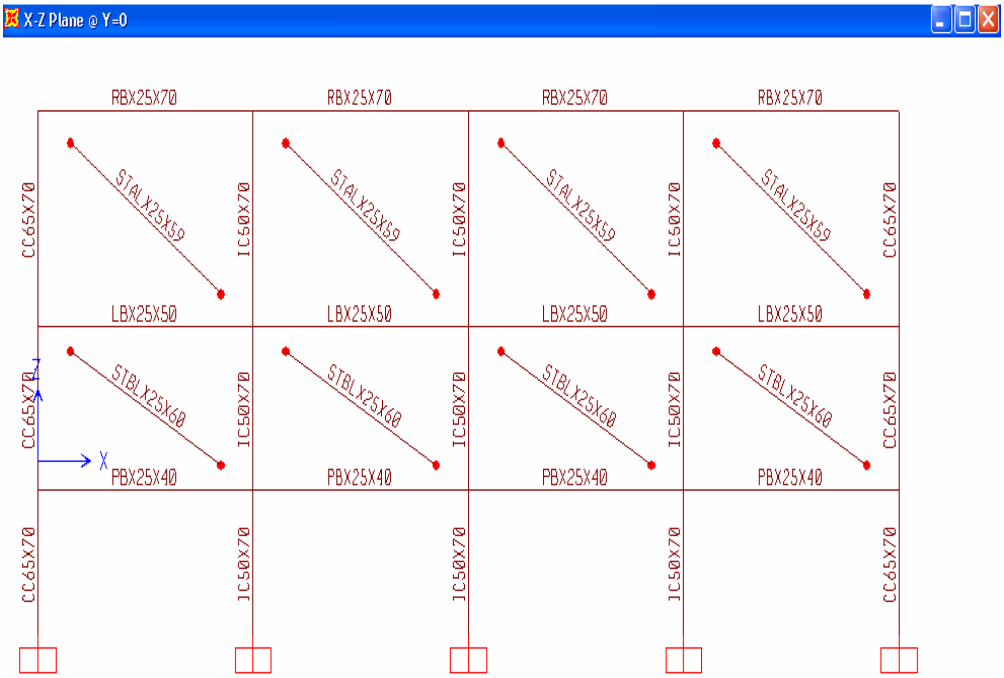


Fig. 5.9 Frame Property Assignment to Equivalent Struts

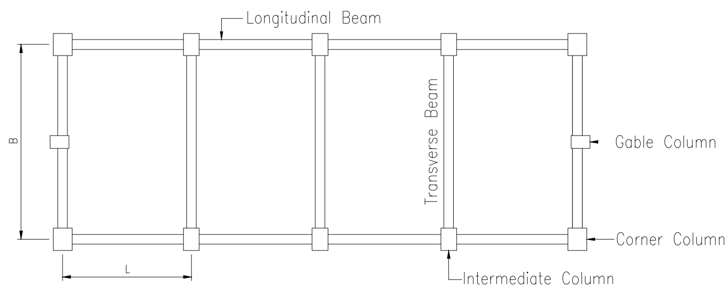
After the assignment of the properties to the respective frame sections, the analysis is performed by selecting the Run Analysis command from the Analyze menu and the results are tabulated.

5.6 RESULTS AND DISCUSSION

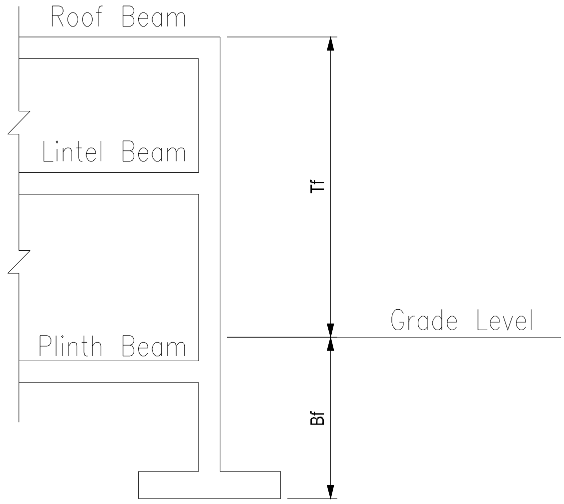
In the present study, the brick infills are modeled by considering the equivalent single diagonal strut approach suggested by IS: 1893 (Part I) Proposed Draft[6] and FEMA-273[7]. The structural modeling of brick infills suggested by FEMA-273[7] takes into account infilled frames without openings and that suggested by IS: 1893 (Part I) Proposed Draft[6] accounts for both solid infilled frames as well as perforated infilled frames. In the present study, 5 models each of bare frames and infilled frames are considered. The comparison between time period and displacement for all the frames has been done. Also, comparison of axial force and moment has been done for corner, intermediate and gable end columns. The following Table 5.1 displays the various structural modeling parameters as per associated model no. designations and has been represented graphically in Fig. 5.1.

Table 5.1 Modeling Parameters

Model No.	Model Designation	Model Parameter				
		L (m)	B (m)	Bf (m)	Tf (m)	A_h %
1	6083610	6	08	3	6	10
2	5083615	5	08	3	6	15
3	6083515	6	08	3	5	15
4	5085520	5	08	5	5	20
5	6084620	6	08	4	6	20



(a)



(b)

Fig. 5.10 Graphical Representation of Modeling Parameter

The difference in displacement for the infilled frames with and without perforation has been observed to be less because opening area ratio has been taken as 10%. It is evident from the chart mentioned in Fig. 5.11 that the displacement for the bare frames is much higher than the infilled frames. The modeling of equivalent diagonal strut makes the structure rigid and thus the percentage difference in displacement of the infilled frames and bare frames varies from 40% to 80%.

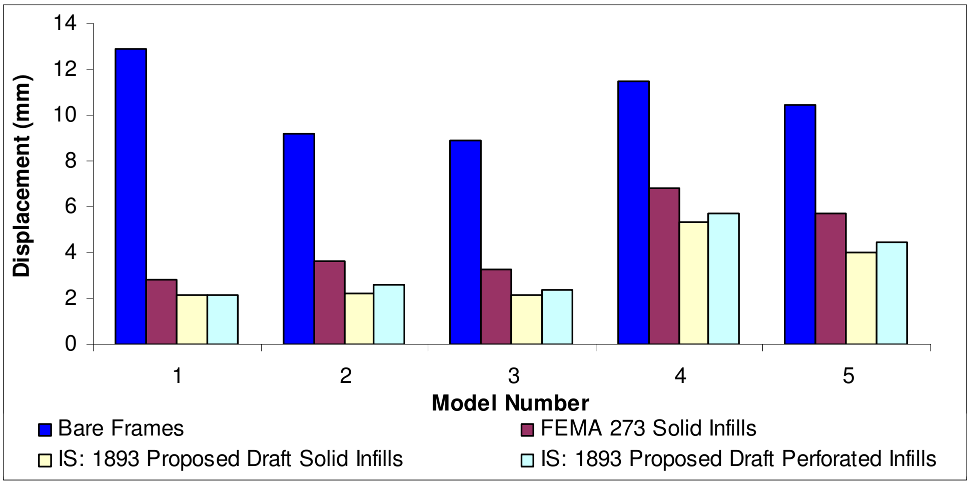


Fig. 5.11 Comparison of Displacement in Bare Frame and Infilled Frame

Similarly, there has been not much difference between the time period for infilled frames with and without openings as observed in Fig. 5.12, due to the fact that the opening area ratio has been taken as 10% for present study. Also the percentage variation in time period for models as per FEMA-273[7] and IS: 1893 (Part I) Proposed Draft[6] varies between 8% to 14%. There exists a percentage difference varying from 24% to 38% for bare frames and infilled frames modeled as per FEMA 273[7].

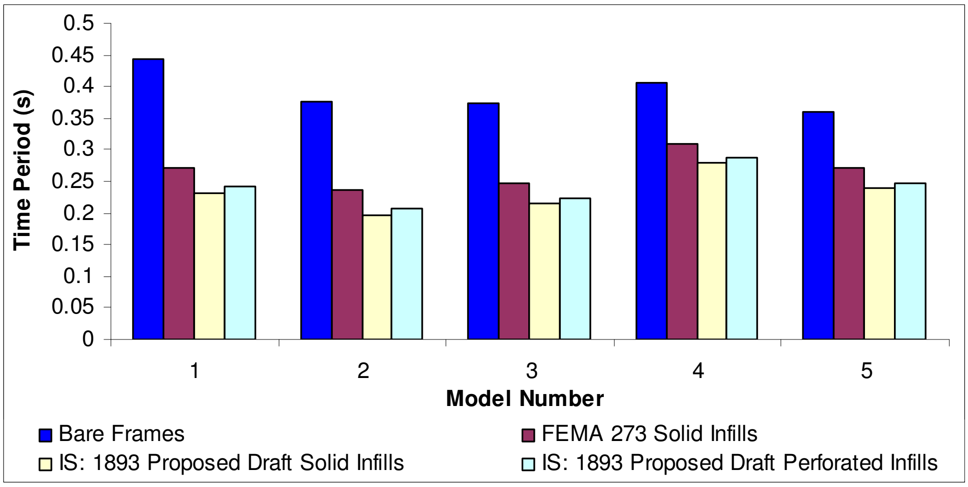


Fig. 5.12 Comparison of Time Period in Bare Frame and Infilled Frame

The modeling of brick infills influences the forces resisted by the structural components because the behavior of bare frame is different from the infilled frames. The graphs are plotted for the forces acting on the various structural components. A comparison is made between the axial force forces in columns for the bare frames and infilled frames. The comparison of analysis results shows that there is variation in the design forces for the B.O.P. buildings under study. The design forces are tabulated in the form of graphs and comparisons are made between various models modeled by various methods mentioned earlier.

The graph displayed in Fig. 5.13 compares the axial force in corner columns. It is observed that there has been wide variation in axial force in corner columns for bare frames and infilled frames. The percentage difference in axial force carried by corner columns with bare frame and infilled frames ranges from 20% to 40% for brick infills modeled as per IS: 1893 (Part I) Proposed Draft[6] and FEMA–273[7]. It has been observed that the percentage difference in axial force for solid frames and perforated frames modeled as per IS: 1893 (Part I) Proposed Draft[6] is less than 1% because the opening area ratio is taken as 10% in present study. Also it has been observed that there has been not much variation in axial force, when equivalent strut is modeled as per IS: 1893 (Part I) Proposed

Draft[6] or FEMA–273[7], i.e. the axial forces are almost the same and are independent of the method used to model the brick infills.

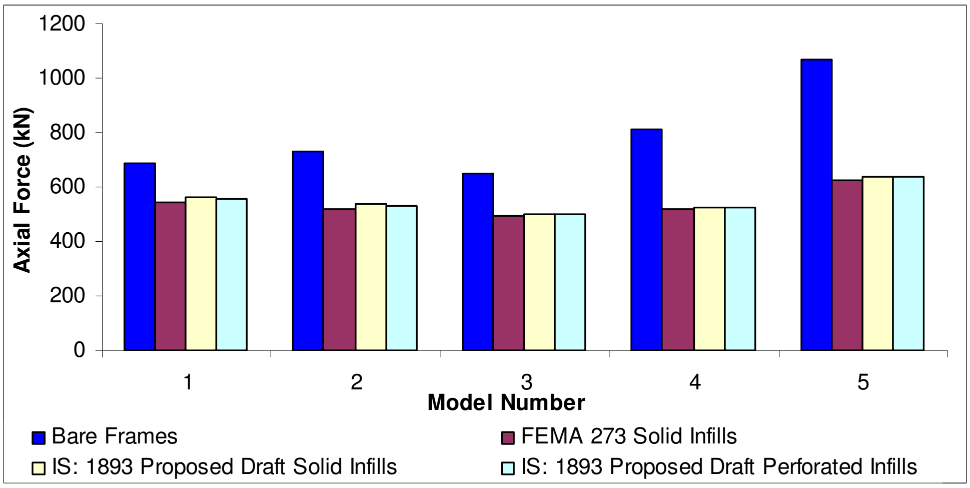


Fig. 5.13 Comparison of Axial Force in Corner Column for Bare Frame and Infilled Frame

In a similar way, a chart depicting variation of axial force for intermediate column as per the methods mentioned earlier has been shown in Fig. 5.14. It has been observed that the axial force in intermediate columns for bare frames and infilled frames is almost the same whether a solid frame or a perforated frame is modeled and thus does not affect the final force obtained. It has been observed that the percentage difference in axial force for solid frames and perforated frames modeled as per IS: 1893 (Part I) Proposed Draft[6] is less than 1% because the opening area ratio has been taken as 10% in present study and thus it does not affect the results significantly.

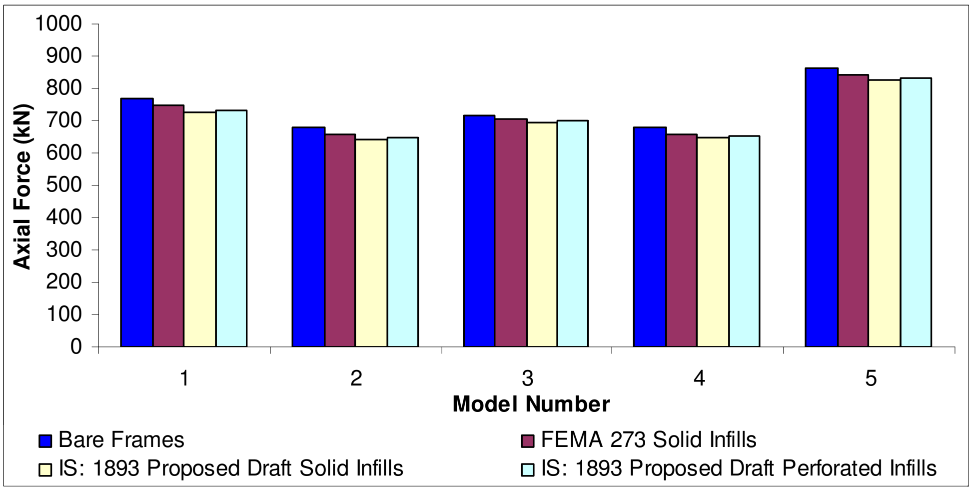


Fig. 5.14 Comparison of Axial Force in Intermediate Column for Bare Frame and Infilled Frame

Similarly, it has been observed that the axial force in gable columns for bare frames and infilled frames is almost the same whether it is a solid frame or a perforated frame for the hypothetical B.O.P. buildings under study as displayed in graph shown in Fig. 5.15. It has been observed that the percentage difference in axial force for solid frames and perforated frames modeled as per IS: 1893 (Part I) Proposed Draft [6] is less than 1% because the opening area ratio has been taken as 10% in present study. Thus, the modeling of brick infills does not make a significant difference in the axial force for the gable columns.

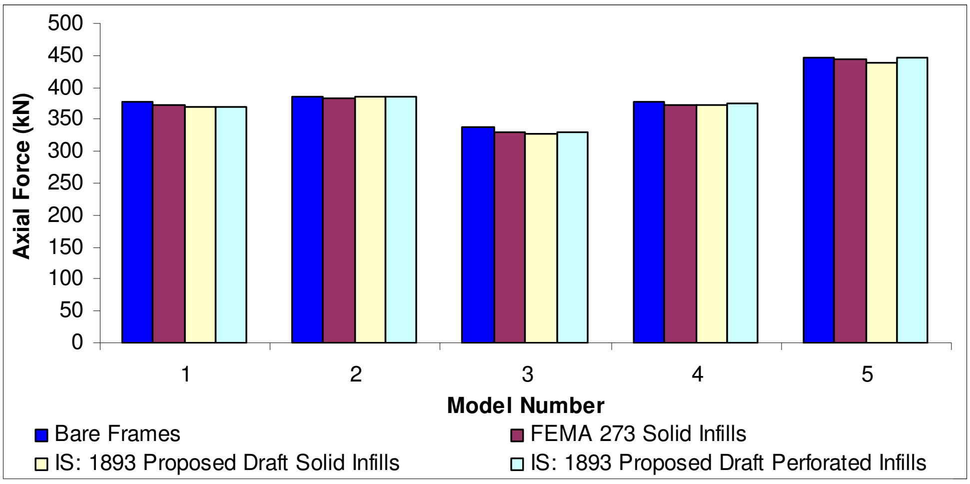


Fig. 5.15 Comparison of Axial Force in Corner Column for Bare Frame and Infilled Frame

Since the comparison of only axial force would result in erroneous results, it is felt that the comparison should be made between the base moments so as to emphasize the modeling of brick infills using equivalent diagonal approach. The chart shown in Fig. 5.16 depicts the variation of base moment in corner column for infilled frames and bare frames. The percentage difference in base moment in corner columns with bare frame and infilled frames ranges from 7% to 20% for brick infills modeled as per FEMA–273[7]. The percentage difference in base moment in corner columns for bare frame and infilled frames ranges from 11% to 26% for brick infills modeled as per IS: 1893(Part I) Proposed Draft[6]. It has been observed that the percentage difference in base moment for solid frames and perforated frames modeled as per IS: 1893 (Part I) Proposed Draft[6] is less than 1% because the opening area ratio is taken as 10% in present study. The variation may be observed if the percentage of opening provided in the B.O.P. building is more than 10%.

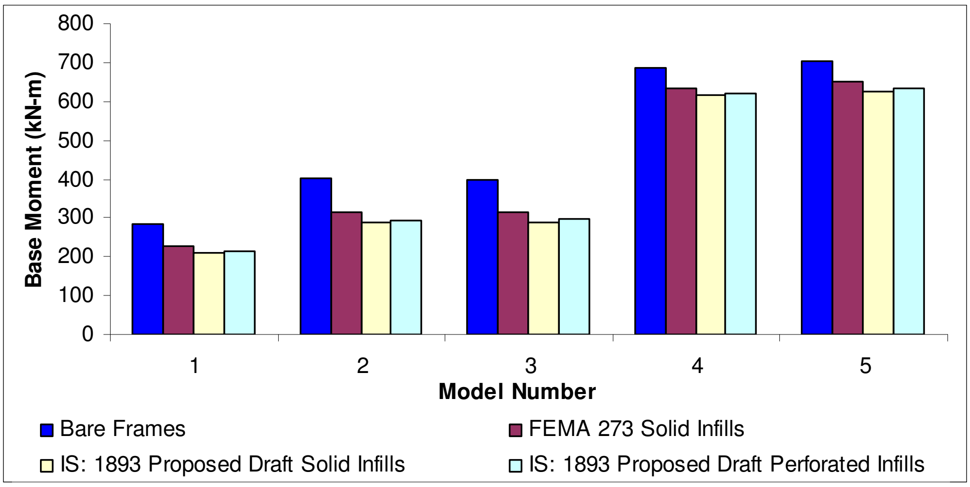


Fig. 5.16 Comparison of Base Moment in Corner Column for Bare Frame and Infilled Frame

The chart shown in Fig. 5.17 indicates that there has been considerable difference in the base moment for the bare frame and infilled frames, in case of intermediate columns. The percentage difference in base moment in intermediate columns with bare frame and infilled frames ranges from 60% to 80% for brick infills modeled as per FEMA–273[7]. The percentage difference in base moment in corner columns for bare frame and infilled frames ranges from 70% to 90% for brick infills modeled as per IS: 1893[6]. It has been observed that the percentage difference in base moment for solid frames and perforated frames modeled as per IS: 1893 (Part I) Proposed Draft[6] is less than 10 to 27% even though the opening area ratio is taken as 10% in present study.

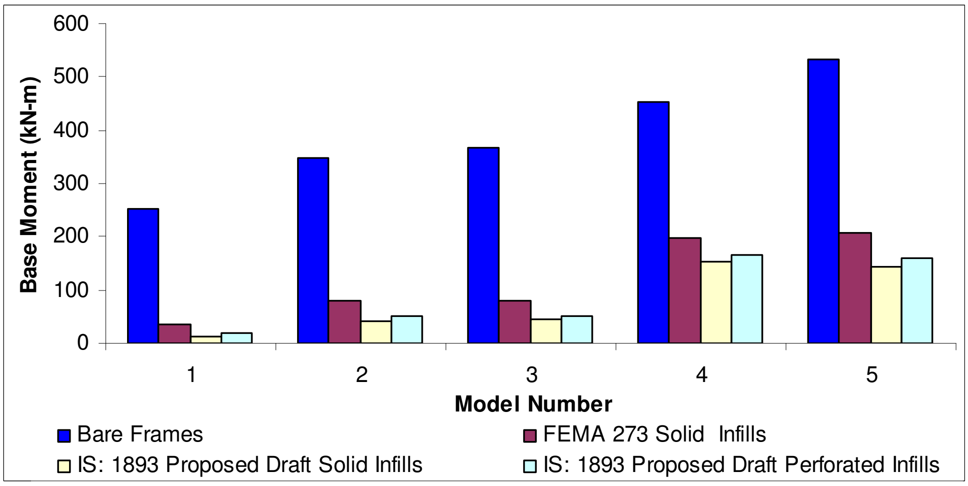


Fig. 5.17 Comparison of Base Moment in Intermediate Column for Bare Frame and Infilled Frame

The chart shown in Fig. 5.18 shows the variation of base moment in gable column for bare frame and infilled frames. The percentage difference in base moment in gable columns with bare frame and infilled frames ranges from 8% to 17% for brick infills modeled as per FEMA–273[7]. The percentage difference in base moment in corner columns for bare frame and infilled frames ranges from 12% to 17% for brick infills modeled as per IS: 1893 (Part I) Proposed Draft[6]. It has been observed that the percentage difference in base moment for solid frames and perforated frames modeled as per IS: 1893 (Part I) Proposed Draft[6] is less than 1% because the opening area ratio has been taken as 10% in present study.

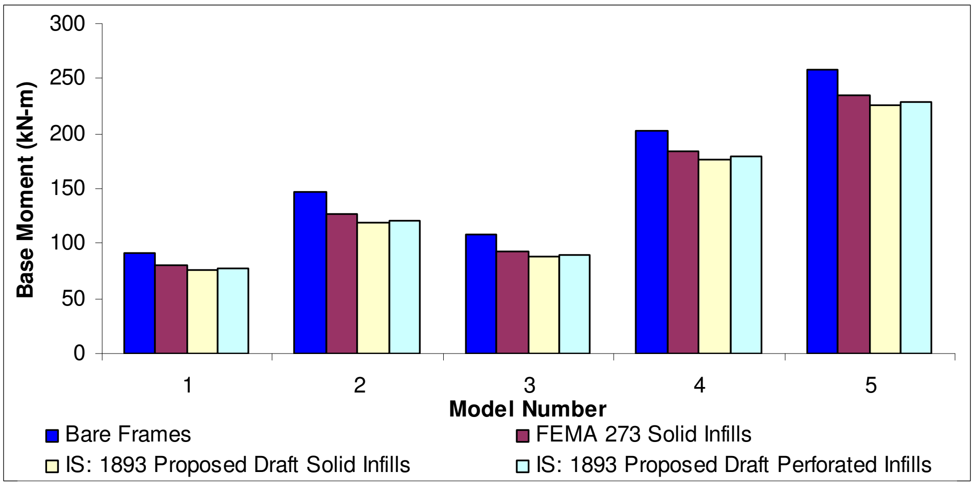


Fig. 5.18 Comparison of Base Moment in Gable Column for Bare Frame and Infilled Frame

From the above graphs, following general observations can be made.

- The equivalent strut method suggested by IS: 1893 (Part I) Proposed Draft[6] is based on fewer parameters and thus can be easily applied to practical problems.

- The equivalent strut method suggested by FEMA–273[7] takes into account the properties of frame as well as masonry and thus requires the appropriate values of weight per unit volume, modulus of elasticity, poisson's ratio, co-efficient of thermal expansion and shear modulus, for the results to be accurate and resemble the original structure.

- The difference in time period of the structure for bare frames and infilled frames has been observed to be large although there is not much difference for solid infiilled frames and perforated frames. The reason for such a large variation is that the model becomes stiff due to modeling of equivalent struts which make the structure rigid. But since the earthquake force has been taken as 10 to 20% of A_h, which is much larger than that calculated as per IS: 1893 (Part I) Proposed Draft [6], the final forces come out to be much less.

- It has been also observed that the bare frames undergo large displacements compared to the infilled frames because of larger time period of bare frames.

- From the results displayed in the graphs, it is evident that there has been considerable difference in the axial forces for corner columns. Although for the intermediate and gable end columns there is not considerable difference for the models under study.

- There has been significant reduction in design base moments for the intermediate columns as compared to corner and intermediate columns. Thus the design can lead to economy.

5.7 SUMMARY

In this chapter, brick infills have been modeled using the equivalent single diagonal strut approach. The method suggested by IS: 1893 (Part I) Proposed Draft[6] and FEMA-273[7] has been used for modeling infilled frames. The internal forces for infilled frames and bare frames have been compared. It has been realized that the modeling of brick infills results in reduction of internal forces in members and thus in economy.

6. INTRODUCTION OF PUSHOVER ANALYSIS IN POWER PLANT BUILDINGS

6.1 GENERAL

This chapter gives an introduction to pushover analysis and also discusses the important terms related to pushover analysis. This chapter focuses on importance of pushover analysis for structural engineer and explains various concepts related to pushover analysis. The chapter also includes practical application of pushover analysis to B.O.P. buildings. The required B.O.P. building model is generated with the help of a program, as explained in chapter 3 and the pushover analysis has been performed using SAP 2000 software.

6.2 INTRODUCTION

An elastic analysis gives good indication of the elastic capacity of structures and indicates where yielding will occur, it accounts for redistribution of forces during progressive yielding. The use of inelastic procedures for design and evaluation is an attempt to help engineer better understand how structures will behave when subjected to major earthquakes, where it is assumed that the elastic capacity of the structure is exceeded.

The non-linear response history analysis is the most rigorous procedure to compute seismic demands so the current structural engineering practice uses simplified, approximate and useful non-linear static or pushover analysis. The nonlinear static procedure considers the individual inelastic behavior of each component of a structure resisting seismic forces, as well as the behavior of structure as a whole. The analysis technique is progressive, allowing the engineer to withstand which components reach threshold before others. An engineer can modify the capacity of structure to generate an envelope of behavior to reflect loss of strength or stiffness due to duration of earthquake. The structure demands are computed by nonlinear static analysis of the structure subjected to monotonically increasing lateral forces with an invariant height-wise distribution until a predetermined target displacement is reached. The force distribution as well as the target displacement is based on the assumption that the response is controlled by the fundamental mode and that the mode shape remains unchanged after the structure yields.

6.2.1 Definition of Non-linear Static Procedure

The Non-Linear Static Procedure of Pushover analysis is defined in the Federal Emergency Management Agency-273[7] document as a non–linear static approximation of the response a structure will undergo when subjected to dynamic earthquake loading. The static approximation consists of applying a vertical distribution of lateral loads to a model which captures the material non-linearities of an existing or previously designed structure and monotonically increasing theses loads until the peak response of the structure is obtained on a base shear vs. roof displacement plot as shown in Fig. 6.1.

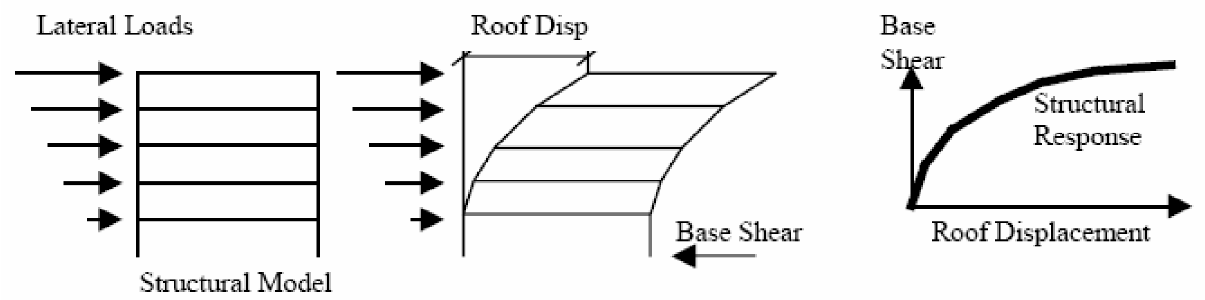


Fig. 6.1 Static Approximation Used in Pushover Analysis

6.2.2 Concept of Pushover Analysis

A performance objective specifies the demand seismic performance of the building. Seismic performance is described by designating the maximum allowable damage state for an identified seismic hazard. Once the building owner selects a performance objective, the engineer can identify the seismic demand to be used in the analysis and the acceptability criteria to be used for evaluation and design of the building's structural and nonstructural systems.

Performance objectives are statements of acceptable performance of the structure. A performance level describes a limiting damage condition which may be considered satisfactory for a given ground motion. The limiting condition is described by the physical damage within the building, the threat to life safety of the building's occupants created by the damage, and the post-earthquake serviceability of the building. The performance target can be specified limits on any response parameter such as stress, strains, displacements, etc. Estimating seismic demands at low performance levels, such as life safety and collapse prevention, requires consideration of inelastic behavior of the structure.

The nonlinear static procedure is intended to provide a simplified approach for directly determining the nonlinear response behavior of a structure at different levels of lateral displacements, ranging from initial elastic response through development of a failure mechanism and initiation of collapse. Response behavior is gauged by measurement of the strength of the structure, at various increments of lateral displacement.

Usually the shear resisted by the system at yield of the first element of the structure is defined as the "elastic strength," although this may not correspond to yield of the entire structure. If a structure is subjected to larger lateral loads than that represented by the elastic strength, a number of elements will yield—eventually forming a mechanism. For most structures, multiple configurations of mechanisms are possible. The mechanism caused by the smallest set of forces is likely to appear before others do. That mechanism is considered to be the dominant mechanism. Standard methods of plastic or "limit" analysis can be used to determine the strength corresponding to such mechanisms. However, such "limit analysis" cannot determine the deformation at the onset of such a mechanism. If the yielding elements are able to strain harden, the mechanism will not allow an increase of deformations without some increase of lateral forces and the mechanism is stable. Moreover, it can be considered as a flexible version of the original frame structure.

If, after the structure develops a mechanism, it deforms an additional substantial amount, elements within the structure may fail (fracture, buckle, etc.) and thus cease to contribute strength to the structural system. In such cases, the strength of the structure will diminish with increasing deformation. In the event of failure of an essential element, or group of elements, the entire structure may lose capacity to carry the gravity or lateral loads. Such loss of load-carrying capacity can also occur if the lateral deformation becomes so great that the P-delta effects exceed the residual lateral stiffness of the structure. Such conditions are defined as collapse and the deformation associated with collapse is defined as the "ultimate deformation." This deformation can be determined by the nonlinear static procedure and also by plastic or limit analysis.

As shown in Fig. 6.2, many structures exhibit a range of behavior between the development of first yielding and development of a mechanism. When the structure deforms while elements are yielding sequentially (shown as progressive yielding), the relation between external forces and deformations cannot be determined by simple limit analysis. For such a case, other methods of analysis are required. The purpose of nonlinear static procedure is to provide a simplified method of determining structural response behavior at deformation levels between those that can be conveniently analyzed using limit state methods. The purpose of pushover analysis is to assess the structural performance in terms of strength and deformation capacity globally as well as in the element level.

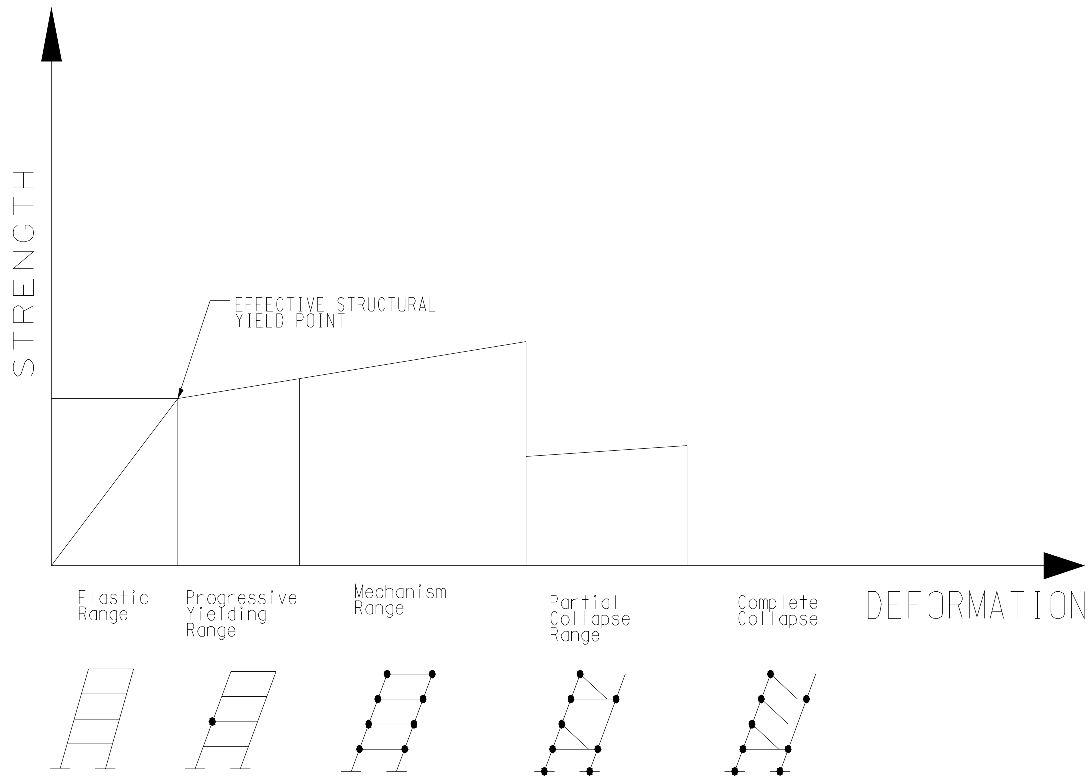


Fig. 6.2 Strength-deformation relation for a Frame Structure

The current seismic codes have been based on extensive research and on observations of actual damage in structures during past earthquakes. The primary goal is to ensure life-safety by requiring structures to have sufficient strength, stiffness and ductility to prevent collapse in very severe earthquakes. A secondary goal is to control the extent of the property damage and maintain the function of the building after the moderate events that are expected to occur more frequently. This is usually achieved through limitations to the anticipated lateral drift of the structure.

The primary goal of the current earthquake design philosophy, i.e. collapse prevention requires the structural members to yield and deform well beyond their elastic limits. Furthermore, frame members are expected to withstand several cycles of reversed inelastic deformation without significant degradation of strength and stiffness. In other words, frame members are expected to have good energy absorption capacity, which could be expressed in terms of ductility, the ratio between the ultimate deformation of the member and the deformation at yield. To ensure a ductile behavior during a major earthquake, current design provisions require special detailing of frame members and connections. Thus, structural systems designed according to current code provisions are expected to resist large inelastic deformations without collapse.

6.3 IMPORTANCE OF PUSHOVER ANALYSIS FOR A STRUCTURAL ENGINEER

The computational time required to perform a full nonlinear dynamic analysis is much more than the pushover analysis, if deemed applicable to the structure at hand, the pushover analysis can prove to be an attractive method for use in a design office setting. It is for this reason; there arises a need for easy to use an accurate nonlinear pushover tool which can be easily used at the design office. Even though in recent years there has been a great amount of research in the development of such nonlinear models and techniques, there is still a great deal of knowledge missing for reinforced concrete structures. In particular, the following modeling issues still need to be thoroughly addressed: bond slip, joint response and non-structural members. While there are currently some programs available to perform the pushover analysis on reinforced concrete structures, the procedure needs to be refined and more experience is needed to fully access its applicability.

Non-linear pushover analysis can be used to estimate the ultimate load carrying capacity of the structure and the ultimate displacement up to which the structure can be displaced without collapse. Ductility and over strength of the structure can be found out from the pushover curve, (i.e. the plot of base shear versus roof displacement). The pushover curve approximates how structures behave after exceeding their elastic limit. Pushover analysis is fairly sophisticated and requires considerable expertise; it is therefore not always feasible to perform a non-linear pushover analysis.

6.4 TYPES OF PUSHOVER ANALYSIS

The lateral load distributions used in the pushover analysis are expected to provide, approximately, a bound of likely distribution of inertial forces that the building experiences during an earthquake. The vertical distribution of inertial forces in an earthquake varies continuously throughout the duration of the ground motion as a function of dynamic characteristics of the structure and the ground motion. The effect of higher modes of vibration may be very significant in tall buildings causing the inertial forces to increase in the upper levels of the structure. A pushover analysis with a single load distribution pattern can only identify a single failure mode and thus overlook other possible failure modes. For this reason, it is crucial to consider several lateral load distributions to be able to capture different possible failure modes. Fig. 6.3 summarizes the pushover analysis tasks. The analysis is grouped under two main categories as shown in Fig. 6.3.

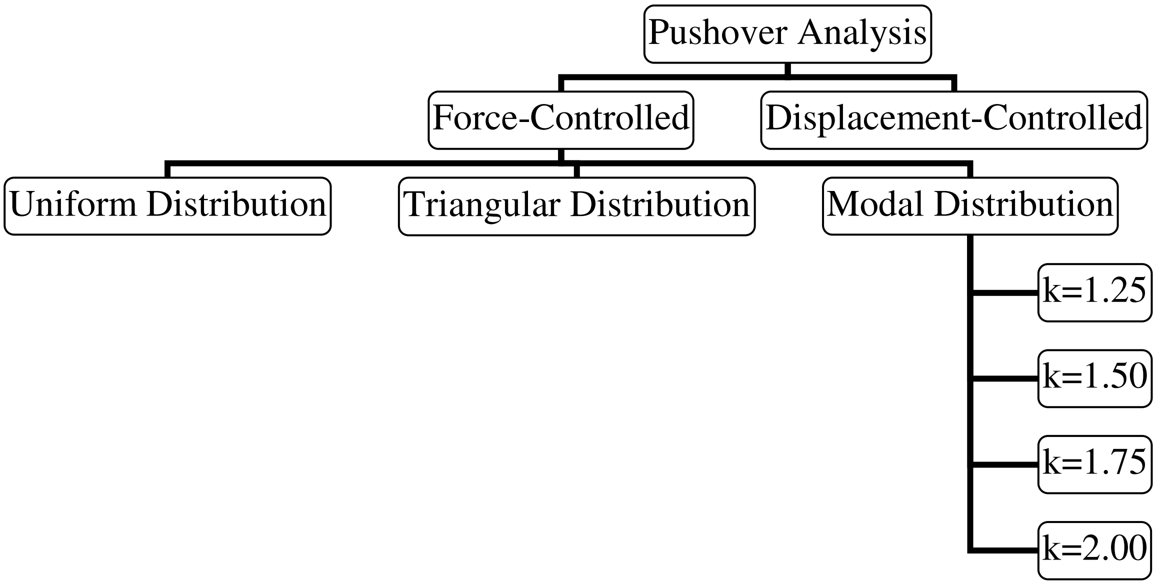


Fig. 6.3 Pushover Analysis Tasks

- Displacement-Controlled:- The displacement-controlled pushover analysis involves the static analysis of the building under a displacement profile corresponding to the first mode of vibration of the building. The lateral load acting on the structure is generally applied as displacement controlled.
- Load-Controlled:-Load-controlled pushover analyses involved an incremental static analysis of the building model under several lateral load

distributions. The gravity loads are acting on the structure is generally applied as load controlled. The load distributions available for analysis are shown in Fig. 6.4.

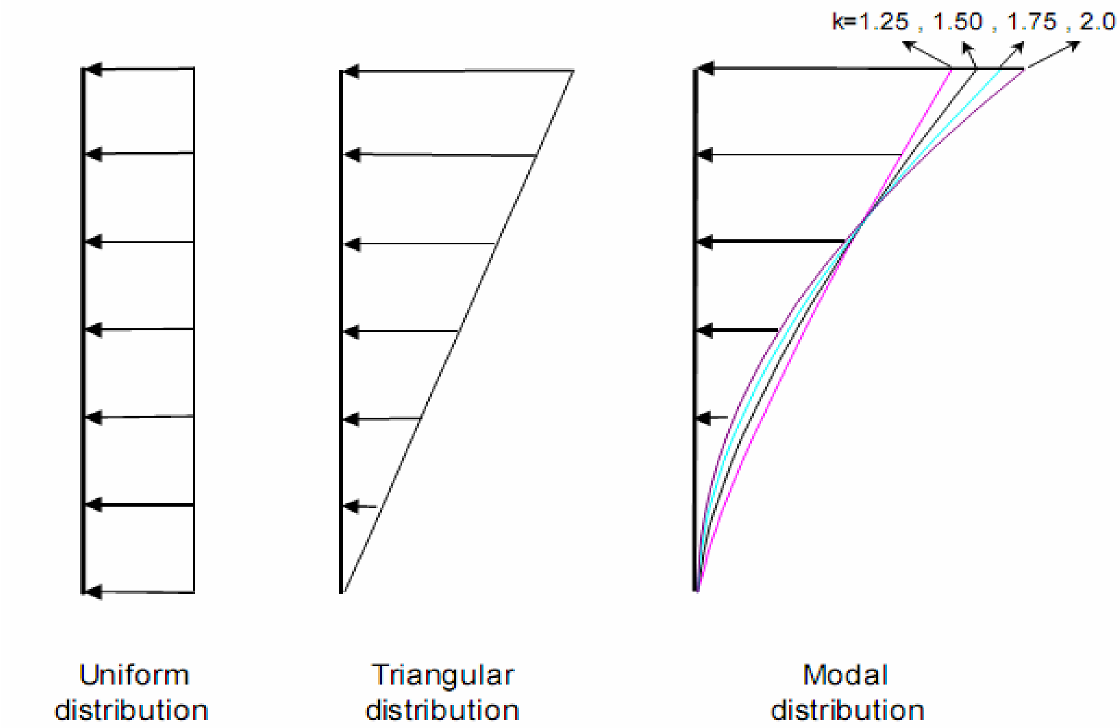


Fig. 6.4 Lateral load distributions used in load-controlled Pushover Analysis

The modal pattern suggested by ATC-33[11] applies increased lateral forces to the upper levels of the building. The distribution is intended to capture the higher mode effects in the seismic response and is defined by the following exponential equations 6.1 and 6.2

$$F_x = C_{VX} V \qquad \text{...(6.1)}$$

$$C_{VX} = \frac{W_X h_x^k}{\sum_{i=1}^{n} w_i h_i^k} \qquad \text{...(6.2)}$$

Where,

C_{VX} = vertical distribution factor

V = total base shear

w_i and W_x = weight at level i or x

k = an exponent related to the structure period

The value of k=1.0 for T<=0.5and k=2.0 for T>=2.5. The intermediate values are linearly interpolated.

This equation results in load distribution from a triangular distribution for an exponent value k of 1.0 to a parabolic distribution for a value of 2.0.

6.5 IMPORTANT PARAMETERS RELATED TO PUSHOVER ANALYSIS

The following are some of the important terms related to pushover analysis.

6.5.1 Demand

Demand is a representation of the of the earthquake ground motion. Ground motions during an earthquake produce complex horizontal displacement patterns in the structures that may vary with time. The displacement demand is an estimate of the maximum expected response of the building during earthquake ground motion, for a given structure and ground motion. The following are the steps to compute demand.

1. Determine the zone of the building according to the location of building site.
2. Classify the seismic source type depending on the location of faults and the magnitude of earthquake shaking as per Table 4.6 of ATC-40[10]. Determine the nearness source factor depending on the closest distance to known seismic source as per Table 4.5 of ATC-40[10].
3. For each earthquake hazard level, the seismic co-efficient C_A and C_V are obtained from Table 4.7 and Table 4.8 of ATC-40[10].
4. Develop the 5% damped elastic response spectrum as shown in Fig. 6.5.

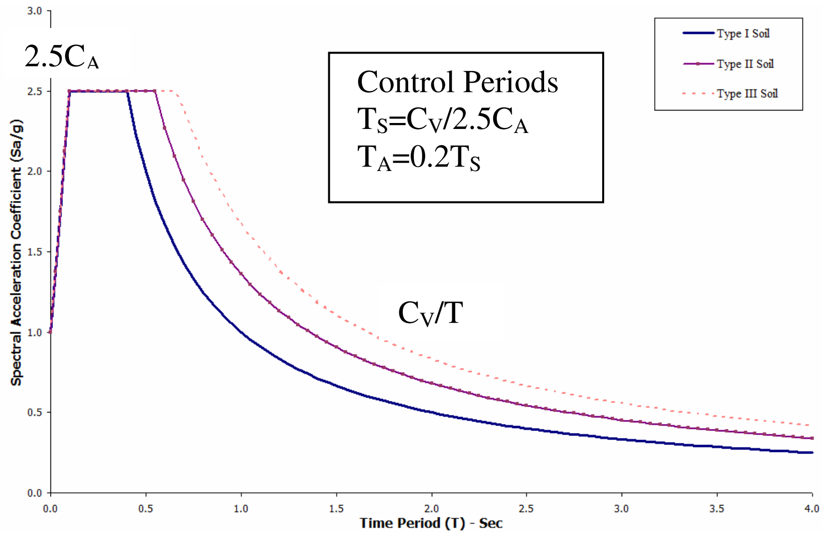


Fig. 6.5 Construction of 5% Damped Elastic Response Spectrum

5. Application of Capacity-Spectrum technique requires that both the demand response spectra and structural capacity be plotted in the spectral acceleration vs. spectral displacement domain. Every point on the response spectrum curve has associated with it a unique spectral acceleration, S_a, spectral velocity, S_v, spectral displacement, S_d and time period T. To convert

response spectrum from the standard S_a vs. T format found in the building code to ADRS format as shown in Fig. 6.6, it is necessary to determine the value of S_{di} for each point on the curve, S_{ai}, T_i. In the ADRS spectrum, the lines radiating from the origin have constant time period T, which can be computed using the following relationship given by Equation 6.3.

$$T = 2\Pi\sqrt{\frac{S_d}{S_a}} \quad \text{...(6.3)}$$

Where,

T = time period

S_d = spectral displacement

S_a = spectral acceleration

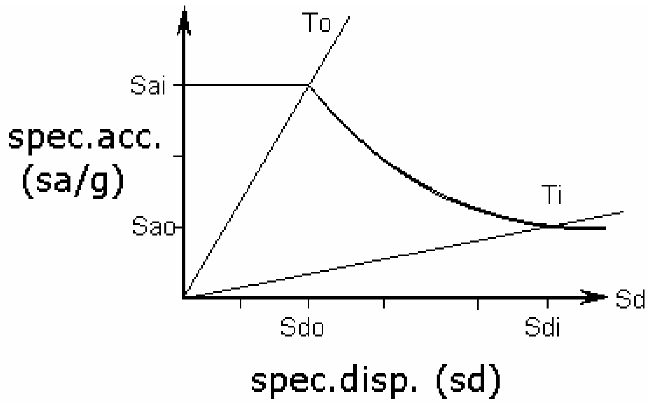


Fig. 6.6 Construction of 5% Damped Elastic Response Spectrum in ADRS Spectra

The damping that occurs when earthquake ground motion drives a structure into the inelastic range can be viewed as a combination of viscous damping that is inherent in the structure and hysteric damping. The effective viscous damping, β_{eff} associated with a maximum displacement of d_{pi} can be estimated from the following Equations 6.4 and 6.5.

$$\beta_{eff} = k\beta_0 + 5 \quad \text{...(6.4)}$$

Where $$\beta_0 = \frac{E_D}{4\Pi E_{So}} \quad \text{...(6.5)}$$

Where,

β_{eff} = effective viscous damping

k = factor depending on the type of structural behavior

E_D = energy dissipated by damping

E_{So} = maximum strain energy

6. Depending on the type of behavior of structure, the allowable spectral acceleration factors SR_A and SR_V are obtained from Table 8.3 of ATC-40[10] and reduced elastic response spectrum is obtained as displayed in Fig. 6.7.

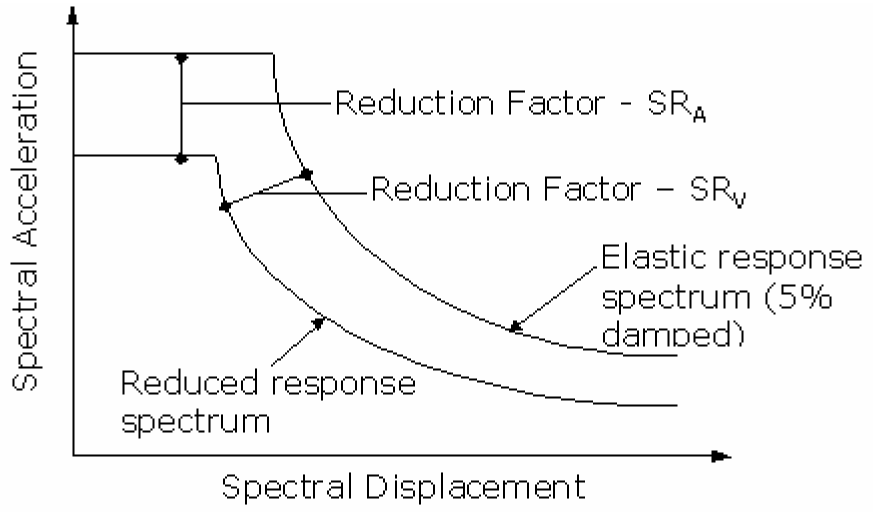


Fig. 6.7 Reduced Elastic Response Spectrum

6.5.2 Capacity

Capacity is a representation of the structure's ability to resist the seismic demand. The overall capacity of a structure depends on the strength and deformation capacities beyond the elastic limits. The capacity curve is generally constructed to represent the first mode response of the structure based on the assumption that the fundamental period of vibration is the predominant response of the structure. The higher mode effects are considered in the analysis of structures with fundamental period greater than one second. The following are the steps to compute capacity:-

1. The first step is to create a computer model of the structure and classify each element as primary or secondary.
2. Secondly, apply lateral story forces to the structure in proportion to the product of the mass and fundamental mode shape; the analysis should also include gravity loads.
3. The following methods are suggested to apply load, depending on the type of structure:-

3.1 For a single story structure, apply a single concentrated horizontal force on the top of the structure.

3.2 Apply lateral forces to each story in proportion to the standard code procedure without the concentrated F at the top.

3.3 Apply lateral forces in proportion to the product of story masses and first mode shape of the elastic mode of the structure.

3.4 For buildings with weak story, the forces are applied in the same manner as in 3.3 until yielding; for each increment beyond yielding, adjust the forces to be consistent with the changing deflected shape.

3.5 For irregular buildings, the load application is similar to 3.3 above, but the effect of higher modes of vibration is included in determining yielding in individual structural elements while plotting the capacity curve for the building in terms of the first mode lateral forces and displacements.

4. The member forces are calculated for the required combinations of the vertical and lateral load.
5. The lateral force should be adjusted to such a level so that some of the members are stressed to within 10 percent of its member strength.
6. Record the base shear and roof displacement and revise the model using zero stiffness for the yielding elements.
7. Apply a new increment of lateral load to the revised structure such that another element yields. Add the increment of lateral load and the corresponding increment of roof displacement to the previous totals to give the accumulated values of base shear and roof displacement, to obtain the capacity curve shown in Fig. 6.8.

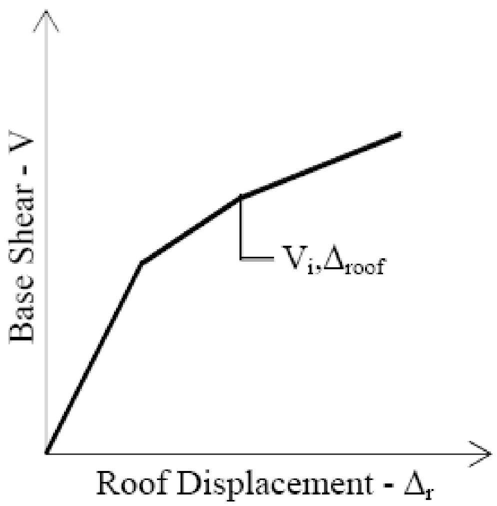


Fig. 6.8 Conceptual Development of Capacity Curve

8. To use the capacity spectrum method, it is necessary to convert the capacity curve, which is in terms of base shear and roof displacement to capacity spectrum, which is a representation of capacity curve in Acceleration-

Displacement Response Spectra (ADRS) format (i.e., S_a versus S_d). The general process for converting the capacity curve to the capacity spectrum, is to first calculate the modal participation factor PF_1 and the modal mass coefficient α_1 using the following Equations 6.6 and 6.7 respectively.

$$PF_1 = \left[\frac{\sum_{i=1}^{N} (w_i \phi_i)/g}{\sum_{i=1}^{N} (w_i \phi_{i1}^2)/g} \right] \quad ...(6.6)$$

$$\alpha_1 = \frac{\left[\sum_{i=1}^{N} (w_i \phi_{i1})/g \right]^2}{\left[\sum_{i=1}^{N} w_i/g \right] \left[\sum_{i=1}^{N} (w_i \phi_{i1}^2)/g \right]} \quad ...(6.7)$$

Where

PF_1 = modal participation factor for the first natural mode

α_1 = modal mass coefficient for the first natural mode

w_i/g = mass assigned to level i

Φ_{i1} = amplitude of mode 1 at level i

N = the level which is the uppermost portion of the structure

9. Then for each point on the capacity curve, V, Δ_{roof}, calculate the associated point S_a, S_d on the capacity spectrum. The following empirical relations given by Equations 6.8 and 6.9 are evaluated to obtain the value of S_a and S_d respectively from the available values of base shear and weight of the structure.

$$S_a = \frac{V/W}{\alpha_1} \quad ...(6.8)$$

$$S_d = \frac{\Delta_{roof}}{PF_1 \phi_{roof1}} \quad ...(6.9)$$

Where

S_a = spectral acceleration

S_d = spectral displacement

V = seismic base shear

W = weight of the building

α_1 = modal mass coefficient for the first natural mode

PF_1 = modal participation factor for the first natural mode

Δ_{roof} = roof displacement

The capacity curve thus obtained in ADRS format after conversion is displayed in Fig. 6.9.

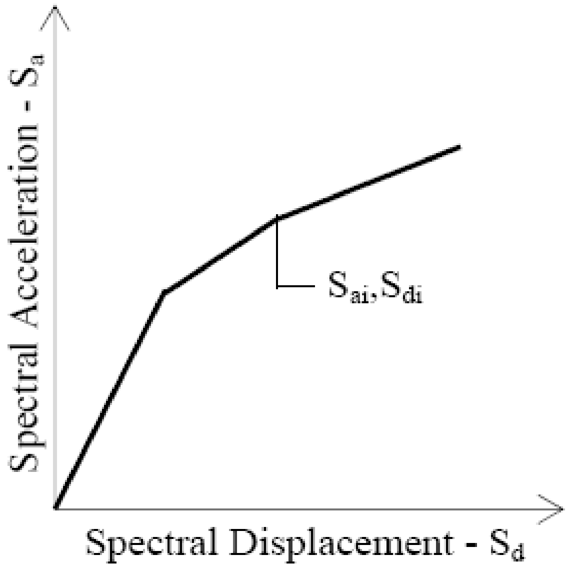


Fig. 6.9 Conversion of Capacity Curve to Capacity Spectrum in ADRS Format

6.5.3 Performance

Once capacity curve and demand displacements are defined, a performance check is performed. A performance check verifies that structural and non-structural components are not damaged beyond the acceptable limits of the performance objective for the forces and displacements implied by the displacement demand. The performance is dependent on the manner that the capacity is able to handle the demand, i.e. the structure must have the capacity to resist the demands of the earthquake such that the performance of the structure is compatible with the design objectives as illustrated in Fig. 6.10.

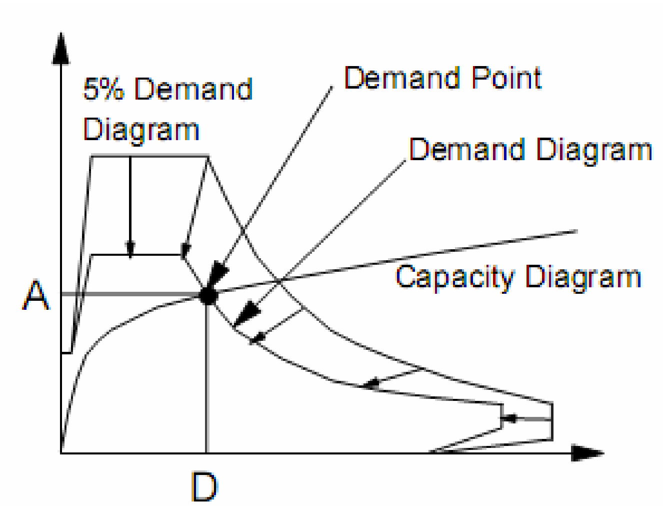


Fig. 6.10 Intersection of Capacity Curve and Reduced Elastic Response Spectrum

6.6 STEPS TO PERFORM PUSHOVER ANALYSIS

The following are some of the important steps to be followed to perform the pushover analysis for a given framed structure:-

1. The first step is to develop a 5% damped (elastic) response spectrum, for the site under consideration.
2. Secondly transform the capacity curve to capacity spectrum
3. Select a performance point a_{pi}, d_{pi} as shown in the Fig. 6.12.
4. Develop a bilinear representation of the capacity spectrum.
5. Calculate the spectral reduction factors and develop the demand spectrum.
6. Plot the demand spectrum on the same plot as the capacity spectrum as illustrated in the following Fig. 6.11.

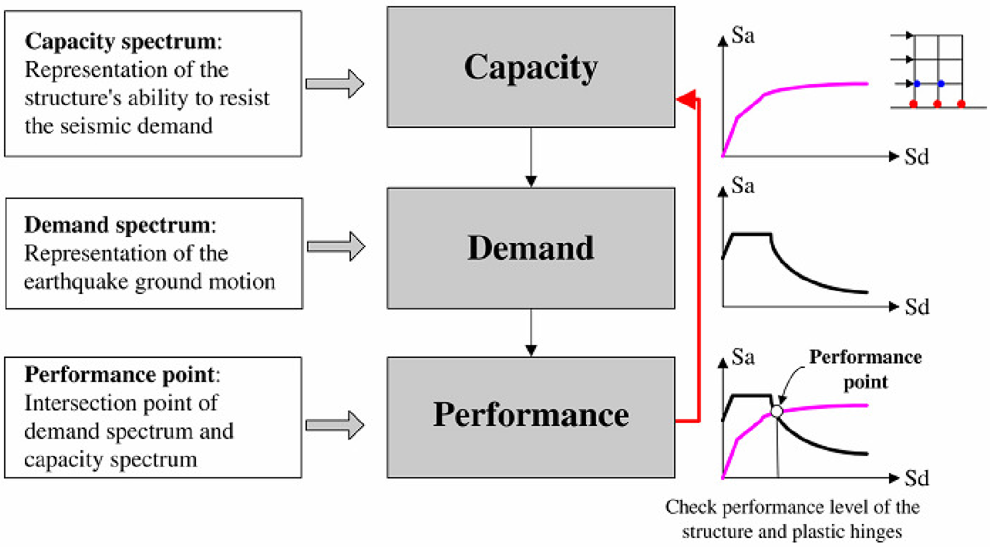


Fig. 6.11 Steps of Pushover Analysis

7. Determine if the demand spectrum intersects the capacity spectrum at the point a_{pi}, d_{pi} or if the displacement at which the demand spectrum intersects the capacity spectrum, d_i, is within acceptable tolerance of d_{pi}.
8. If the demand spectrum intersects the capacity spectrum within acceptable tolerance as shown in Fig. 6.12, then the trial performance point, a_{pi}, d_{pi}, is the performance point, a_p,d_p and the displacement d_p, represents the maximum structural displacement expected for the demand earthquake. When the capacity spectrum is saw tooth curve, that is, the final composite capacity spectrum is constructed from several different capacity spectra which account for strength degradation of elements, special care must be taken in determining the performance point.

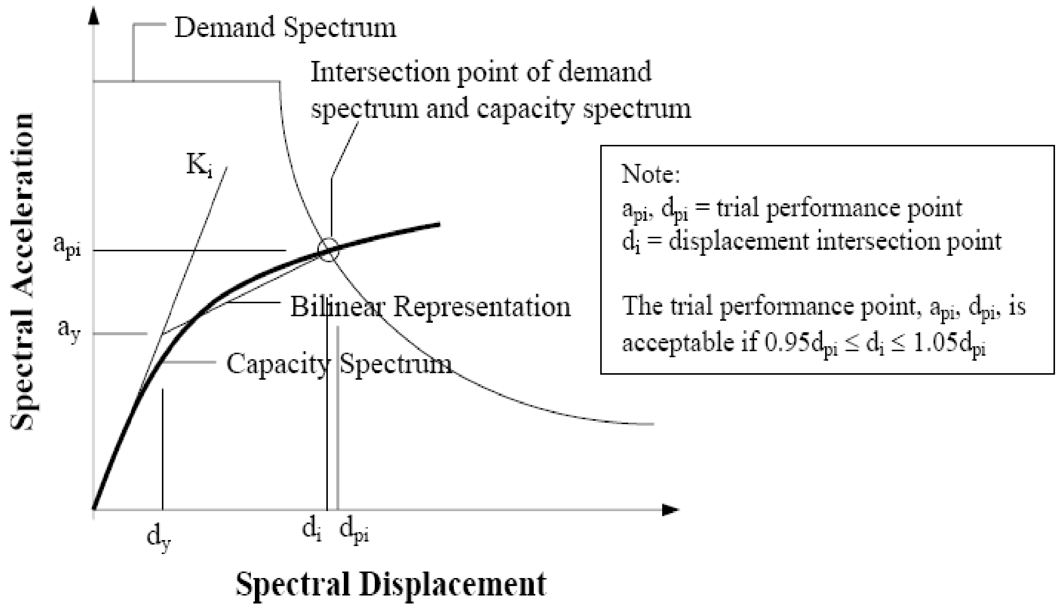


Fig. 6.12 Intersection of Demand and Capacity Spectrum within Acceptable Tolerance

6.7 LIMITATIONS OF PUSHOVER ANALYSIS

1. The pushover analysis estimates the building response by two parameters namely base shear and roof drift.
2. The pushover analysis is performed considering the lateral load only, while the effect of vertical component of load is ignored while performing the analysis.
3. The two very important terms i.e. structural capacity and seismic demand are dealt separately while explaining the concept of pushover analysis, but in reality the two terms are inter-dependent and difficult to separate.
4. The pushover analysis assumes that the structural components of the building do not fail due to secondary effects before the plastic mechanism.
5. The maximum displacement achieved will be directly related to the shape of the lateral load distribution applied to the structure. If the shape of the lateral load differs from the shape which the structure attains when loaded dynamically, the calculated maximum displacement could grossly overestimate what the dynamic analysis would predict.
6. Although the structural cost is higher, the analysis cost is higher because more sophisticated tools and techniques along with skilled professionals are required to perform pushover analysis.

7. The theoretical foundation for pushover analysis is very difficult to depend; because the load application is assumed to be monotonic but in reality the earthquake ground motion is never monotonic.

6.8 ADVANTAGES OF PUSHOVER ANALYSIS

The following are some of the advantages of performing pushover analysis:-

1. The response of the building during strong earthquake shaking is not linearly elastic. The pushover analysis provides useful insight into the non-linear behavior of the building under dynamic earthquake loading.
2. The nonlinear analysis furnishes useful information about the weak links present in the structural system of the building components.
3. The pushover analysis is an advanced technique to study the behavior of the building under dynamic earthquake loading.
4. The cost of retrofit can be reduced tremendously and thus results in saving of cost.

6.9 BUILDING PERFORMANCE LEVELS AND RANGES

Performance levels are associated with earthquake hazard and design levels. The performance objectives are statements of acceptable performance of the structure. Each building performance level is made up of structural performance level that describes the limiting damage state of the structural systems and a non-structural performance level that describes the limiting damage state of the nonstructural systems. The following are some of the important definitions given in FEMA-273[7]**.**

- Performance Level:- It is defined as the intended post-earthquake condition of a building, a well defined point on a scale measuring how much loss is caused by earthquake damage. In addition to causalities, loss may be in terms of property and operational capability.
- Performance Range:- It is a range or band of performance, rather than a discrete level.
- Designations of Performance Levels and Ranges:-Performance is separated into descriptions of damage of structural and nonstructural systems; structural designations are S-1 through S-5 and nonstructural designations are N-A through N-D.

- Building Performance Level:- The combination of a structural performance level and a non-structural performance level to form a complete description of an overall damage level.
- Rehabilitation Objective:-The combinations of a performance level or range with seismic demand criteria.

Three structural performance levels and four nonstructural performance levels are used to form the four basic building performance levels. The three Structural Performance Levels and two Structural Performance Ranges are given names and number designations which consist of the following:-

- Immediate Occupancy Performance Level, S-1: The post –earthquake damage state in which only very limited structural damage state in which only very limited structural damage has occurred.
- Damage Control Performance Range, S-2: This term is actually not a specific level but a range of post-earthquake damage states that could vary from S-1 to S-3.
- Life Safety Performance Level, S-3: The post-earthquake damage state in which significant damage to the structure has occurred but in which some margin against total or partial collapse remains.
- Limited Safety Performance Range, S-4:
- Collapse Prevention Performance Level, S-5: This level is the limiting post-earthquake structural damage state in which the building's structural system is on the verge of experiencing partial or total collapse.

The four Non-Structural Performance Levels are given names and letter designations which consist of:-

- Operational Performance Level, N-A: The post-earthquake damage state in which non-structural elements and structural systems are generally in place and functional.
- Immediate Occupancy Performance Level, N-B: The post-earthquake damage state in which nonstructural elements and systems are generally in place; minor disruption and cleanup is expected.
- Life Safety Performance Level, N-C: This post-earthquake damage state could include considerable damage to non-structural components and systems but should not include collapse or falling of items heavy enough to cause severe injuries either within or outside the building.

- Hazards Reduced Performance Level, N-D: This post-earthquake damage state could include extensive damage to non-structural components and systems but should not include collapse or failing of large and heavy items that could cause significant injury to groups of people.

Combinations of a structural performance and a non-structural performance level form a building performance level to completely describe the desired limiting damage state for the building as illustrated in Fig. 6.13

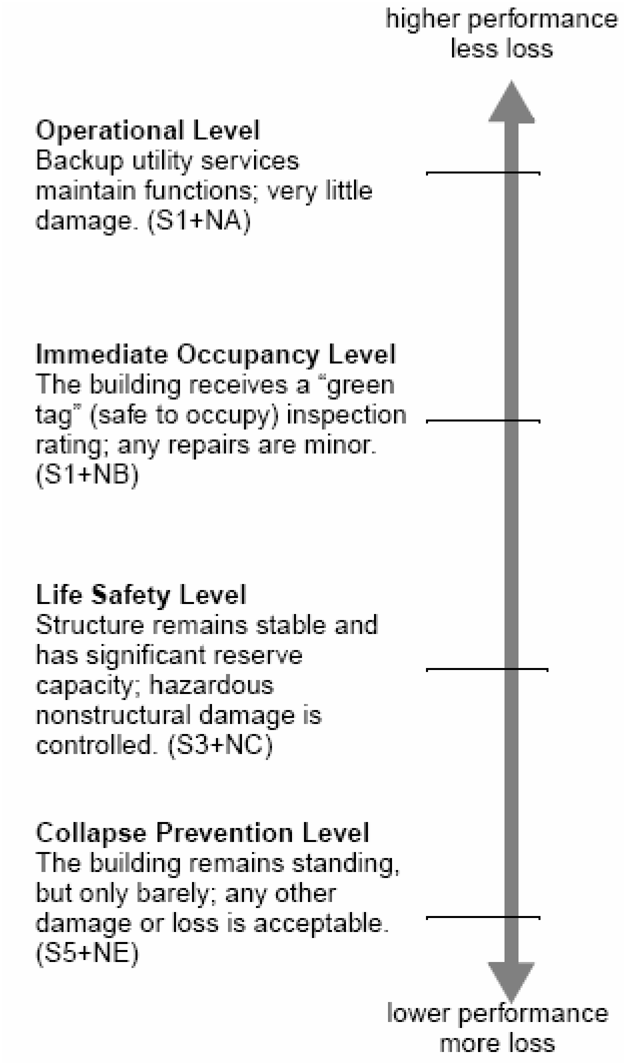


Fig. 6.13 Combination of Building Performance Levels

The Fig. 6.14 illustrates a generalized load-deformation relation appropriate for most concrete elements. The following main points relate to the depicted load-deformation relation:-

- Point A corresponds to the unloaded condition. The analysis must recognize that gravity loads may induce initial forces and deformations that should be accounted for in the model. Therefore, the lateral loading may commence at a point other than the origin of the load-deformation relation.

- Point B has resistance equal to the nominal yield strength, which is usually less than the nominal strength.
- The slope from B to C, ignoring the effects of gravity loads acting through lateral displacements, is usually taken as between 5% and 10% of the initial slope.
- The ordinate at C corresponds to the nominal strength, while the abscissa corresponds to the deformation at which significant strength degradation begins.
- The drop in resistance from C to D represents initial failure of the component. The primary components of the lateral force resisting system should not be permitted to deform beyond this point.
- The residual resistance from D to E may be assumed to be equal to 20% of the nominal strength, if it is not available.
- The point E defines the maximum deformation capacity.

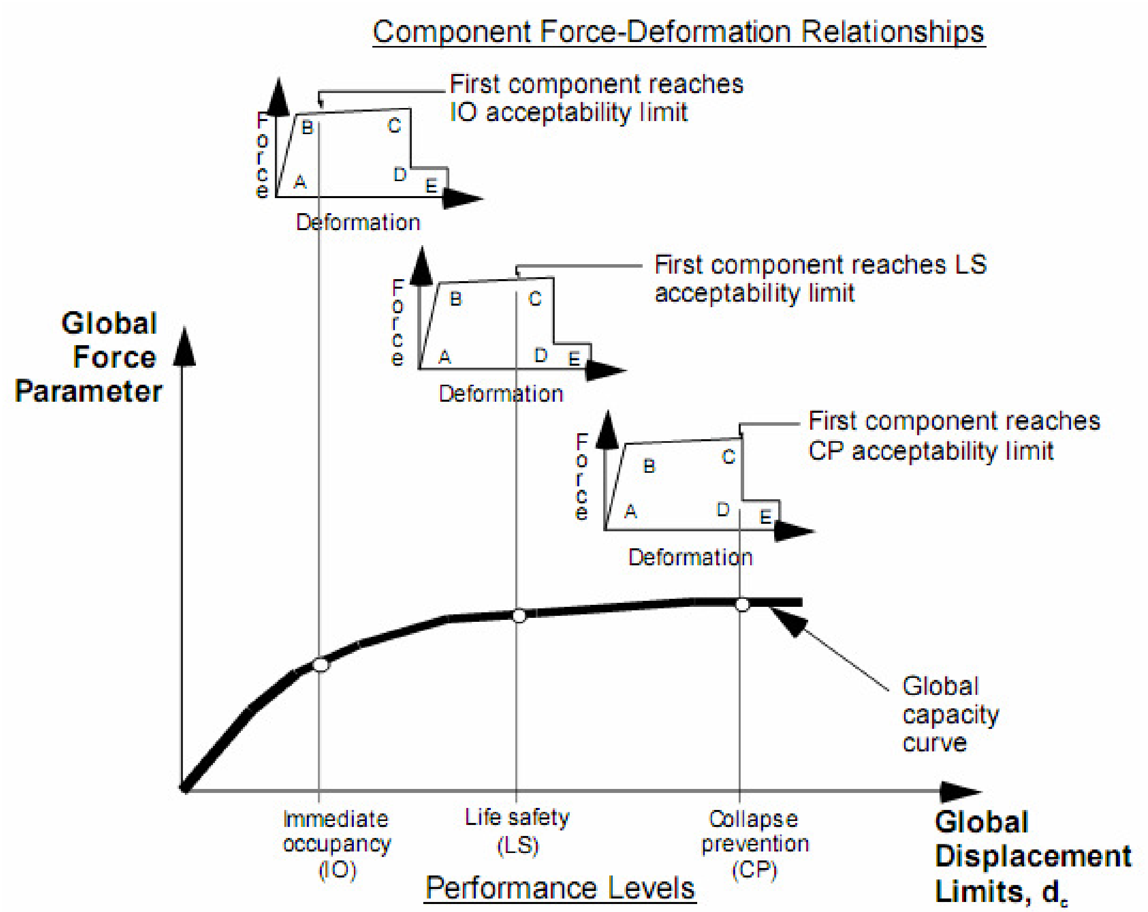


Fig. 6.14 Generalized Force-Deformation Relationships

6.10 APPLICATIONS OF PUSHOVER ANALYSIS

The following are some of the important applications of pushover analysis.

- The pushover analysis leads to damage control in addition to life safety.
- The pushover analysis helps to address impacts of structural irregularities for newly constructed buildings.
- The pushover analysis helps in rehabilitation by prioritizing potential damage locations and thus leads to economic viability**.**

6.11 PERFORMING PUSHOVER ANALYSIS THROUGH SAP 2000

The building under study is modeled and the static analysis is performed. Thereafter the design of all components is performed through SAP, as per relevant Indian Standards. Then next the model is unlocked to assign hinges to structural elements.

All the columns which participate in the lateral load resisting system are selected and the default hinges are assigned from the Assign menu as shown in Fig. 6.15. The default properties are used for the hinges.

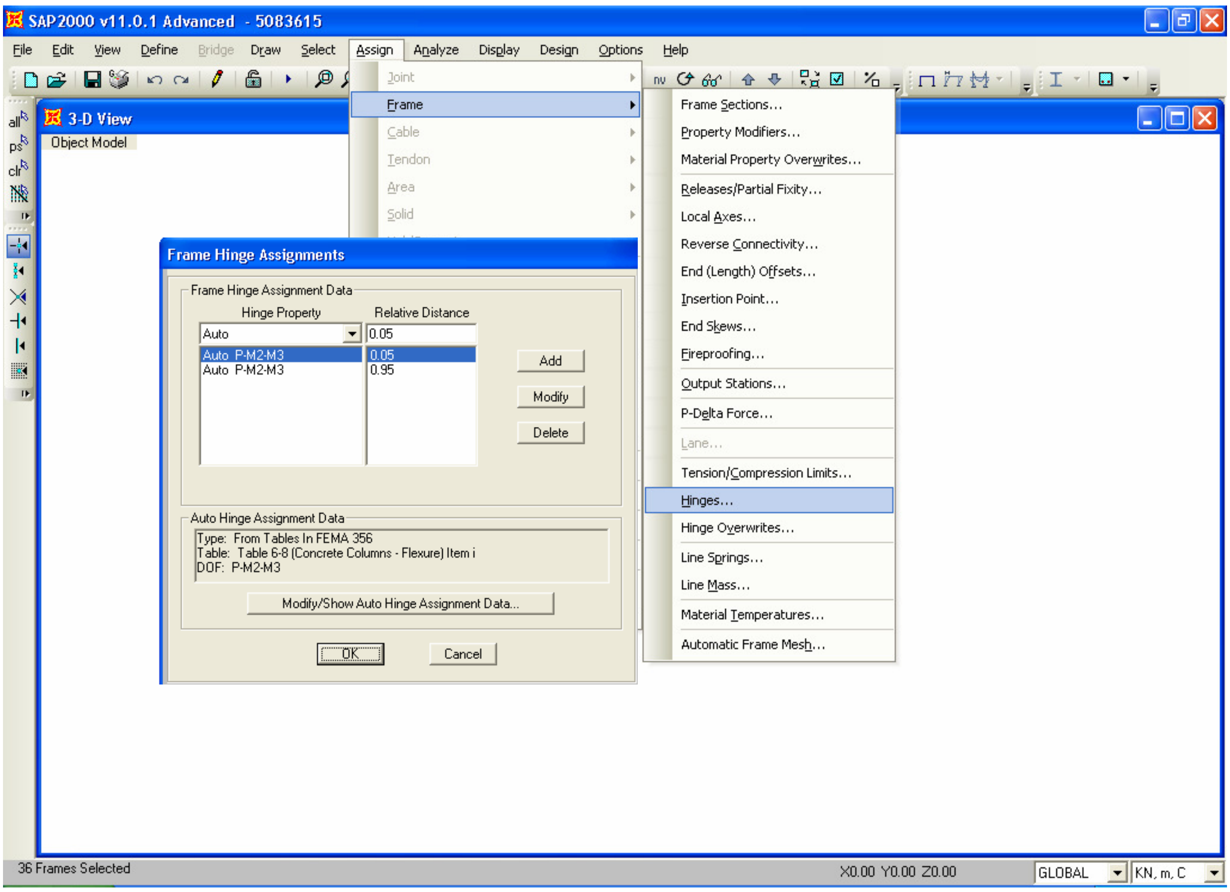


Fig. 6.15 Hinge Assignment to the Column

The location of hinge formation is generally taken at the face of column. Here the hinges are assumed to be located at a relative distance of .05L from the beam ends. The columns are assumed to primary elements, as they help in resisting lateral loads acting on the structure and the relevant modeling parameters are obtained from Table 6-8 of FEMA-356[8] for columns as shown in the following Fig. 6.16

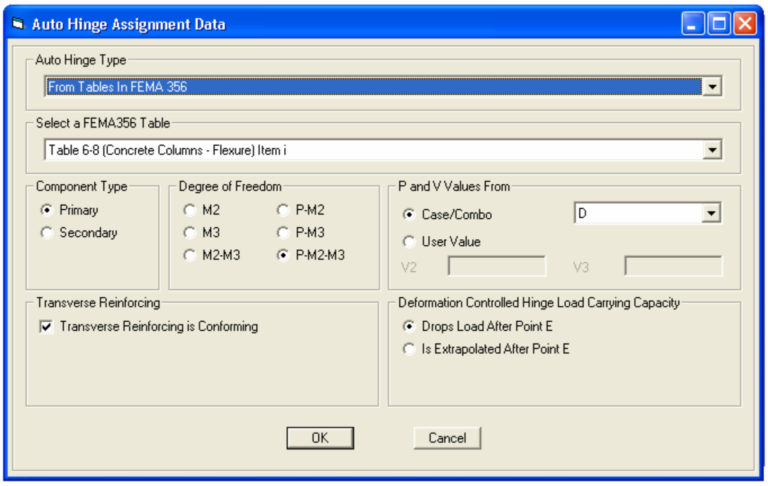


Fig. 6.16 Columns Assigned as Primary Element

Similarly, all the beams except the secondary beams are selected and the default hinge properties are assigned from the Assign menu. The hinge location is assumed at a relative distance of 0.05L and 0.95L. Also the beams are assumed to as secondary elements and the relevant properties are obtained from Table 6.7 of FEMA-356[8], as displayed in the following Fig. 6.17. The default hinge properties are used for the analysis.

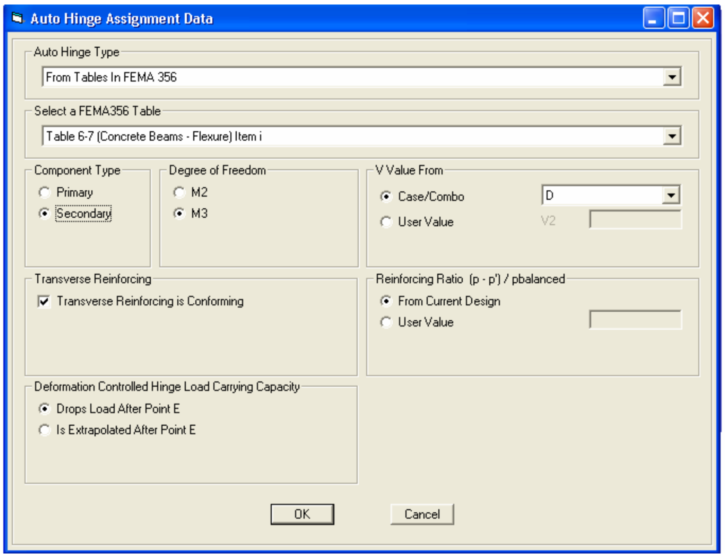


Fig. 6.17 Hinge Assignment to the Beams

The mathematical model of the building is first subjected to the static gravity loads to determine the stresses within the structural elements. The full load is applied and the final results are saved. Push z is the case in which the gravity loads are applied up to their total force magnitude as shown in Fig. 6.18.

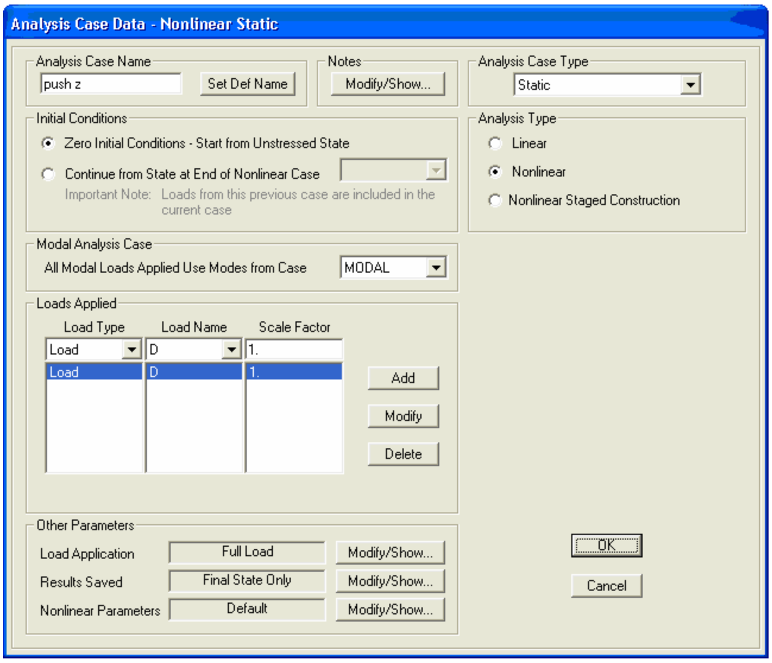


Fig. 6.18 Force-Controlled Nonlinear Static Pushover Case push z Applied in the Gravity Direction

The mathematical model of the building is subjected to monotonically increasing lateral forces until either a target displacement is exceeded or the building collapses. The target displacement may be calculated be taken as .4% of building height. In general, non-linear static procedure involves the monotonic application of lateral forces or displacements to a nonlinear mathematical model of a building until the displacement of the control node in the mathematical model exceeds a target displacement.

Here in the present case, nonlinear static case push x is applied in the lateral x-direction until a monitored displacement equal to 0.4% of building is achieved. The push x load case continues from the end of push z, i.e. the gravity load push as shown in Fig. 6.19.

Similarly, nonlinear static case push y is applied in the lateral y-direction until a monitored displacement equal to 0.4% of building is achieved. The push y load case continues from the end of push z, i.e. the gravity load push as shown in Fig. 6.20.

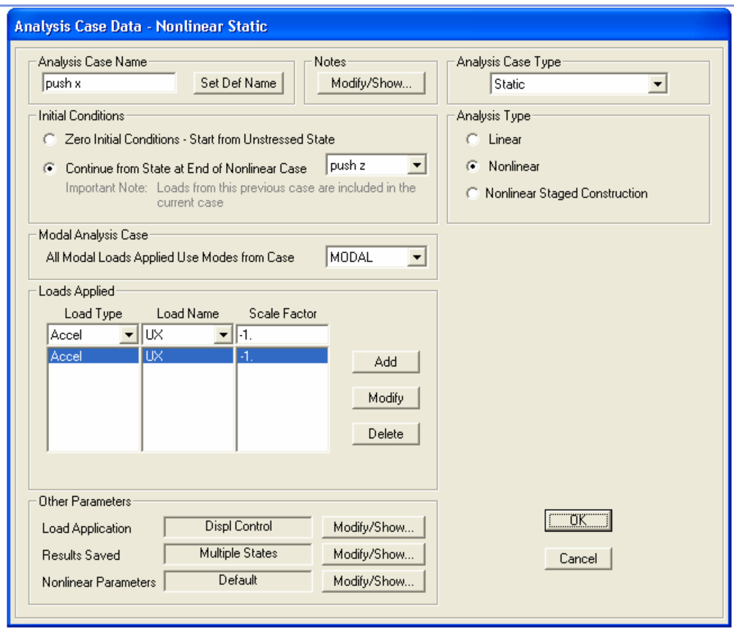


Fig. 6.19 Displacement-Controlled Nonlinear Static Pushover Case push x Applied in the X-Direction

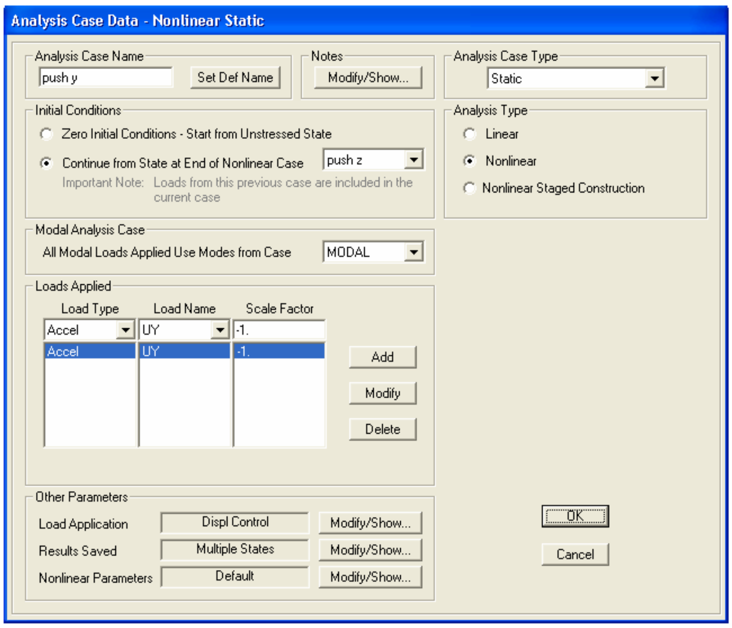


Fig. 6.20 Displacement-Controlled Nonlinear Static Pushover Case push y Applied in the Y-Direction

Also, since no specific data regarding the nearness source factor for a particular site under construction is available, the soil profile S_D is assumed and the related values of N_A and N_B are assumed depending on the seismic source type. Furthermore the values of seismic co-efficient C_A and C_V are assumed as 0.4. Also the structure behavior is taken as Type B (building with moderate reduction of area and moderate hysteretic behavior).

The Fig. 6.21 shows the ATC-40[10] parameters assumed and assigned to the building under study.

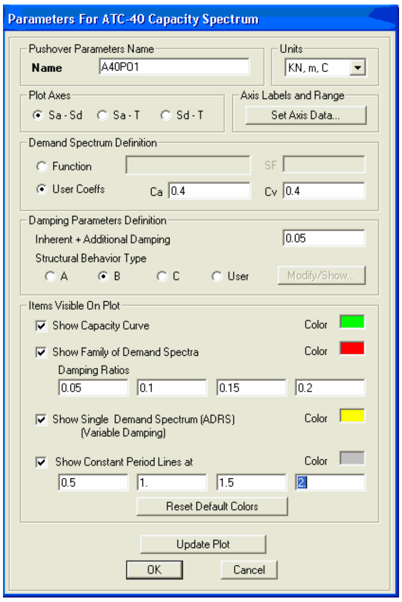


Fig. 6.21 Parameters for ATC-40 Capacity Spectrum

The non-linear static analysis is performed using the Assign Option from the Assign menu. The static pushover curve can be seen by selecting the Display Option from the Display menu as illustrated in Fig. 6.22.

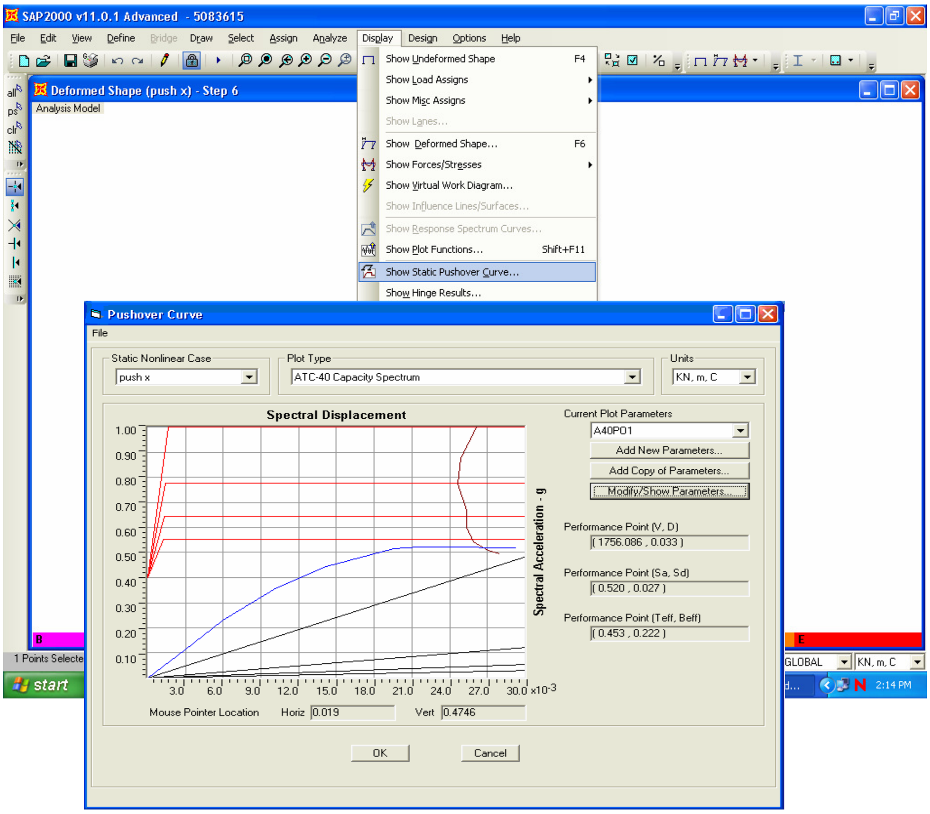


Fig. 6.22 Display of ATC-40 Capacity Spectrum

The capacity curve can also be viewed by selecting the capacity curve option from the plot type as shown in Fig. 6.23.

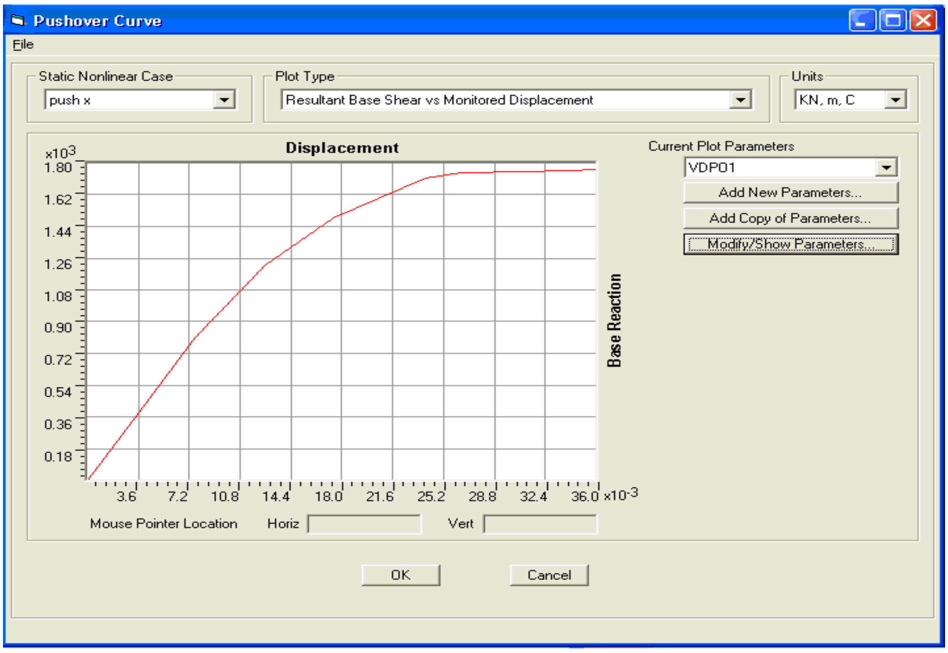


Fig. 6.23 Display of Capacity Curve

The hinges formed at the end of pushover case indicate the failure modes in the structure. The colour coded hinges formed at the end of each step pertaining to each performance level can be observed by selecting the Show Deform Shape command from the Display menu as illustrated in Fig. 6.24.

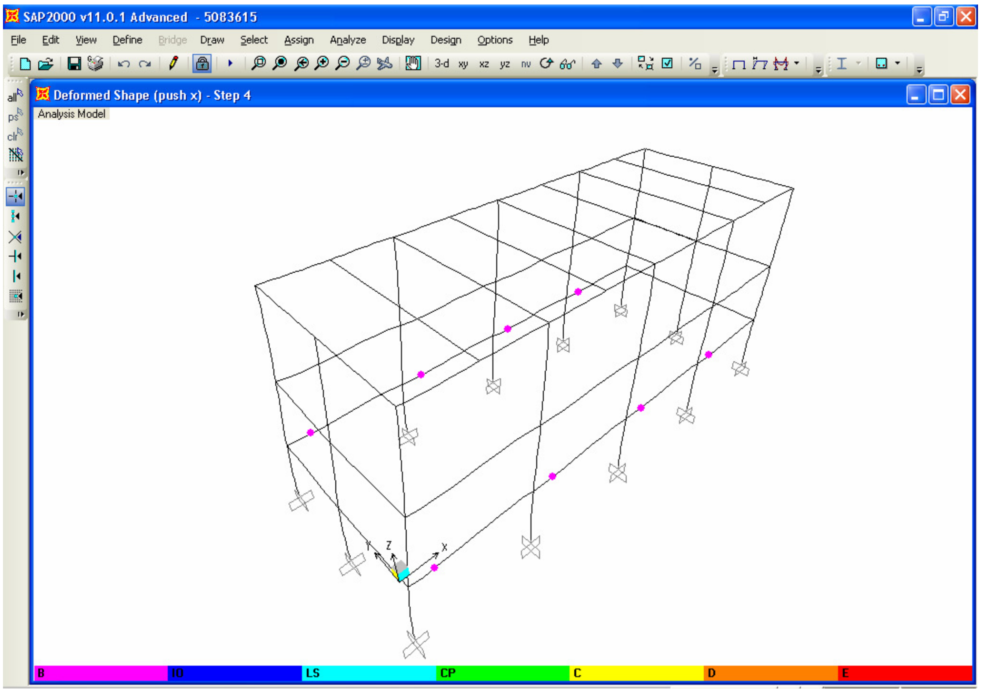


Fig. 6.24 Formation of Colour Coded Hinges

6.12 APPLICATION TO BALANCE OF PLANT BUILDINGS

The current codes have been based on extensive research and on observations of actual damage in structures during past earthquakes. The primary goal of these codes is to ensure life safety by requiring structures to have sufficient stiffness, strength and ductility to prevent collapse in very severe earthquakes. A secondary goal is to control the extent of property damage and maintain the function of the building after moderate events that are expected to occur more frequently. The entire theory of pushover analysis is based on the concept that the building should have capacity to satisfy the demand.

- Geometry:- In the present study, a building having model no. 5083615 and 5083610 are undertaken for study. The roof slab is considered 150mm thick. All external walls are 250mm thick and the parapet is assumed to be 150mm thick and 1200 mm high. The combined axial and flexural type of hinges is defined at 5% span length from either ends for all columns and beams. The dimensions of structural components are same as that specified in Chapter 4. The plan of the building is shown in Fig. 6.25.

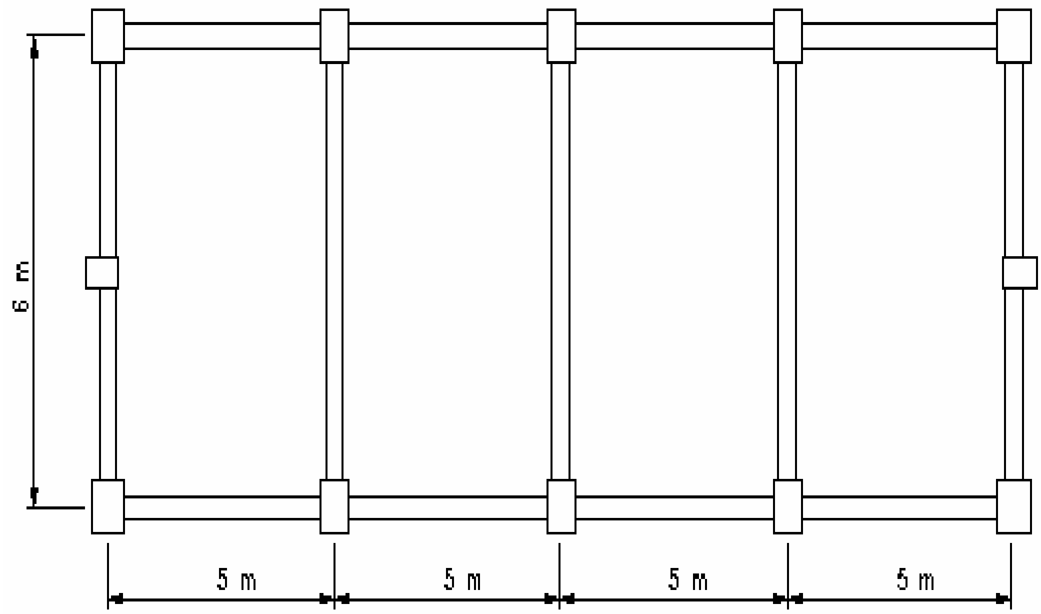


Fig. 6.25 Plan of building

- Loading:- The model is subjected to a waterproofing load of 1.5 kN/m^2 and live load of 1.5 kN/m^2 on the roof. The wall load acts on the plinth and lintel beams. Seismic loads in the two lateral directions are considered as per the seismic coefficient method specified in the Indian standard code

IS: 1893 (Part I)-2002[13] considering the value of A_h as 15% and 10% for the respective models.

- Pushover Analysis:- The static analysis is carried out for the given dead, live and earthquake loads. Typically, three pushover cases are defined. The push z is the gravity load case wherein the gravity loads are applied up to their total force magnitude in steps. The push x and push y cases are defined for the push in lateral x and y directions. The displacement at the roof level node is monitored up to the magnitude of 0.4% of the building height.
- Results:- For, the first model, the building is pushed in x and y direction up to a monitored displacement of 36mm and the analysis is performed. It is observed from the ATC-40 Capacity Spectrum curve that the performance point obtained after the first iteration is 33 mm as shown in Fig. 6.26. Thus, the displacement at the performance point does not lie in the range of +5% to -5%.

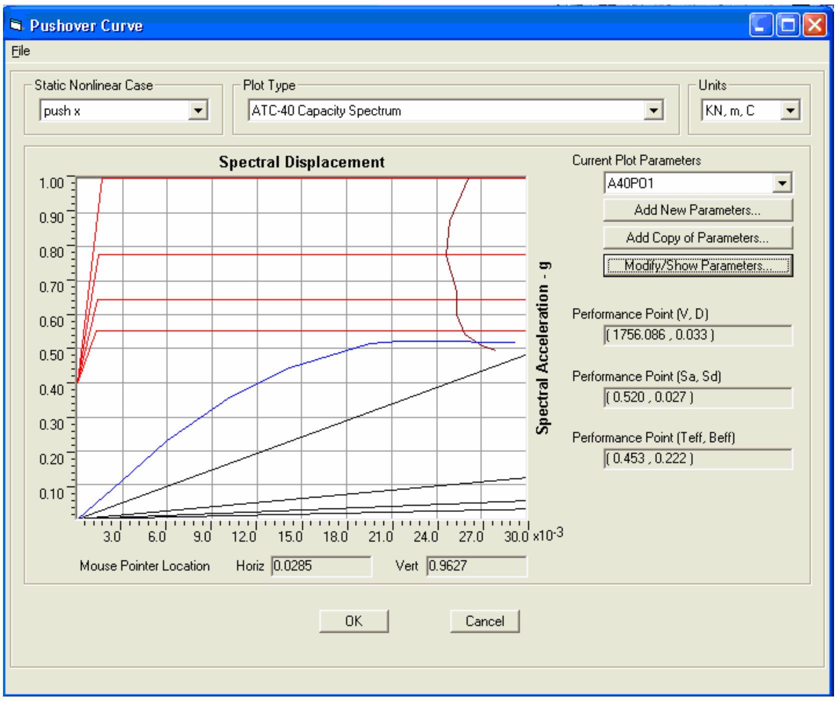


Fig. 6.26 Displacement at the Performance point after the First Iteration

Therefore, iteration is carried out and the building is pushed in the lateral directions for a monitored displacement of 33mm and static non-linear analysis is performed. It is observed from the ATC-40 Capacity Spectrum curve shown in Fig. 6.27 that the displacement at the performance point is 32 mm, which is in the acceptable range of +5% to -5%.

Thus, the target displacement is achieved after the second iteration.

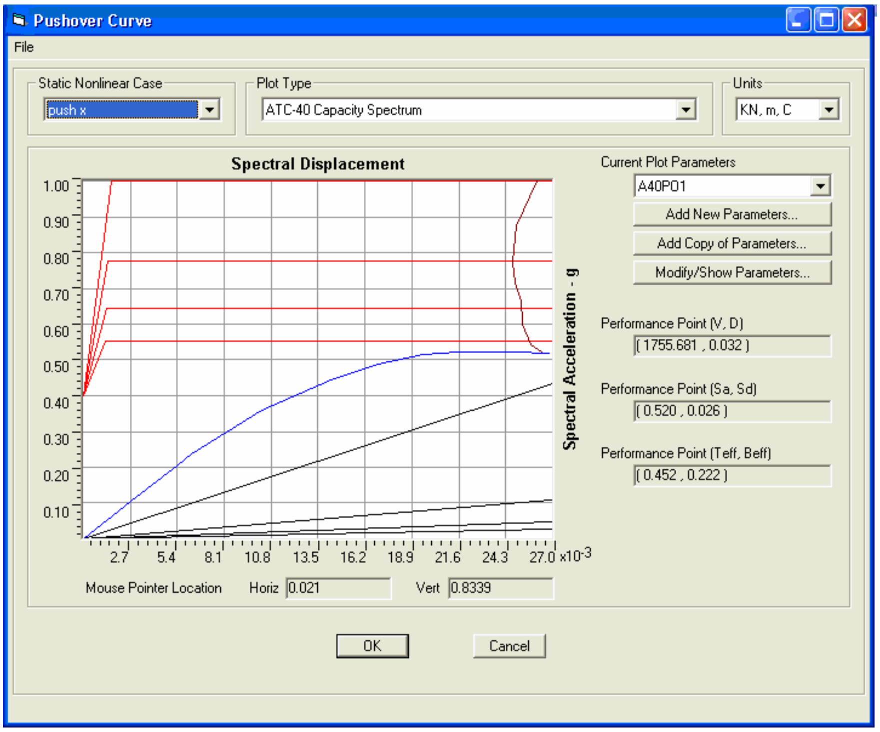


Fig. 6.27 Displacement at the Performance point after the Second Iteration

The capacity curve for the building under study is displayed in the following Fig. 6.28.

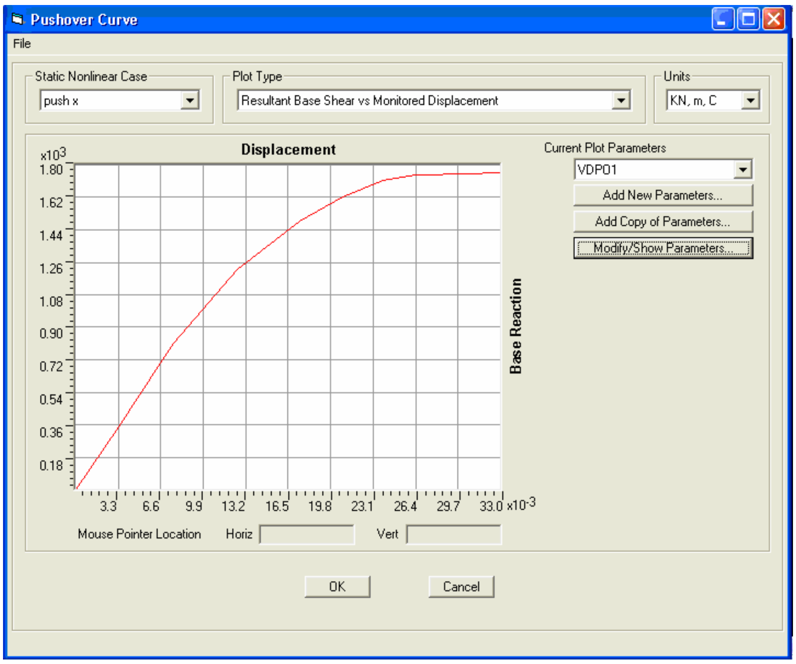


Fig. 6.28 Capacity Curve after the Second Iteration

The results of the analysis are presented in the form of deformed shape attained at the end of step 5 as shown in Fig. 6.29.

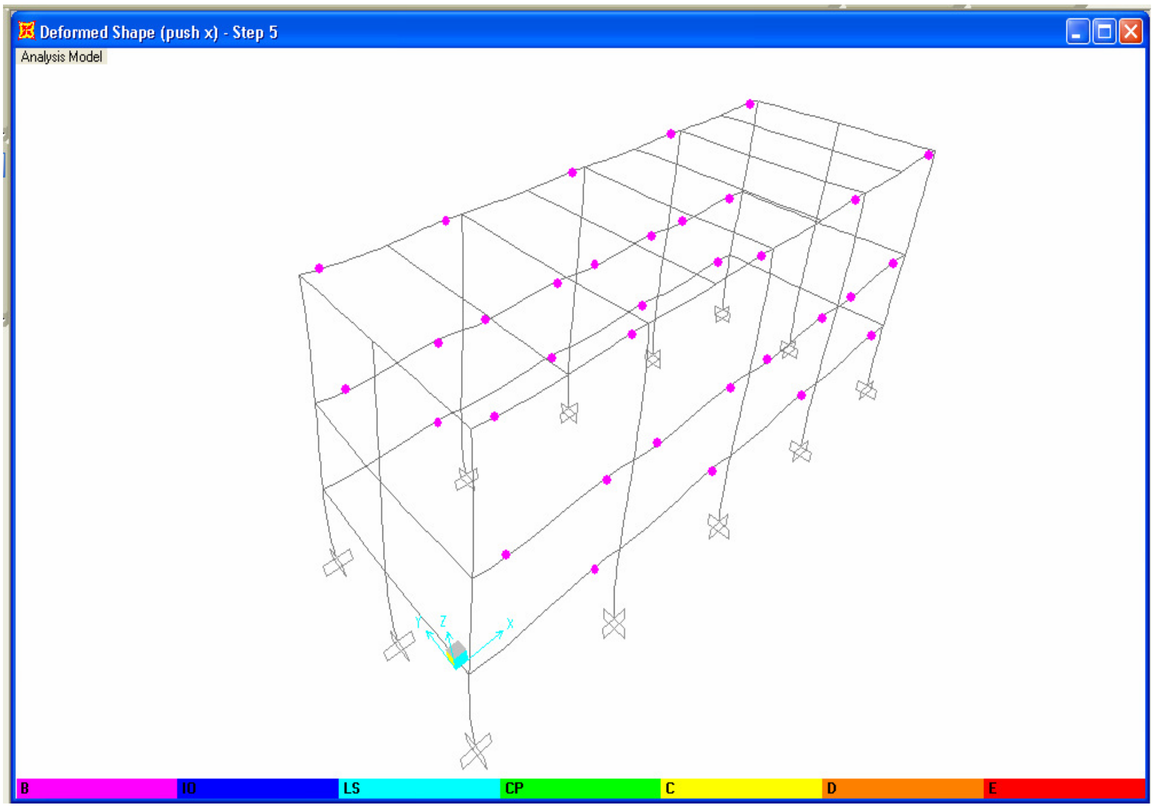


Fig. 6.29 Hinge Formation at the End of Step 5

Similarly, for the second model having A_h equal to 10%, the loads are applied in the similar manner as described earlier for the first model. The target displacement of 36 mm is not reached after the first iteration. Therefore, a second iteration is carried out till the building reaches a monitored displacement of 13 mm.

Discussion: The Table 6.1 shows the number of hinges developed up to the performance point for the first model and Table 6.2 shows the number of hinges developed up to the performance point for the second model.

Table 6.1 Hinges formed up to Performance Point for model 1

Roof displ. (m)	Base force (kN)	A-B	B-IO	IO-LS	LS-CP	CP-C	C-D	D-E	>E	TOTAL
.033	1756.7	90	60	0	0	0	0	0	0	150

Table 6.2 Hinges formed up to Performance Point for model 2

Roof displ. (m)	Base force (kN)	A-B	B-IO	IO-LS	LS-CP	CP-C	C-D	D-E	>E	TOTAL
.013	964.876	128	22	0	0	0	0	0	0	150

- It has been observed from the results that the hinges are formed in the range of B-IO. The hinges are formed up to the immediate occupancy level, which indicates that building has been designed for the immediate occupancy level.
- The power plant structures are of utmost importance and post-earthquake situation demands that the power plant building should be functional immediately after the earthquake. It is desired that after a severe disaster like an earthquake, the structural as well as the non-structural components of the building are generally in place.
- The power plant is an important infrastructural unit and the power supply should be available in hospitals, schools, etc. for rehabilitation purpose.
- The primary requirement after an earthquake is that the remedial measures should continue without any obstruction which can only happen if electricity is available.
- It is foreseen that current Indian Codes may incorporate pushover analysis in the in future, so the pushover analysis is introduced in current study. In order to survive competition in the global market, L&T-S-L desires that their engineers should be prepared if pushover analysis is introduced in the next revision of Indian codes. Since, seismic engineering is going more advanced, an attempt has been made to apply advance tools and techniques to power plant structures.

6.13 SUMMARY

In this chapter, the theory and concepts related to pushover analysis has been discussed. Also, the pushover analysis is applied to B.O.P. building, so as to verify its performance level.

7. SUMMARY AND FUTURE SCOPE OF WORK

7.1 SUMMARY

Cost effective power plant design is vital for the engineering design firm. Firms and engineers having the ability and reputation for designing reliable, low-cost power plants & systems are sought in the increasingly competitive environment. There exists enormous opportunities for the engineers and firms who are able to compete with the growing electric utility industry. The main objective of this study is to develop a database for B.O.P. buildings, as they are required in each and every power plant. Power plant layout for particular capacity is generalized and if another plant of same capacity is to constructed at different location, then attempt is made that same layout can be used.

There exits variation in the foundation level, roof level, soil bearing capacity, zone, bay width and width of B.O.P. buildings. Therefore, in order to prepare a database, a tool is developed to create building models in short interval of time. A Visual Basic application is developed to create building models, with minimum possible input. The program can generate 900 odd lines of SAP *.$2k file in few seconds and thus accelerates the rate of work.

In the present study, total 150 odd buildings are analyzed and designed. Also apart from macros written for frame generation and *.$2k file, macro is also written for consolidating the data and compiling the data in a single worksheet in order to facilitate the easy plotting of graphs

The brick infills are introduced in B.O.P. buildings and its effect on cost is studied. The brick infill are modeled as per IS: 1893 (Part I) Draft**[6]** and FEMA-273**[7]**. It is observed that modeling of brick infills gives significant reduction in axial forces and base moments columns. Presently brick infills are not modeled in B.O.P. buildings modeled at L&T-S&L, but after the present study it is suggested to model brick infills in B.O.P. buildings in future projects.

The pushover analysis is carried out on B.O.P. buildings and a preliminary study is carried out to evaluate the building performance. Since, earthquake engineering is becoming more advanced; it is felt that advance tools and techniques should be applied to power plant buildings when such requirements are mandatory or recommended in code revisions.

7.2 CONCLUSIONS

From the above study following conclusions can be made

1. The data base has been prepared with significant attention which will help in estimating various structural quantities. Analysis and design of 150 odd buildings and deriving 67 factors to represent different structural quantities will help significantly in quick estimate during proposal making and even during detailed engineering. Even a less skilled fresh learning engineer can quickly estimate the quantities with fairly good accuracy.
2. This database and graphs will result in saving of time in future and also help to complete the proposals for various projects within the stipulated time. For a large company like L&T-S&L, delivering design output in a stringent time schedule is one of the challenges. This will help in quick estimation of framing element sizes and accelerate the design process.
3. This database will be kept in company's repository and will be enriched by adding data of buildings designed now onwards.
4. The modeling of brick infills as per IS: 1893 (Part I) Draft**[6]** is relatively simpler as it requires a definition of fewer parameters compared to FEMA-273**[7]**. It is thus suggested that in order to model brick infills in practical problems, IS: 1893 (Draft) method should be adopted.
5. The modeling of brick infills gives significant reduction in forces in various components of building. Thus, it is suggested to model brick infills in future projects, so as to achieve economy. For a large company like L&T-S&L, even if 3% to 5% of concrete quantity is saved, it would result in significant economy.
6. From the results, of the pushover analysis it is learnt that the power plant buildings be designed for immediate occupancy, so that during the post earthquake scenario, there is least possible damage to these buildings. In the post-earthquake situation it is required that there is least possible damage of the buildings, so that the remedial measures can be carried out easily.
7. It is foreseen that current Indian Codes may incorporate pushover analysis in the in future, so the pushover analysis is introduced in current study. In

order to survive competition in the global market, L&T-S&L desires that their engineers should be prepared if pushover analysis is introduced in the next revision of Indian codes. Since, seismic engineering is going more advanced, an attempt is made to apply advance tools and techniques to power plant structures.

7.3 FUTURE SCOPE OF WORK

The present study can be extended as follows:-

1. The number of buildings can be increased in the database by varying different parameters like width, roof height, foundation level, soil bearing capacity and building length.

2. The brick infills can be modeled in more number of buildings, to provide a consistent basis for comparison.

3. The nonlinear push over analysis can be performed on more number of infilled frames as well as bare frames, to study the behavior of B.O.P. buildings.

4. The present visual basic tool may be modified for multistoried buildings and could thus be used to prepare a database for multistoried buildings.

5. The nonlinear push over analysis can be performed on multistoried buildings with infilled frames.

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A.1 GENERAL

This section discusses the visual basic program as well as the input and output files generated through excel:-

Frame data generation:

The following program is used to generate the nodal coordinates, members, member definition and member property assignment, dead and live load calculation and assignment of dead, live and earthquake load to each member and node respectively.

```
Sub GenFrameData()
Dim InSh As Object
Dim OutSh As Object
Dim EqSh As Object
Set InSh = ThisWorkbook.Worksheets("Inputpage")
Set OutSh = ThisWorkbook.Worksheets("Outputpage")
Set EqSh = ThisWorkbook.Worksheets("Eqpage")
Dim XBayNo, YBayNo
Dim XBay, YBay
Dim GableExist
Dim GableDist
Dim FdnLvl, LBLvl, PBLvl, RoofLvl
Dim CColX, CColY
Dim IColX, IColY
Dim GColX, GColY
Dim PBX_b, PBX_D
Dim PBY_b, PBY_D
Dim LBX_b, LBX_D
Dim LBY_b, LBY_D
Dim RBX_b, RBX_D
Dim RBY_b, RBY_D
Dim Sec_No
Dim Sec_b, Sec_D
Dim JtNo, JtX, JtY, JtZ
```

```
Dim MemID, MemJ, MemK
Dim MemLoc
Dim Mem_b, Mem_D
Dim RowWrite
Dim I, J, K
Dim SlabThk
Dim WPLoad
Dim RoofLL, RoofDL
Dim DenConc
Dim SlabThk
Dim WPLoad
Dim RoofLL, RoofDL
Dim DenConc
Dim DLRfUDLEnd, DLRfUDLInt
Dim LLRfUDLEnd, LLRfUDLInt
Dim ParaHt
Dim ParaW
Dim ParaDen
Dim ParaUDL
Dim WallThX
Dim WallThY
Dim WallDen
Dim WallUDLPBX, WallUDLPBY, WallUDLLBX, WallUDLLBY
Dim WallHtPBX, WallHtPBY, WallHtLBX, WallHtLBY
XBayNo = InSh.Cells(7, 4)
YBayNo = InSh.Cells(8, 4)
XBay = InSh.Cells(7, 6)
YBay = InSh.Cells(8, 6)
GableExist = InSh.Cells(10, 6)
If GableExist = "Yes" Then GableDist = InSh.Cells(11, 6)
FdnLvl = InSh.Cells(14, 6)
PBLvl = InSh.Cells(15, 6)
LBLvl = InSh.Cells(16, 6)
RoofLvl = InSh.Cells(17, 6)
Sec_No = InSh.Cells(18, 6)
```

```
CColX = InSh.Cells(22, 5)
CColY = InSh.Cells(22, 6)
IColX = InSh.Cells(23, 5)
IColY = InSh.Cells(23, 6)
GColX = InSh.Cells(24, 5)
GColY = InSh.Cells(24, 6)
PBX_b = InSh.Cells(27, 5)
PBX_D = InSh.Cells(27, 6)
PBY_b = InSh.Cells(28, 5)
PBY_D = InSh.Cells(28, 6)
LBX_b = InSh.Cells(31, 5)
LBX_D = InSh.Cells(31, 6)
LBY_b = InSh.Cells(32, 5)
LBY_D = InSh.Cells(32, 6)
RBX_b = InSh.Cells(36, 5)
RBX_D = InSh.Cells(36, 6)
RBY_b = InSh.Cells(37, 5)
RBY_D = InSh.Cells(37, 6)
Sec_b = InSh.Cells(38, 5)
Sec_D = InSh.Cells(38, 6)
SlabThk = InSh.Cells(40, 5)
WPLoad = InSh.Cells(41, 5)
RoofLL = InSh.Cells(42, 5)
DenConc = InSh.Cells(40, 7)
RoofDL = SlabThk / 1000 * DenConc + WPLoad
DLRfUDLEnd = XBay / (2 * (Sec_No + 1)) * RoofDL
DLRfUDLInt = XBay / (1 * (Sec_No + 1)) * RoofDL
LLRfUDLEnd = XBay / (2 * (Sec_No + 1)) * RoofLL
LLRfUDLInt = XBay / (1 * (Sec_No + 1)) * RoofLL
ParaHt = InSh.Cells(45, 5) / 1000
ParaW = InSh.Cells(46, 5) / 1000
ParaDen = InSh.Cells(47, 5)
ParaUDL = ParaHt * ParaW * ParaDen
WallThX = InSh.Cells(50, 5) / 1000
WallThY = InSh.Cells(51, 5) / 1000
```

```
WallDen = InSh.Cells(52, 5)
WallHtPBX = LBLvl - PBLvl - LBX_D / 1000
WallHtPBY = LBLvl - PBLvl - LBY_D / 1000
WallHtLBX = RoofLvl - LBLvl - RBX_D / 1000
WallHtLBY = RoofLvl - LBLvl - RBY_D / 1000
WallUDLPBX = WallThX * WallHtPBX * WallDen
WallUDLPBY = WallThY * WallHtPBY * WallDen
WallUDLLBX = WallThX * WallHtLBX * WallDen
WallUDLLBY = WallThY * WallHtLBY * WallDen
OutSh.Activate
Range("A5:IV65000").Select
Selection.ClearContents
OutSh.Cells(4, 2) = "Jt"
OutSh.Cells(4, 3) = "X"
OutSh.Cells(4, 4) = "Y"
OutSh.Cells(4, 5) = "Z"
OutSh.Cells(4, 9) = "MN"
OutSh.Cells(4, 10) = "J"
OutSh.Cells(4, 11) = "K"
OutSh.Cells(4, 12) = "MLoc"
OutSh.Cells(4, 13) = "b"
OutSh.Cells(4, 14) = "D"
OutSh.Cells(4, 15) = "SecName"
Cells(1, 1).Select
RowWrite = 5
For K = 1 To 4
Select Case K
Case 1
JtZ = FdnLvl
Case 2
JtZ = PBLvl
Case 3
JtZ = LBLvl
Case 4
JtZ = RoofLvl
```

```
End Select
For J = 1 To YBayNo + 1
For I = 1 To XBayNo + 1
JtNo = I + (J - 1) * 10 + (K - 1) * 100
JtX = (I - 1) * XBay
JtY = (J - 1) * YBay
OutSh.Cells(RowWrite, 2) = JtNo
OutSh.Cells(RowWrite, 3) = JtX
OutSh.Cells(RowWrite, 4) = JtY
OutSh.Cells(RowWrite, 5) = JtZ
If JtZ = FdnLvl Then
OutSh.Cells(RowWrite, 6) = "R"
End If
RowWrite = RowWrite + 1
If K = 4 And I <= XBayNo Then
dist = XBay / (Sec_No + 1)
For jj = 1 To Sec_No
JtNo = I + (J - 1) * 10 + (K - 1) * 1000
JtX = (I - 1) * XBay + dist * jj
OutSh.Cells(RowWrite, 2) = JtNo
OutSh.Cells(RowWrite, 3) = JtX
OutSh.Cells(RowWrite, 4) = JtY
OutSh.Cells(RowWrite, 5) = JtZ
RowWrite = RowWrite + 1
Next jj
End If
If GableExist = "Yes" Then
If (I = 1 Or I = XBayNo + 1) And J = 1 Then
JtX = (I - 1) * XBay
JtY = GableDist
JtNo = I + (J - 0) * 20 + (K - 1) * 100
OutSh.Cells(RowWrite, 2) = JtNo
OutSh.Cells(RowWrite, 3) = JtX
OutSh.Cells(RowWrite, 4) = JtY
OutSh.Cells(RowWrite, 5) = JtZ
```

```
If JtZ = FdnLvl Then
OutSh.Cells(RowWrite, 6) = "R"
End If
RowWrite = RowWrite + 1
End If
End If
Next I
Next J
Next K
RowWrite = 5
For J = 1 To YBayNo + 1
For I = 1 To XBayNo + 1
For K = 1 To 3
MemJ = I + (J - 1) * 10 + (K - 1) * 100
MemK = I + (J - 1) * 10 + (K) * 100
MemID = (I * 1000) + (J - 1) * 10 + K
OutSh.Cells(RowWrite, 9) = MemID
OutSh.Cells(RowWrite, 10) = MemJ
OutSh.Cells(RowWrite, 11) = MemK
If (I = 1 Or I = XBayNo + 1) And (J = 1 Or J = YBayNo + 1) Then
OutSh.Cells(RowWrite, 12) = "CC"
OutSh.Cells(RowWrite, 13) = CColX
OutSh.Cells(RowWrite, 14) = CColY
Else
OutSh.Cells(RowWrite, 12) = "IC"
OutSh.Cells(RowWrite, 13) = IColX
OutSh.Cells(RowWrite, 14) = IColY
End If
RowWrite = RowWrite + 1
Next K
Next I
Next J
Dim GableBeam
If GableExist = "Yes" Then
GableBeam = 2
```

```
Else
GableBeam = 1
End If
If GableBeam = 2 Then
For I = 1 To XBayNo + 1
For K = 1 To 3
If I = 1 Or I = XBayNo + 1 Then
MemJ = (K - 1) * 100 + 20 + I
MemK = (K - 0) * 100 + 20 + I
If I = 1 Then MemID = 1000 + (I + 1) * 10 + K
If I <> 1 Then MemID = 1000 + (I + 0) * 10 + K
OutSh.Cells(RowWrite, 9) = MemID
OutSh.Cells(RowWrite, 10) = MemJ
OutSh.Cells(RowWrite, 11) = MemK
OutSh.Cells(RowWrite, 12) = "GC"
OutSh.Cells(RowWrite, 13) = GColX
OutSh.Cells(RowWrite, 14) = GColY
RowWrite = RowWrite + 1
End If
Next K
Next I
End If
For K = 1 To 3
For J = 1 To YBayNo + 1
For I = 1 To XBayNo '+ 1
MemID = (I + (J - 1) * 10) + K * 100
MemJ = (I + (J - 1) * 10) + K * 100
MemK = (I + (J - 1) * 10) + 1 + K * 100
OutSh.Cells(RowWrite, 9) = MemID
OutSh.Cells(RowWrite, 10) = MemJ
OutSh.Cells(RowWrite, 11) = MemK
Select Case K
Case 1
OutSh.Cells(RowWrite, 12) = "PBX"
OutSh.Cells(RowWrite, 13) = PBX_b
```

```
OutSh.Cells(RowWrite, 14) = PBX_D
Case 2
OutSh.Cells(RowWrite, 12) = "LBX"
OutSh.Cells(RowWrite, 13) = LBX_b
OutSh.Cells(RowWrite, 14) = LBX_D
Case 3
OutSh.Cells(RowWrite, 12) = "RBX"
OutSh.Cells(RowWrite, 13) = RBX_b
OutSh.Cells(RowWrite, 14) = RBX_D
End Select
RowWrite = RowWrite + 1
Next I
Next J
Next K
For K = 3 To 3
For J = 1 To 1
For I = 2 To XBayNo
MemJ = I + (J - 1) * 10 + (K - 0) * 100
MemK = I + (J - 0) * 10 + (K - 0) * 100
MemID = (I - 1 + (J - 0) * 40) + K * 100
OutSh.Cells(RowWrite, 9) = MemID
OutSh.Cells(RowWrite, 10) = MemJ
OutSh.Cells(RowWrite, 11) = MemK
OutSh.Cells(RowWrite, 12) = "RBY"
OutSh.Cells(RowWrite, 13) = RBY_b
OutSh.Cells(RowWrite, 14) = RBY_D
RowWrite = RowWrite + 1
Next I
Next J
Next K
For K = 3 To 3
For J = 1 To 1
For I = 1 To XBayNo '+ 1
MemJ = I + (J - 1) * 10 + (K - 0) * 1000
MemK = I + (J - 0) * 10 + (K - 0) * 1000
```

```
MemID = (I + (J - 0) * 40) + K * 1000
OutSh.Cells(RowWrite, 9) = MemID
OutSh.Cells(RowWrite, 10) = MemJ
OutSh.Cells(RowWrite, 11) = MemK
OutSh.Cells(RowWrite, 12) = "SB"
OutSh.Cells(RowWrite, 13) = Sec_b
OutSh.Cells(RowWrite, 14) = Sec_D
RowWrite = RowWrite + 1
Next I
Next J
Next K
For K = 1 To 3
For I = 1 To XBayNo + 1
For J = 1 To GableBeam
If (I = 1 Or I = XBayNo + 1) Then
If GableBeam = 2 Then
If J = 1 Then
MemJ = I + K * 100
MemK = I + K * 100 + 20
End If
If J = 2 Then
MemJ = I + K * 100 + 20
MemK = I + K * 100 + 10
End If
If I = 1 Then MemID = (J + (1 - 0) * 20) + K * 100
If I = XBayNo + 1 Then MemID = (J + (1 - 0) * 50) + K * 100
End If
If GableBeam = 1 Then
MemJ = I + K * 100
MemK = I + K * 100 + 10
If I = 1 Then MemID = (J + (1 - 0) * 20) + K * 100
If I = XBayNo + 1 Then MemID = (J + (1 - 0) * 50) + K * 100
End If
OutSh.Cells(RowWrite, 9) = MemID
OutSh.Cells(RowWrite, 10) = MemJ
```

```
OutSh.Cells(RowWrite, 11) = MemK
Select Case K
Case 1
OutSh.Cells(RowWrite, 12) = "PBY"
OutSh.Cells(RowWrite, 13) = PBY_b
OutSh.Cells(RowWrite, 14) = PBY_D
Case 2
OutSh.Cells(RowWrite, 12) = "LBY"
OutSh.Cells(RowWrite, 13) = LBY_b
OutSh.Cells(RowWrite, 14) = LBY_D
Case 3
OutSh.Cells(RowWrite, 12) = "RBY"
OutSh.Cells(RowWrite, 13) = RBY_b
OutSh.Cells(RowWrite, 14) = RBY_D
End Select
RowWrite = RowWrite + 1
End If
Next J
Next I
Next K
RowRead = 5
Dim MyText
Do While OutSh.Cells(RowRead, 9) <> ""
MyText = OutSh.Cells(RowRead, 12)
MyText = MyText & Mid(OutSh.Cells(RowRead, 13), 1, 2)
MyText = MyText & "X"
MyText = MyText & Mid(OutSh.Cells(RowRead, 14), 1, 2)
OutSh.Cells(RowRead, 15) = MyText
RowRead = RowRead + 1
Loop
OutSh.Cells(4, 16) = "DL Wall"
OutSh.Cells(4, 17) = "DL Slab"
OutSh.Cells(4, 18) = "LL Slab"
RowRead = 5
Do While OutSh.Cells(RowRead, 9) <> ""
```

```
OutSh.Cells(RowRead, 16) = ""
OutSh.Cells(RowRead, 17) = ""
OutSh.Cells(RowRead, 18) = ""
If OutSh.Cells(RowRead, 12) = "PBX" Then OutSh.Cells(RowRead, 16) =
WallUDLPBX
If OutSh.Cells(RowRead, 12) = "PBY" Then OutSh.Cells(RowRead, 16) =
WallUDLPBY
If OutSh.Cells(RowRead, 12) = "LBX" Then OutSh.Cells(RowRead, 16) =
WallUDLLBX
If OutSh.Cells(RowRead, 12) = "LBY" Then OutSh.Cells(RowRead, 16) =
WallUDLLBY
If OutSh.Cells(RowRead, 12) = "RBX" Then OutSh.Cells(RowRead, 16) =
ParaUDL
If OutSh.Cells(RowRead, 12) = "RBY" Then
MemID = OutSh.Cells(RowRead, 9)
If MemID < 341 Or MemID > 350 Then
OutSh.Cells(RowRead, 16) = ParaUDL
OutSh.Cells(RowRead, 17) = DLRfUDLEnd
OutSh.Cells(RowRead, 18) = LLRfUDLEnd
Else
OutSh.Cells(RowRead, 17) = DLRfUDLInt
OutSh.Cells(RowRead, 18) = LLRfUDLInt
End If
End If
If OutSh.Cells(RowRead, 12) = "SB" Then
OutSh.Cells(RowRead, 17) = DLRfUDLInt
OutSh.Cells(RowRead, 18) = LLRfUDLInt
End If
RowRead = RowRead + 1
Loop
Dim X1, X2, Y1, Y2, Z1, Z2
RowRead = 5
Do While OutSh.Cells(RowRead, 9) <> ""
MemID = OutSh.Cells(RowRead, 9)
MemJ = OutSh.Cells(RowRead, 10)
```

```
MemK = OutSh.Cells(RowRead, 11)
OutSh.Cells(2, 2) = MemJ
OutSh.Cells(3, 2) = MemK
X1 = OutSh.Cells(2, 3)
Y1 = OutSh.Cells(2, 4)
Z1 = OutSh.Cells(2, 5)
X2 = OutSh.Cells(3, 3)
Y2 = OutSh.Cells(3, 4)
Z2 = OutSh.Cells(3, 5)
OutSh.Cells(RowRead, 8) = Sqr((X1 - X2) ^ 2 + (Y1 - Y2) ^ 2 + (Z1 - Z2) ^ 2)
RowRead = RowRead + 1
Loop
RowRead = 5
For I = 1 To XBayNo + 1
OutSh.Cells(RowRead, 71) = "X"
OutSh.Cells(RowRead, 72) = Chr(65 + I - 1)
OutSh.Cells(RowRead, 73) = (I - 1) * XBay
RowRead = RowRead + 1
Next I
For J = 1 To YBayNo + 1
If J = 1 Then
OutSh.Cells(RowRead, 71) = "Y"
OutSh.Cells(RowRead, 72) = 1
OutSh.Cells(RowRead, 73) = (J - 1) * YBay
End If
If J = YBayNo + 1 Then
If GableExist = "Yes" Then
OutSh.Cells(RowRead, 71) = "Y"
OutSh.Cells(RowRead, 72) = 2
OutSh.Cells(RowRead, 73) = GableDist
RowRead = RowRead + 1
OutSh.Cells(RowRead, 71) = "Y"
OutSh.Cells(RowRead, 72) = J + 1
OutSh.Cells(RowRead, 73) = (J - 1) * YBay
Else
```

```
OutSh.Cells(RowRead, 71) = "Y"
OutSh.Cells(RowRead, 72) = J '+ 1
OutSh.Cells(RowRead, 73) = (J - 1) * YBay
End If
End If
RowRead = RowRead + 1
Next J
For K = 1 To 4
Select Case K
Case 1
JtZ = FdnLvl
lvlname = "Fdn"
Case 2
JtZ = PBLvl
lvlname = "Plinth"
Case 3
JtZ = LBLvl
lvlname = "Lintel"
Case 4
JtZ = RoofLvl
lvlname = "Roof"
End Select
OutSh.Cells(RowRead, 71) = "Z"
OutSh.Cells(RowRead, 72) = lvlname
OutSh.Cells(RowRead, 73) = JtZ
RowRead = RowRead + 1
Next K
ThisWorkbook.Worksheets("SectionName").Activate
Range("A3").Select
ActiveSheet.PivotTables("PivotTable1").RefreshTable
InSh.Activate
InSh.Cells(1, 1).Select
End Sub
```

Sap file generation:

The following program is used to generate the SAP text file in the prerequisite format. The SAP file so generated contains the member definition and member property assignment, load combination, rigid diaphragm definition and assignment, member releases and assignment, support condition definition and assignment.

```
Sub WriteFirstPart()
Dim InSh As Object
Dim SAPSh As Object
Dim OutSh As Object
Dim SecSh As Object
Dim EqSh As Object
Set InSh = ThisWorkbook.Worksheets("Inputpage")
Set SAPSh = ThisWorkbook.Worksheets("SAPFILE")
Set OutSh = ThisWorkbook.Worksheets("OutputPage")
Set SecSh = ThisWorkbook.Worksheets("SectionName")
Set EqSh = ThisWorkbook.Worksheets("Eqpage")
Dim RowSAP, RowRead
Dim Quote4
SAPSh.Activate
Cells.Select
Selection.ClearContents
Cells(1, 1).Select
RowSAP = 2
Quote4 = """"
SAPSh.Cells(RowSAP, 1) = "File F:\SAP\tr_7.$2k was saved on 11/3/07 at
15:48:42"
RowSAP = RowSAP + 2
SAPSh.Cells(RowSAP, 1) = "TABLE: " & Quote4 & "ACTIVE DEGREES OF
FREEDOM" & Quote4
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "UX=Yes   UY=Yes   UZ=Yes   RX=Yes
RY=Yes   RZ=Yes"
RowSAP = RowSAP + 2
```

```
SAPSh.Cells(RowSAP, 1) = "TABLE: " & Quote4 & "ANALYSIS CASE
DEFINITIONS" & Quote4
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "  Case=D   Type=LinStatic   InitialCond=Zero
RunCase=Yes"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "  Case=Lr   Type=LinStatic   InitialCond=Zero
RunCase=Yes"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "  Case=EQX   Type=LinStatic
InitialCond=Zero   RunCase=Yes"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "  Case=EQY   Type=LinStatic
InitialCond=Zero   RunCase=Yes"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Case=MODAL   Type=LinModal
InitialCond=Zero   RunCase=Yes"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "ANALYSIS OPTIONS" &
Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Solver=Advanced   Force32Bit=No
StiffCase=None   GeomMod=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "AUTO WAVE 3 - WAVE
CHARACTERISTICS - GENERAL" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   WaveChar=Default   WaveType=" & Quote4
& "From Theory" & Quote4 & "   KinFactor=1   SWaterDepth=45
WaveHeight=18   WavePeriod=12   WaveTheory=Linear"
```

```
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "CASE - MODAL 1 -
GENERAL" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Case=MODAL   ModeType=Eigen
MaxNumModes=12   MinNumModes=1   EigenShift=0   EigenCutoff=0
EigenTol=0.000000001   AutoShift=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "CASE - STATIC 1 -
LOAD ASSIGNMENTS" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Case=EQX   LoadType=" & Quote4 & "Load
case" & Quote4 & "   LoadName=EQX   LoadSF=1"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Case=EQY   LoadType=" & Quote4 & "Load
case" & Quote4 & "   LoadName=EQY   LoadSF=1"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Case=Lr   LoadType=" & Quote4 & "Load
case" & Quote4 & "   LoadName=Lr   LoadSF=1"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Case=D   LoadType=" & Quote4 & "Load
case" & Quote4 & "   LoadName=D   LoadSF=1"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "COMBINATION
DEFINITIONS" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB101   ComboType=" &
```

```
Quote4 & "Linear Add" & Quote4 & "   CaseName=D   ScaleFactor=1
SteelDesign=No   ConcDesign=No   AlumDesign=No   ColdDesign=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB101   CaseName=Lr
ScaleFactor=1"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB102   ComboType=" &
Quote4 & "Linear Add" & Quote4 & "   CaseName=D   ScaleFactor=0.9
SteelDesign=No   ConcDesign=No   AlumDesign=No   ColdDesign=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB102   CaseName=EQX
ScaleFactor=1.2"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB103   ComboType=" &
Quote4 & "Linear Add" & Quote4 & "   CaseName=D   ScaleFactor=0.9
SteelDesign=No   ConcDesign=No   AlumDesign=No   ColdDesign=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB103   CaseName=EQX
ScaleFactor=-1.2"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB104   ComboType=" &
Quote4 & "Linear Add" & Quote4 & "   CaseName=D   ScaleFactor=0.9
SteelDesign=No   ConcDesign=No   AlumDesign=No   ColdDesign=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB104   CaseName=EQY
ScaleFactor=1.2"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB105   ComboType=" &
Quote4 & "Linear Add" & Quote4 & "   CaseName=D   ScaleFactor=0.9
SteelDesign=No   ConcDesign=No   AlumDesign=No   ColdDesign=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB105   CaseName=EQY
ScaleFactor=-1.2"
RowSAP = RowSAP + 1
```

```
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB106   ComboType=" &
Quote4 & "Linear Add" & Quote4 & "   CaseName=D   ScaleFactor=0.9
SteelDesign=No   ConcDesign=No   AlumDesign=No   ColdDesign=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB106   CaseName=Lr
ScaleFactor=0.9"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB107   ComboType=" &
Quote4 & "Linear Add" & Quote4 & "   CaseName=D   ScaleFactor=1
SteelDesign=No   ConcDesign=No   AlumDesign=No   ColdDesign=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB107   CaseName=Lr
ScaleFactor=1"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB107   CaseName=EQX
ScaleFactor=1"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB108   ComboType=" &
Quote4 & "Linear Add" & Quote4 & "   CaseName=D   ScaleFactor=1
SteelDesign=No   ConcDesign=No   AlumDesign=No   ColdDesign=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB108   CaseName=Lr
ScaleFactor=1"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB108   CaseName=EQY
ScaleFactor=1"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB201   ComboType=" &
Quote4 & "Linear Add" & Quote4 & "   CaseName=D   ScaleFactor=1.5
SteelDesign=No   ConcDesign=No   AlumDesign=No   ColdDesign=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB201   CaseName=Lr
ScaleFactor=1.5"
RowSAP = RowSAP + 1
```

```
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB202   ComboType=" &
Quote4 & "Linear Add" & Quote4 & "   CaseName=D   ScaleFactor=1.5
SteelDesign=No   ConcDesign=No   AlumDesign=No   ColdDesign=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB202   CaseName=EQX
ScaleFactor=1.5"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB203   ComboType=" &
Quote4 & "Linear Add" & Quote4 & "   CaseName=D   ScaleFactor=1.5
SteelDesign=No   ConcDesign=No   AlumDesign=No   ColdDesign=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB203   CaseName=EQX
ScaleFactor=-1.5"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB204   ComboType=" &
Quote4 & "Linear Add" & Quote4 & "   CaseName=D   ScaleFactor=1.5
SteelDesign=No   ConcDesign=No   AlumDesign=No   ColdDesign=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB204   CaseName=EQY
ScaleFactor=1.5"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB205   ComboType=" &
Quote4 & "Linear Add" & Quote4 & "   CaseName=D   ScaleFactor=1.5
SteelDesign=No   ConcDesign=No   AlumDesign=No   ColdDesign=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB205   CaseName=EQY
ScaleFactor=-1.5"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB206   ComboType=" &
Quote4 & "Linear Add" & Quote4 & "   CaseName=D   ScaleFactor=1.2
SteelDesign=No   ConcDesign=No   AlumDesign=No   ColdDesign=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB206   CaseName=Lr
ScaleFactor=1.2"
```

```
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB206   CaseName=EQX
ScaleFactor=1.2"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB207   ComboType=" &
Quote4 & "Linear Add" & Quote4 & "   CaseName=D   ScaleFactor=1.2
SteelDesign=No   ConcDesign=No   AlumDesign=No   ColdDesign=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB207   CaseName=Lr
ScaleFactor=1.2"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB207   CaseName=EQX
ScaleFactor=-1.2"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB208   ComboType=" &
Quote4 & "Linear Add" & Quote4 & "   CaseName=D   ScaleFactor=1.2
SteelDesign=No   ConcDesign=No   AlumDesign=No   ColdDesign=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB208   CaseName=Lr
ScaleFactor=1.2"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB208   CaseName=EQY
ScaleFactor=1.2"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB209   ComboType=" &
Quote4 & "Linear Add" & Quote4 & "   CaseName=D   ScaleFactor=1.2
SteelDesign=No   ConcDesign=No   AlumDesign=No   ColdDesign=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB209   CaseName=Lr
ScaleFactor=1.2"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB209   CaseName=EQY
ScaleFactor=-1.2"
RowSAP = RowSAP + 1
```

```
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB210   ComboType=" & Quote4 & "Linear Add" & Quote4 & "   CaseName=D   ScaleFactor=0.9   SteelDesign=No   ConcDesign=No   AlumDesign=No   ColdDesign=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB210   CaseName=EQX   ScaleFactor=1.5"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB211   ComboType=" & Quote4 & "Linear Add" & Quote4 & "   CaseName=D   ScaleFactor=0.9   SteelDesign=No   ConcDesign=No   AlumDesign=No   ColdDesign=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB211   CaseName=EQX   ScaleFactor=-1.5"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB212   ComboType=" & Quote4 & "Linear Add" & Quote4 & "   CaseName=D   ScaleFactor=0.9   SteelDesign=No   ConcDesign=No   AlumDesign=No   ColdDesign=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB212   CaseName=EQY   ScaleFactor=1.5"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB213   ComboType=" & Quote4 & "Linear Add" & Quote4 & "   CaseName=D   ScaleFactor=0.9   SteelDesign=No   ConcDesign=No   AlumDesign=No   ColdDesign=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ComboName=COMB213   CaseName=EQY   ScaleFactor=-1.5"
RowSAP = RowSAP + 2
SAPSh.Cells(1, 1) = RowSAP
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "CONNECTIVITY - FRAME" & Quote4 & ""
RowSAP = RowSAP + 1
RowRead = 5
Do While OutSh.Cells(RowRead, 9) <> ""
```

```
MemID = OutSh.Cells(RowRead, 9)
MemJ = OutSh.Cells(RowRead, 10)
MemK = OutSh.Cells(RowRead, 11)
SAPSh.Cells(RowSAP, 1) = "   FRAME=" & MemID & " " & "JOINTI=" &
MemJ & " " & "JOINTJ=" & MemK & " IsCurved=NO"
RowSAP = RowSAP + 1
RowRead = RowRead + 1
Loop
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "CONSTRAINT
DEFINITIONS - DIAPHRAGM" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Name=DIAPH1   CoordSys=GLOBAL
Axis=Z   MultiLevel=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "COORDINATE
SYSTEMS" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Name=GLOBAL   Type=Cartesian   X=0
Y=0   Z=0   AboutZ=0   AboutY=0   AboutX=0"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "DATABASE FORMAT
TYPES" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   UnitsCurr=Yes   OverrideE=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "FRAME AUTO MESH
```

```
ASSIGNMENTS" & Quote4 & ""
RowSAP = RowSAP + 1
RowRead = 5
Do While OutSh.Cells(RowRead, 9) <> ""
MemID = OutSh.Cells(RowRead, 9)
SAPSh.Cells(RowSAP, 1) = "   FRAME=" & MemID & " AutoMesh=Yes
AtJoints=Yes   AtFrames=No   NumSegments=0   MaxLength=0
MaxDegrees=0"
RowSAP = RowSAP + 1
RowRead = RowRead + 1
Loop
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "FRAME DESIGN
PROCEDURES" & Quote4 & ""
RowSAP = RowSAP + 1
RowRead = 5
Do While OutSh.Cells(RowRead, 9) <> ""
MemID = OutSh.Cells(RowRead, 9)
SAPSh.Cells(RowSAP, 1) = "   FRAME=" & MemID & " DesignProc=" &
Quote4 & "From Material" & Quote4
RowSAP = RowSAP + 1
RowRead = RowRead + 1
Loop
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "FRAME LOADS -
DISTRIBUTED" & Quote4 & ""
RowSAP = RowSAP + 1
Dim MemLen
Dim LoadCase
Dim LoadVal
RowRead = 5
Do While OutSh.Cells(RowRead, 9) <> ""
```

```
text1 = ""
If OutSh.Cells(RowRead, 16) > 0 Or OutSh.Cells(RowRead, 17) > 0 Then
MemID = OutSh.Cells(RowRead, 9)
MemLen = OutSh.Cells(RowRead, 8)
LoadCase = "D"
LoadVal = OutSh.Cells(RowRead, 16) + OutSh.Cells(RowRead, 17)
text1 = text1 & "   Frame=" & MemID
text1 = text1 & "   LoadCase=" & LoadCase
text1 = text1 & "   CoordSys=GLOBAL   Type=Force   Dir=Gravity
DistType=RelDist   RelDistA=0   RelDistB=1   AbsDistA=0   AbsDistB=" &
MemLen
text1 = text1 & "   FOverLA=" & LoadVal
text1 = text1 & "   FOverLB=" & LoadVal
SAPSh.Cells(RowSAP, 1) = text1
RowSAP = RowSAP + 1
End If
RowRead = RowRead + 1
Loop
RowRead = 5
Do While OutSh.Cells(RowRead, 9) <> ""
text1 = ""
If OutSh.Cells(RowRead, 18) > 0 Then
MemID = OutSh.Cells(RowRead, 9)
MemLen = OutSh.Cells(RowRead, 8)
LoadCase = "Lr"
LoadVal = OutSh.Cells(RowRead, 18)
text1 = text1 & "   Frame=" & MemID
text1 = text1 & "   LoadCase=" & LoadCase
text1 = text1 & "   CoordSys=GLOBAL   Type=Force   Dir=Gravity
DistType=RelDist   RelDistA=0   RelDistB=1   AbsDistA=0   AbsDistB=" &
MemLen
text1 = text1 & "   FOverLA=" & LoadVal
text1 = text1 & "   FOverLB=" & LoadVal
SAPSh.Cells(RowSAP, 1) = text1
```

```
RowSAP = RowSAP + 1
End If
RowRead = RowRead + 1
Loop
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "FRAME OUTPUT
STATION ASSIGNMENTS" & Quote4 & ""
RowSAP = RowSAP + 1
RowRead = 5
Do While OutSh.Cells(RowRead, 9) <> ""
MemID = OutSh.Cells(RowRead, 9)
SAPSh.Cells(RowSAP, 1) = "   FRAME=" & MemID & "
StationType=MaxStaSpcg   MaxStaSpcg=0.5   AddAtElmInt=Yes
AddAtPtLoad=Yes"
RowSAP = RowSAP + 1
RowRead = RowRead + 1
Loop
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "FRAME RELEASE
ASSIGNMENTS 1 - GENERAL" & Quote4 & ""
RowSAP = RowSAP + 1
RowRead = 5
Do While OutSh.Cells(RowRead, 9) <> ""
If OutSh.Cells(RowRead, 12) = "SB" Then
MemID = OutSh.Cells(RowRead, 9)
SAPSh.Cells(RowSAP, 1) = "   FRAME=" & MemID & "   PI=No   V2I=No
V3I=No   TI=Yes   M2I=Yes   M3I=Yes   PJ=No   V2J=No   V3J=No
TJ=No   M2J=Yes   M3J=Yes"
RowSAP = RowSAP + 1
End If
RowRead = RowRead + 1
Loop
```

```
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "FRAME SECTION
ASSIGNMENTS" & Quote4 & ""
RowSAP = RowSAP + 1
Dim MemSec
RowRead = 5
Do While OutSh.Cells(RowRead, 9) <> ""
MemID = OutSh.Cells(RowRead, 9)
MemSec = OutSh.Cells(RowRead, 15)
SAPSh.Cells(RowSAP, 1) = "   FRAME=" & MemID & "   AutoSelect=N.A.
AnalSect=" & MemSec & "   MatProp=Default"
RowSAP = RowSAP + 1
RowRead = RowRead + 1
Loop
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "FRAME SECTION
PROPERTIES 01 - GENERAL" & Quote4 & ""
RowSAP = RowSAP + 1
Call SectionProp
RowRead = 5
Do While SecSh.Cells(RowRead, 5) <> ""
text1 = ""
text2 = ""
If SecSh.Cells(RowRead, 5) = 1 Then
SecName = SecSh.Cells(RowRead, 7)
t3 = SecSh.Cells(RowRead, 8)
t2 = SecSh.Cells(RowRead, 9)
Ax = SecSh.Cells(RowRead, 10)
J = SecSh.Cells(RowRead, 11)
I33 = SecSh.Cells(RowRead, 12)
I22 = SecSh.Cells(RowRead, 13)
AS2 = SecSh.Cells(RowRead, 14)
AS3 = SecSh.Cells(RowRead, 15)
```

```
S33 = SecSh.Cells(RowRead, 16)
S22 = SecSh.Cells(RowRead, 17)
Z33 = SecSh.Cells(RowRead, 18)
Z22 = SecSh.Cells(RowRead, 19)
R33 = SecSh.Cells(RowRead, 20)
R22 = SecSh.Cells(RowRead, 21)
text1 = text1 & "   SectionName=" & SecName
text1 = text1 & "   Material=CONCRETE   Shape=Rectangular   t3=" & t3
text1 = text1 & "   t2=" & t2
text1 = text1 & "   Area =" & Ax
text1 = text1 & "   TorsConst =" & J
text1 = text1 & "   I33 =" & I33
text1 = text1 & "   I22=" & I22
text1 = text1 & "   AS2=" & AS2
text1 = text1 & "   AS3=" & AS3
text1 = text1 & "   S33=" & S33
text1 = text1 & "   S22=" & S22
text1 = text1 & "   Z33=" & Z33 & " _"
text2 = text2 & "   Z22=" & Z22
text2 = text2 & "   R33=" & R33
text2 = text2 & "   R22=" & R22
text2 = text2 & "   Color=Gray8Dark   FromFile=No   AMod=1   A2Mod=1
A3Mod=1   JMod=1   I2Mod=1   I3Mod=1   MMod=1   WMod=1   Notes="
& Quote4 & "Added 11/17/2007 10:33:18 AM" & Quote4 & ""
SAPSh.Cells(RowSAP, 1) = text1
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = text2
RowSAP = RowSAP + 1
End If
RowRead = RowRead + 1
Loop
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "FRAME SECTION
```

```
PROPERTIES 02 - CONCRETE COLUMN" & Quote4 & ""
RowSAP = RowSAP + 1
RowRead = 5
Do While SecSh.Cells(RowRead, 5) <> ""
If SecSh.Cells(RowRead, 5) = 1 And UCase(SecSh.Cells(RowRead, 6)) =
"C" Then
SAPSh.Cells(RowSAP, 1) = "   SectionName=" & SecSh.Cells(RowRead, 7)
& "   RebarMatL=A615Gr60   RebarMatC=A615Gr60
ReinfConfig=Rectangular   LatReinf=Ties   Cover=0.04   NumBars3Dir=3
NumBars2Dir=3   BarSizeL=10d   BarSizeC=#8   SpacingC=0.15
NumCBars2=3   NumCBars3=3   ReinfType=Design"
RowSAP = RowSAP + 1
End If
RowRead = RowRead + 1
Loop
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "FRAME SECTION
PROPERTIES 03 - CONCRETE BEAM" & Quote4 & ""
RowSAP = RowSAP + 1
RowRead = 5
Do While SecSh.Cells(RowRead, 5) <> ""
If SecSh.Cells(RowRead, 5) = 1 And UCase(SecSh.Cells(RowRead, 6)) =
"B" Then
SAPSh.Cells(RowSAP, 1) = "   SectionName=" & SecSh.Cells(RowRead, 7)
& "   RebarMatL=A615Gr60   RebarMatC=A615Gr60   TopCover=0.06
BotCover=0.06   TopLeftArea=0   TopRghtArea=0   BotLeftArea=0
BotRghtArea=0"
RowSAP = RowSAP + 1
End If
RowRead = RowRead + 1
Loop
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
```

```
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "FUNCTION - PLOT
FUNCTIONS" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   PlotFunc=" & Quote4 & "Input Energy" &
Quote4 & "   Type=Energy   Component=Input   Mode=All"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "FUNCTION - POWER
SPECTRAL DENSITY - USER" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Name=UNIFPSD   Frequency=0   Value=1"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Name=UNIFPSD   Frequency=1   Value=1"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "FUNCTION - RESPONSE
SPECTRUM - USER" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Name=UNIFRS   Period=0   Accel=1
FuncDamp=0.05"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Name=UNIFRS   Period=1   Accel=1"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "FUNCTION - STEADY
STATE - USER" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Name=UNIFSS   Frequency=0   Value=1"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Name=UNIFSS   Frequency=1   Value=1"
RowSAP = RowSAP + 1
```

```
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "FUNCTION - TIME
HISTORY - USER" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Name=RAMPTH   Time=0   Value=0"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Name=RAMPTH   Time=1   Value=1"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Name=RAMPTH   Time=4   Value=1"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Name=UNIFTH   Time=0   Value=1"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Name=UNIFTH   Time=1   Value=1"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "GRID LINES" & Quote4
& ""
RowSAP = RowSAP + 1
RowRead = 5
Do While OutSh.Cells(RowRead, 71) <> ""
text1 = ""
text1 = text1 & "   CoordSys=GLOBAL   AxisDir=" & OutSh.Cells(RowRead,
71)
text1 = text1 & "   GridID=" & OutSh.Cells(RowRead, 72)
text1 = text1 & "   XRYZCoord=" & OutSh.Cells(RowRead, 73)
If RowRead = 5 Then
text1 = text1 & "   LineType=Primary   LineColor=Gray8Dark   Visible=Yes
BubbleLoc=End   AllVisible=Yes   BubbleSize=1.25"
Else
text1 = text1 & "   LineType=Primary   LineColor=Gray8Dark   Visible=Yes
BubbleLoc=End"
End If
```

```
SAPSh.Cells(RowSAP, 1) = text1
RowRead = RowRead + 1
RowSAP = RowSAP + 1
Loop
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   CoordSys=GLOBAL   AxisDir=X   GridID=A
XRYZCoord=0   LineType=Primary   LineColor=Gray8Dark   Visible=Yes
BubbleLoc=End   AllVisible=Yes   BubbleSize=1.25"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "GROUPS 1 -
DEFINITIONS" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   GroupName=All   Selection=Yes
SectionCut=Yes   Steel=Yes   Concrete=Yes   Aluminum=Yes
ColdFormed=Yes   Stage=Yes   Bridge=Yes   AutoSeismic=No
AutoWind=No   MassWeight=Yes"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "JOINT CONSTRAINT
ASSIGNMENTS" & Quote4 & ""
RowSAP = RowSAP + 1
RowRead = 5
Do While OutSh.Cells(RowRead, 2) <> ""
If OutSh.Cells(RowRead, 2) > 300 And OutSh.Cells(RowRead, 2) < 400
Then
text1 = "   Joint=" & OutSh.Cells(RowRead, 2) & "   Constraint=DIAPH1"
SAPSh.Cells(RowSAP, 1) = text1
RowSAP = RowSAP + 1
End If
RowRead = RowRead + 1
Loop
SAPSh.Cells(RowSAP, 1) = " "
```

```
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "JOINT COORDINATES"
& Quote4 & ""
RowSAP = RowSAP + 1
RowRead = 5
Do While OutSh.Cells(RowRead, 2) <> ""
JtNo = OutSh.Cells(RowRead, 2)
JtX = OutSh.Cells(RowRead, 3)
JtY = OutSh.Cells(RowRead, 4)
JtZ = OutSh.Cells(RowRead, 5)
MyText = "   JOINT=" & JtNo
MyText = MyText & "   CoordSys=GLOBAL   CoordType=Cartesian   XorR="
& JtX
MyText = MyText & "   Y=" & JtY
MyText = MyText & "   Z=" & JtZ & "   SpecialJt=No"
SAPSh.Cells(RowSAP, 1) = MyText
RowSAP = RowSAP + 1
RowRead = RowRead + 1
Loop
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "JOINT LOADS - FORCE"
& Quote4 & ""
RowSAP = RowSAP + 1
RowRead = 168
Do While EqSh.Cells(RowRead, 3) <> ""
text1 = "   Joint=" & EqSh.Cells(RowRead, 3) & "   LoadCase=EQX
CoordSys=GLOBAL   F1=" & EqSh.Cells(RowRead, 7) & "   F2=0   F3=0
M1=0   M2=0   M3=0"
SAPSh.Cells(RowSAP, 1) = text1
RowSAP = RowSAP + 1
RowRead = RowRead + 1
Loop
RowRead = 168
```

```
Do While EqSh.Cells(RowRead, 3) <> ""
text1 = "   Joint=" & EqSh.Cells(RowRead, 3) & "   LoadCase=EQY
CoordSys=GLOBAL   F1=0   F2=" & EqSh.Cells(RowRead, 7) & "   F3=0
M1=0   M2=0   M3=0"
SAPSh.Cells(RowSAP, 1) = text1
RowSAP = RowSAP + 1
RowRead = RowRead + 1
Loop
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "JOINT RESTRAINT
ASSIGNMENTS" & Quote4 & ""
RowSAP = RowSAP + 1
RowRead = 5
Do While OutSh.Cells(RowRead, 2) <> ""
If OutSh.Cells(RowRead, 6) = "R" Then
JtNo = OutSh.Cells(RowRead, 2)
MyText = "   Joint=" & JtNo
MyText = MyText & "   U1=Yes   U2=Yes   U3=Yes   R1=Yes   R2=Yes
R3=Yes"
SAPSh.Cells(RowSAP, 1) = MyText
RowSAP = RowSAP + 1
End If
RowRead = RowRead + 1
Loop
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "JOINT PATTERN
DEFINITIONS" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Pattern=DEFAULT"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "LOAD CASE
```

```
DEFINITIONS" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   LoadCase=D   DesignType=DEAD
SelfWtMult=1"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   LoadCase=Lr   DesignType=LIVE
SelfWtMult=0"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   LoadCase=EQX   DesignType=QUAKE
SelfWtMult=0   AutoLoad=None"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   LoadCase=EQY   DesignType=QUAKE
SelfWtMult=0   AutoLoad=None"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "MASSES 1 - MASS
SOURCE" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   MassFrom=Elements"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "MATERIAL PROPERTIES
01 - GENERAL" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Material=4000Psi   Type=Concrete
SymType=Isotropic   TempDepend=No   Color=Blue   Notes=" & Quote4 &
"Normalweight f'c = 4 ksi added 11/17/2007 10:25:51 AM" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Material=A615Gr60   Type=Rebar
SymType=Uniaxial   TempDepend=No   Color=White   Notes=" & Quote4 &
"ASTM A615 Grade 60 added 11/17/2007 10:33:18 AM" & Quote4 & ""
RowSAP = RowSAP + 1
```

```
SAPSh.Cells(RowSAP, 1) = "   Material=A992Fy50   Type=Steel
SymType=Isotropic   TempDepend=No   Color=Gray8Dark   Notes=" &
Quote4 & "ASTM A992 Fy=50 ksi added 11/17/2007 10:25:51 AM" &
Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Material=CONCRETE   Type=Concrete
SymType=Isotropic   TempDepend=No   Color=Blue   Notes=" & Quote4 &
"ASTM A36 added 11/17/2007 10:32:06 AM" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "MATERIAL PROPERTIES
02 - BASIC MECHANICAL PROPERTIES" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Material=4000Psi
UnitWeight=23.563121614979   UnitMass=2.40276960611018
E1=24855578.2847654   G12=10356490.9519856   U12=0.2
A1=0.0000099"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Material=A615Gr60
UnitWeight=76.9728639422648   UnitMass=7.84904737995992
E1=199947978.795958   A1=0.0000117"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Material=A992Fy50
UnitWeight=76.9728639422648   UnitMass=7.84904737995992
E1=199947978.795958   G12=76903068.767676   U12=0.3
A1=0.0000117"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Material=CONCRETE   UnitWeight=24
UnitMass=2.4   E1=25000000   G12=9474864   U12=0.18
A1=0.0000099"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "MATERIAL PROPERTIES
03A - STEEL DATA" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Material=A992Fy50
```

```
Fy=344737.894475789   Fu=448159.262818526
EffFy=379211.683923368   EffFu=492975.189100378
SSCurveOpt=Simple   SSHysType=Kinematic   SHard=0.015   SMax=0.11
SRup=0.17"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "MATERIAL PROPERTIES
03B - CONCRETE DATA" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Material=CONCRETE
Fc=20684.2736685473   LtWtConc=No   SSCurveOpt=Simple
SSHysType=Kinematic   SFc=0.002   SCap=0.005   FAngle=0   DAngle=0"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "MATERIAL PROPERTIES
03E - REBAR DATA" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Material=A615Gr60
Fy=413685.473370947   Fu=620528.21005642
EffFy=455054.020708041   EffFu=682581.031062062
SSCurveOpt=Simple   SSHysType=Kinematic   SHard=0.01   SCap=0.09
UseCTDef=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "MATERIAL PROPERTIES
06 - DAMPING PARAMETERS" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Material=4000Psi   ModalRatio=0
VisMass=0   VisStiff=0   HysMass=0   HysStiff=0"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
```

```
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Material=A615Gr60   ModalRatio=0
VisMass=0   VisStiff=0   HysMass=0   HysStiff=0"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Material=A992Fy50   ModalRatio=0
VisMass=0   VisStiff=0   HysMass=0   HysStiff=0"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Material=CONCRETE   ModalRatio=0
VisMass=0   VisStiff=0   HysMass=0   HysStiff=0"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "OPTIONS - COLORS -
DISPLAY" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   DeviceType=Screen   Points=Yellow
LinesFrame=Yellow   LinesFrmExt=Yellow   LinesCable=Green
LinesTendon=Green   SpringLinks=Green   Restraints=Green
Releases=Green   Axes=Cyan   Text=Green   ShadowLines=Gray8Dark _"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "      GuideLines=Gray8Dark   Highlight=Red
Selection=White   AreaFillBot=Red   AreaFillTop=16744703
AreaFillSd=Red   AreaEdge=DarkRed   SolidF1=Red   SolidF2=Blue
SolidF3=Green   SolidF4=Yellow   SolidF5=White   SolidF6=Cyan _"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "      SolidEdge=DarkRed   Floor=Gray4
Background=Black   BGLowLeft=Black   BGLowRight=Black
BGUpRight=Black   Darkness=0.5"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   DeviceType=Printer   Points=Gray8Dark
```

```
LinesFrame=Black   LinesFrmExt=Gray4   LinesCable=Black
LinesTendon=Black   SpringLinks=Gray8Dark   Restraints=Gray8Dark
Releases=Gray4   Axes=Black   Text=Black   ShadowLines=Gray4 _"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "        GuideLines=Gray4   Highlight=Black
Selection=Black   AreaFillBot=Gray4   AreaFillTop=Gray8Dark
AreaFillSd=Gray4   AreaEdge=Black   SolidF1=Gray1Light   SolidF2=Gray2
SolidF3=Gray3   SolidF4=Gray4   SolidF5=Gray5 _"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "        SolidF6=Gray6   SolidEdge=Black
Floor=Gray4   Background=White   BGLowLeft=White   BGLowRight=White
BGUpRight=White   Darkness=0.5"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   DeviceType=" & Quote4 & "Color Printer" &
Quote & "   Points=Black   LinesFrame=7303023   LinesFrmExt=White
LinesCable=Green   LinesTendon=Green   SpringLinks=Green
Restraints=9408399   Releases=Green   Axes=Cyan   Text=Black
ShadowLines=Gray8Dark _"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "        GuideLines=10461087   Highlight=Red
Selection=10504778   AreaFillBot=16634568   AreaFillTop=14277119
AreaFillSd=16634568   AreaEdge=7303023   SolidF1=10122991
SolidF2=16756912   SolidF3=11599795   SolidF4=12713983 _"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "        SolidF5=White   SolidF6=16777128
SolidEdge=7303023   Floor=10461087   Background=White
BGLowLeft=White   BGLowRight=14671839   BGUpRight=White
Darkness=0.5"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "OPTIONS - COLORS -
OUTPUT" & Quote4 & ""
RowSAP = RowSAP + 1
```

```
SAPSh.Cells(RowSAP, 1) = "   DeviceType=Screen   Contour1=13107400
Contour2=6553828   Contour3=Red   Contour4=16639
Contour5=Orange   Contour6=43775   Contour7=54527
Contour8=Yellow   Contour9=65408   Contour10=Green
Contour11=8453888   Contour12=Cyan _"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "        Contour13=16755200
Contour14=16733440   Contour15=Blue   Transpare=0.5   Ratio1=Cyan
Ratio2=Green   Ratio3=Yellow   Ratio4=Orange   Ratio5=Red
RatioNotD=Gray4   RatioNotC=Red   RatioVal1=0.5   RatioVal2=0.7
RatioVal3=0.9 _"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "        RatioVal4=1   DFillPos=Yellow
DFillNeg=Red   DFillRPos=Blue   DFillRNeg=Cyan"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   DeviceType=Printer   Contour1=Black
Contour2=3158064   Contour3=4210752   Contour4=5263440
Contour5=6316128   Contour6=7368816   Contour7=Gray8Dark
Contour8=Gray7   Contour9=Gray6   Contour10=Gray5
Contour11=Gray4 _"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "        Contour12=Gray3   Contour13=Gray2
Contour14=Gray1Light   Contour15=White   Transpare=0   Ratio1=Gray2
Ratio2=Gray4   Ratio3=Gray8Dark   Ratio4=4210752   Ratio5=Black
RatioNotD=Gray4   RatioNotC=Black   RatioVal1=0.5 _"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "        RatioVal2=0.7   RatioVal3=0.9
RatioVal4=1   DFillPos=Gray8Dark   DFillNeg=Gray8Dark
DFillRPos=4210752   DFillRNeg=4210752"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   DeviceType=" & Quote4 & "Color Printer" &
Quote4 & "   Contour1=13107400   Contour2=6553828   Contour3=Red
Contour4=16639   Contour5=Orange   Contour6=43775
Contour7=54527   Contour8=Yellow   Contour9=65408
```

```
Contour10=Green   Contour11=8453888 _"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "        Contour12=Cyan   Contour13=16755200
Contour14=16733440   Contour15=Blue   Transpare=0.5   Ratio1=Cyan
Ratio2=Green   Ratio3=Yellow   Ratio4=Orange   Ratio5=Red
RatioNotD=Gray4   RatioNotC=Red   RatioVal1=0.5   RatioVal2=0.7 _"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "        RatioVal3=0.9   RatioVal4=1
DFillPos=Red   DFillNeg=Red   DFillRPos=Blue   DFillRNeg=Blue"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "PREFERENCES -
ALUMINUM DESIGN - AA-ASD 2000" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   THDesign=Envelopes   FrameType=" &
Quote4 & "Moment Frame" & Quote4 & "   SRatioLimit=1   MaxIter=1
LatFact=1.33333333333333   UseLatFact=No   Bridge=No"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "PREFERENCES - COLD
FORMED DESIGN - AISI-ASD96" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   THDesign=Envelopes   FrameType=" &
Quote4 & "Braced Frame" & Quote4 & "   SRatioLimit=1   MaxIter=1
OmegaBS=1.67   OmegaBUS=1.67   OmegaBLTB=1.67   OmegaVS=1.67
OmegaVNS=1.5   OmegaT=1.67   OmegaC=1.8"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "PREFERENCES -
CONCRETE DESIGN - ACI 318-05/IBC 2003" & Quote4 & ""
RowSAP = RowSAP + 1
```

```
SAPSh.Cells(RowSAP, 1) = "   THDesign=Envelopes   NumCurves=24
NumPoints=11   MinEccen=Yes   PatLLF=0.75   UFLimit=0.95   SeisCat=D
PhiT=0.9   PhiCTied=0.65   PhiCSpiral=0.7   PhiV=0.75   PhiVSeismic=0.6
PhiVJoint=0.85"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "PREFERENCES -
DIMENSIONAL" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   MergeTol=0.001   FineGrid=0.25
Nudge=0.25   SelectTol=3   SnapTol=12   SLineThick=1   PLineThick=4
MaxFont=8   MinFont=3   AutoZoom=10   ShrinkFact=70
TextFileLen=240"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "PREFERENCES - STEEL
DESIGN - AISC-LRFD93" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   THDesign=Envelopes   FrameType=" &
Quote4 & "Moment Frame" & Quote4 & "   PatLLF=0.75   SRatioLimit=0.95
MaxIter=1   PhiB=0.9   PhiC=0.85   PhiT=0.9   PhiV=0.9   PhiCA=0.9
CheckDefl=No   DLRat=120   SDLAndLLRat=120   LLRat=360
TotalRat=240   NetRat=240"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "PROGRAM CONTROL" &
Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   ProgramName=SAP2000   Version=11.0.1
CurrUnits=" & Quote4 & "KN, m, C" & Quote4 & "   SteelCode=AISC-
LRFD93   ConcCode=" & Quote4 & "ACI 318-05/IBC2003" & Quote4 & "
```

```
AlumCode=" & Quote4 & "AA-ASD 2000" & Quote4 & "   ColdCode=AISI-
ASD96   RegenHinge=Yes"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "PROJECT
INFORMATION" & Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Item=" & Quote4 & "Company Name" &
Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Item=" & Quote4 & "Client Name" & Quote4
& ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Item=" & Quote4 & "Project Name" &
Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Item=" & Quote4 & "Project Number" &
Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Item=" & Quote4 & "Model Name" & Quote4
& ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Item=" & Quote4 & "Model Description" &
Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Item=" & Quote4 & "Revision Number" &
Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Item=" & Quote4 & "Frame Type" & Quote4
& ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Item=Engineer"
RowSAP = RowSAP + 1
```

```
SAPSh.Cells(RowSAP, 1) = "   Item=Checker"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Item=Supervisor"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Item=" & Quote4 & "Issue Code" & Quote4
& ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   Item=" & Quote4 & "Design Code" & Quote4
& ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "TABLE:  " & Quote4 & "REBAR SIZES" &
Quote4 & ""
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=#2   Area=0.000032258
Diameter=0.00635"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=#3   Area=7.09675996154547E-
05   Diameter=0.009525"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=#4   Area=1.29032001922727E-
04   Diameter=0.0127"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=#5   Area=1.99999601538181E-
04   Diameter=0.015875"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=#6   Area=2.83870398461819E-
04   Diameter=0.01905"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=#7   Area=3.87096015381813E-
04   Diameter=0.022225"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=#8   Area=5.09676413843632E-
```

```
04   Diameter=0.0254"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=#9   Area=0.00064516
Diameter=2.86512005329132E-02"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=#10   Area=8.1935318769455E-
04   Diameter=3.22579995155334E-02"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=#11   Area=1.00644956308365E-
03   Diameter=3.58139991521835E-02"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=#14   Area=0.00145161
Diameter=4.30021989583969E-02"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=#18   Area=0.00258064
Diameter=5.73277992248535E-02"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=10M   Area=1.00000004162606E-
04   Diameter=1.13000003604438E-02"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=15M   Area=2.00000008325212E-
04   Diameter=1.60000002402959E-02"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=20M   Area=3.00000012487818E-
04   Diameter=1.95000002928606E-02"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=25M   Area=5.00000020813031E-
04   Diameter=2.52000011414055E-02"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=30M   Area=7.00000029138243E-
04   Diameter=2.99000000675832E-02"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=35M   Area=1.00000004162606E-
03   Diameter=3.57000012990997E-02"
```

```
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=45M   Area=1.50000006243909E-
03   Diameter=4.37000014192476E-02"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=55M   Area=2.50000010406515E-
03   Diameter=0.056400002372922"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=6d   Area=2.83000004150781E-05
Diameter=6.00000009011096E-03"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=8d   Area=5.03000013308514E-05
Diameter=8.00000012014795E-03"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=10d   Area=7.85000032676458E-
05   Diameter=1.00000001501849E-02"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=12d   Area=1.13000004703745E-
04   Diameter=1.20000001802219E-02"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=14d   Area=1.54000006410413E-
04   Diameter=1.40000002102589E-02"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=16d   Area=2.01000008366838E-
04   Diameter=1.60000002402959E-02"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=20d   Area=3.14000013070583E-
04   Diameter=2.00000003003699E-02"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=25d   Area=4.91000020438396E-
04   Diameter=2.50000003754623E-02"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "   RebarID=26d   Area=5.31000022103439E-
04   Diameter=2.60000003904808E-02"
RowSAP = RowSAP + 1
```

```
SAPSh.Cells(RowSAP, 1) = "   RebarID=28d   Area=6.16000025641654E-
04   Diameter=2.80000004205178E-02"
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = " "
RowSAP = RowSAP + 1
SAPSh.Cells(RowSAP, 1) = "END TABLE DATA"
RowSAP = RowSAP + 1
Cells(RowSAP, 1).Select
RowSAP = RowSAP + 1
SAPSh.Cells(1, 1) = ""
InSh.Activate
InSh.Cells(1, 1).Select
End Sub

Function WriteText(x, y)
WriteText = x & """" & y & """"
End Function

Sub SectionProp()
Dim SecSh As Object
Set SecSh = ThisWorkbook.Worksheets("SectionName")
Dim Ax, J, I33, I22, AS2, AS3, S33, S22, Z33, Z22, R33, R22
Dim SecName
Dim t3, t2
RowRead = 5
Do While SecSh.Cells(RowRead, 5) <> ""
If SecSh.Cells(RowRead, 5) = 1 Then
SecName = SecSh.Cells(RowRead, 7)
t3 = SecSh.Cells(RowRead, 8)
t2 = SecSh.Cells(RowRead, 9)
Ax = t3 * t2
a = Application.WorksheetFunction.Max(t3, t2)
b = Application.WorksheetFunction.Min(t3, t2)
J = a * b ^ 3 * (1 / 3 - 0.21 * b / a) * (1 - (b / a) ^ 4 / 12)
```

```
I33 = 1 / 12 * t2 * t3 ^ 3
I22 = 1 / 12 * t3 * t2 ^ 3
AS2 = 5 / 6 * t2 * t3
AS3 = 5 / 6 * t2 * t3
S33 = t2 * t3 ^ 2 / 6
S22 = t3 * t2 ^ 2 / 6
Z33 = 0.25 * t2 * t3 ^ 2
Z22 = 0.25 * t3 * t2 ^ 2
R33 = Sqr(I33 / Ax)
R22 = Sqr(I22 / Ax)
SecSh.Cells(RowRead, 10) = Ax
SecSh.Cells(RowRead, 11) = J
SecSh.Cells(RowRead, 12) = I33
SecSh.Cells(RowRead, 13) = I22
SecSh.Cells(RowRead, 14) = AS2
SecSh.Cells(RowRead, 15) = AS3
SecSh.Cells(RowRead, 16) = S33
SecSh.Cells(RowRead, 17) = S22
SecSh.Cells(RowRead, 18) = Z33
SecSh.Cells(RowRead, 19) = Z22
SecSh.Cells(RowRead, 20) = R33
SecSh.Cells(RowRead, 21) = R22
End If
RowRead = RowRead + 1
Loop
End Sub
```

B.1 GENERAL

The following output is generated for the frame data in visual basic:-

JOINT	X	Y	Z
1	0	0	-3
21	0	5	-3
2	5	0	-3
3	10	0	-3
4	15	0	-3
5	20	0	-3
25	20	5	-3
11	0	10	-3
12	5	10	-3
13	10	10	-3
14	15	10	-3
15	20	10	-3
101	0	0	-0.5
121	0	5	-0.5
102	5	0	-0.5
103	10	0	-0.5
104	15	0	-0.5
105	20	0	-0.5
125	20	5	-0.5
111	0	10	-0.5
112	5	10	-0.5
113	10	10	-0.5
114	15	10	-0.5
115	20	10	-0.5
201	0	0	2.3
221	0	5	2.3
202	5	0	2.3
203	10	0	2.3
204	15	0	2.3
205	20	0	2.3
225	20	5	2.3
211	0	10	2.3
212	5	10	2.3

213	10	10	2.3
214	15	10	2.3
215	20	10	2.3
301	0	0	6
3001	2.5	0	6
321	0	5	6
302	5	0	6
3002	7.5	0	6
303	10	0	6
3003	12.5	0	6
304	15	0	6
3004	17.5	0	6
305	20	0	6
325	20	5	6
311	0	10	6
3011	2.5	10	6
312	5	10	6
3012	7.5	10	6
313	10	10	6
3013	12.5	10	6
314	15	10	6
3014	17.5	10	6
315	20	10	6

MEMBER							DL	DL	LL
NO.	J	K	MLoc	b	D	SecName	Wall	Slab	Slab
1001	1	101	CC	550	550	CC55X55			
1002	101	201	CC	550	550	CC55X55			
1003	201	301	CC	550	550	CC55X55			
2001	2	102	IC	450	650	IC45X65			
2002	102	202	IC	450	650	IC45X65			
2003	202	302	IC	450	650	IC45X65			
3001	3	103	IC	450	650	IC45X65			
3002	103	203	IC	450	650	IC45X65			
3003	203	303	IC	450	650	IC45X65			
4001	4	104	IC	450	650	IC45X65			
4002	104	204	IC	450	650	IC45X65			
4003	204	304	IC	450	650	IC45X65			
5001	5	105	CC	550	550	CC55X55			

5002	105	205	CC	550	550	CC55X55	
5003	205	305	CC	550	550	CC55X55	
1011	11	111	CC	550	550	CC55X55	
1012	111	211	CC	550	550	CC55X55	
1013	211	311	CC	550	550	CC55X55	
2011	12	112	IC	450	650	IC45X65	
2012	112	212	IC	450	650	IC45X65	
2013	212	312	IC	450	650	IC45X65	
3011	13	113	IC	450	650	IC45X65	
3012	113	213	IC	450	650	IC45X65	
3013	213	313	IC	450	650	IC45X65	
4011	14	114	IC	450	650	IC45X65	
4012	114	214	IC	450	650	IC45X65	
4013	214	314	IC	450	650	IC45X65	
5011	15	115	CC	550	550	CC55X55	
5012	115	215	CC	550	550	CC55X55	
5013	215	315	CC	550	550	CC55X55	
1021	21	121	GC	600	400	GC60X40	
1022	121	221	GC	600	400	GC60X40	
1023	221	321	GC	600	400	GC60X40	
1051	25	125	GC	600	400	GC60X40	
1052	125	225	GC	600	400	GC60X40	
1053	225	325	GC	600	400	GC60X40	
101	101	102	PBX	250	600	PBX25X60	11
102	102	103	PBX	250	600	PBX25X60	11
103	103	104	PBX	250	600	PBX25X60	11
104	104	105	PBX	250	600	PBX25X60	11
111	111	112	PBX	250	600	PBX25X60	11
112	112	113	PBX	250	600	PBX25X60	11
113	113	114	PBX	250	600	PBX25X60	11
114	114	115	PBX	250	600	PBX25X60	11
201	201	202	LBX	250	600	LBX25X60	15
202	202	203	LBX	250	600	LBX25X60	15
203	203	204	LBX	250	600	LBX25X60	15
204	204	205	LBX	250	600	LBX25X60	15
211	211	212	LBX	250	600	LBX25X60	15
212	212	213	LBX	250	600	LBX25X60	15
213	213	214	LBX	250	600	LBX25X60	15
214	214	215	LBX	250	600	LBX25X60	15
301	301	302	RBX	250	700	RBX25X70	4.5

302	302	303	RBX	250	700	RBX25X70	4.5		
303	303	304	RBX	250	700	RBX25X70	4.5		
304	304	305	RBX	250	700	RBX25X70	4.5		
311	311	312	RBX	250	700	RBX25X70	4.5		
312	312	313	RBX	250	700	RBX25X70	4.5		
313	313	314	RBX	250	700	RBX25X70	4.5		
314	314	315	RBX	250	700	RBX25X70	4.5		
341	302	312	RBY	250	700	RBY25X70		12.75	3.75
342	303	313	RBY	250	700	RBY25X70		12.75	3.75
343	304	314	RBY	250	700	RBY25X70		12.75	3.75
3041	3001	3011	SB	250	700	SB25X70		12.75	3.75
3042	3002	3012	SB	250	700	SB25X70		12.75	3.75
3043	3003	3013	SB	250	700	SB25X70		12.75	3.75
3044	3004	3014	SB	250	700	SB25X70		12.75	3.75
121	101	121	PBY	250	450	PBY25X45	11.25		
122	121	111	PBY	250	450	PBY25X45	11.25		
151	105	125	PBY	250	450	PBY25X45	11.25		
152	125	115	PBY	250	450	PBY25X45	11.25		
221	201	221	LBY	250	550	LBY25X55	15		
222	221	211	LBY	250	550	LBY25X55	15		
251	205	225	LBY	250	550	LBY25X55	15		
252	225	215	LBY	250	550	LBY25X55	15		
321	301	321	RBY	250	700	RBY25X70	4.5	6.375	1.875
322	321	311	RBY	250	700	RBY25X70	4.5	6.375	1.875
351	305	325	RBY	250	700	RBY25X70	4.5	6.375	1.875
352	325	315	RBY	250	700	RBY25X70	4.5	6.375	1.875

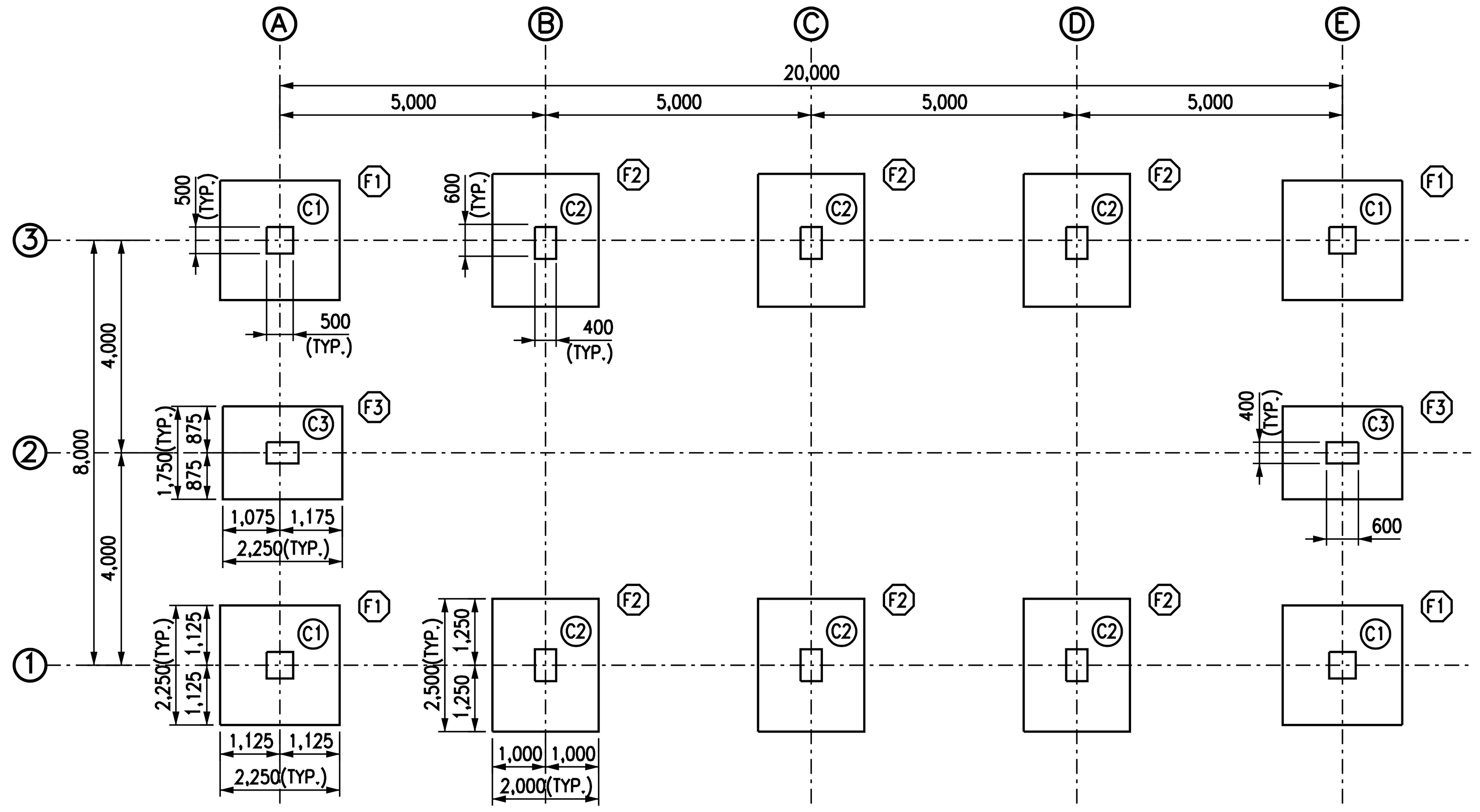
C.1 GENERAL

Following is the list of useful websites.

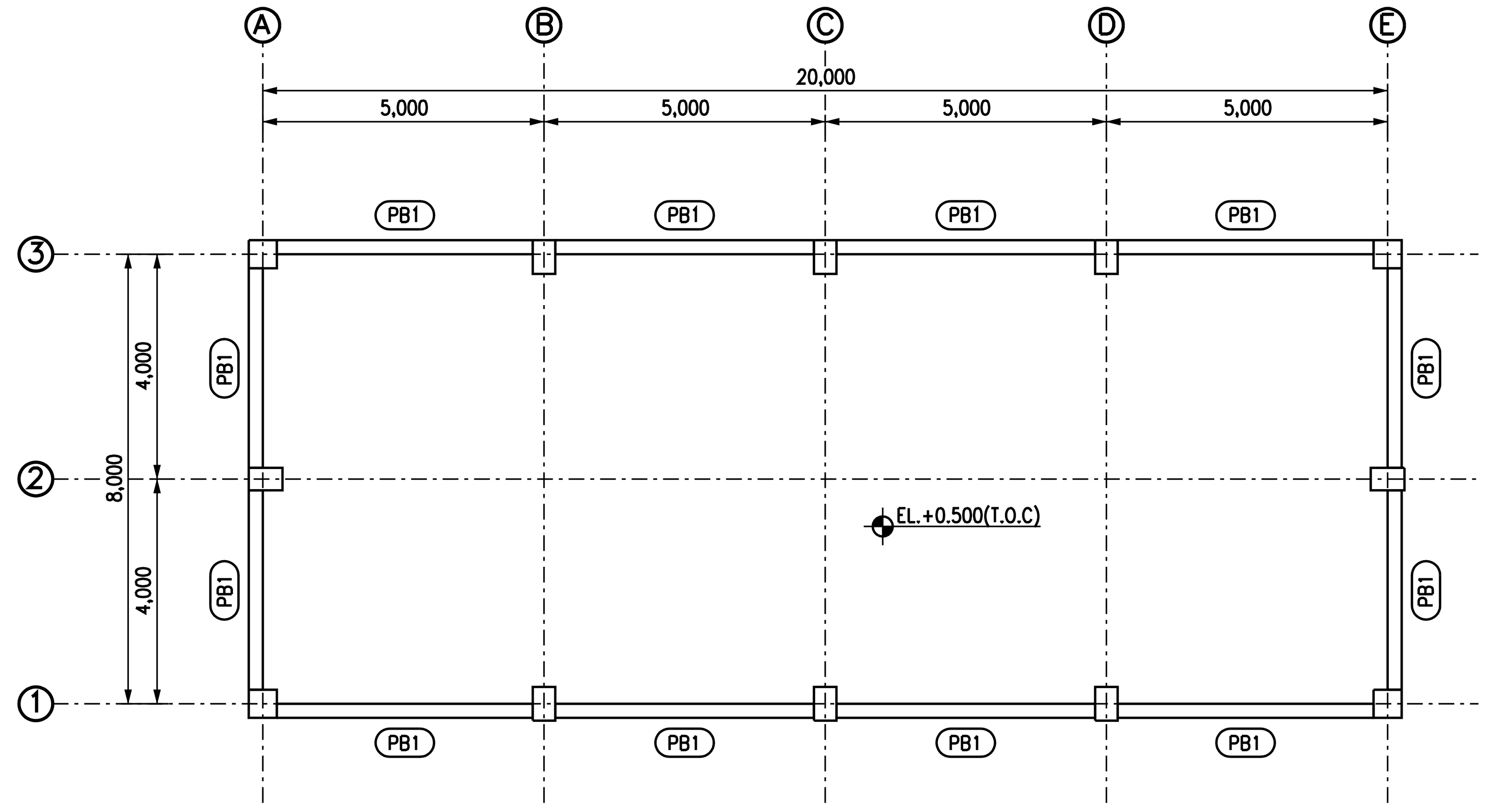
- www.google.com
- www.nicee.org
- www.iitk.ac.in
- www.asce.com
- www.sciencedirect.com
- www.csiberkeley.com

D.1 GENERAL

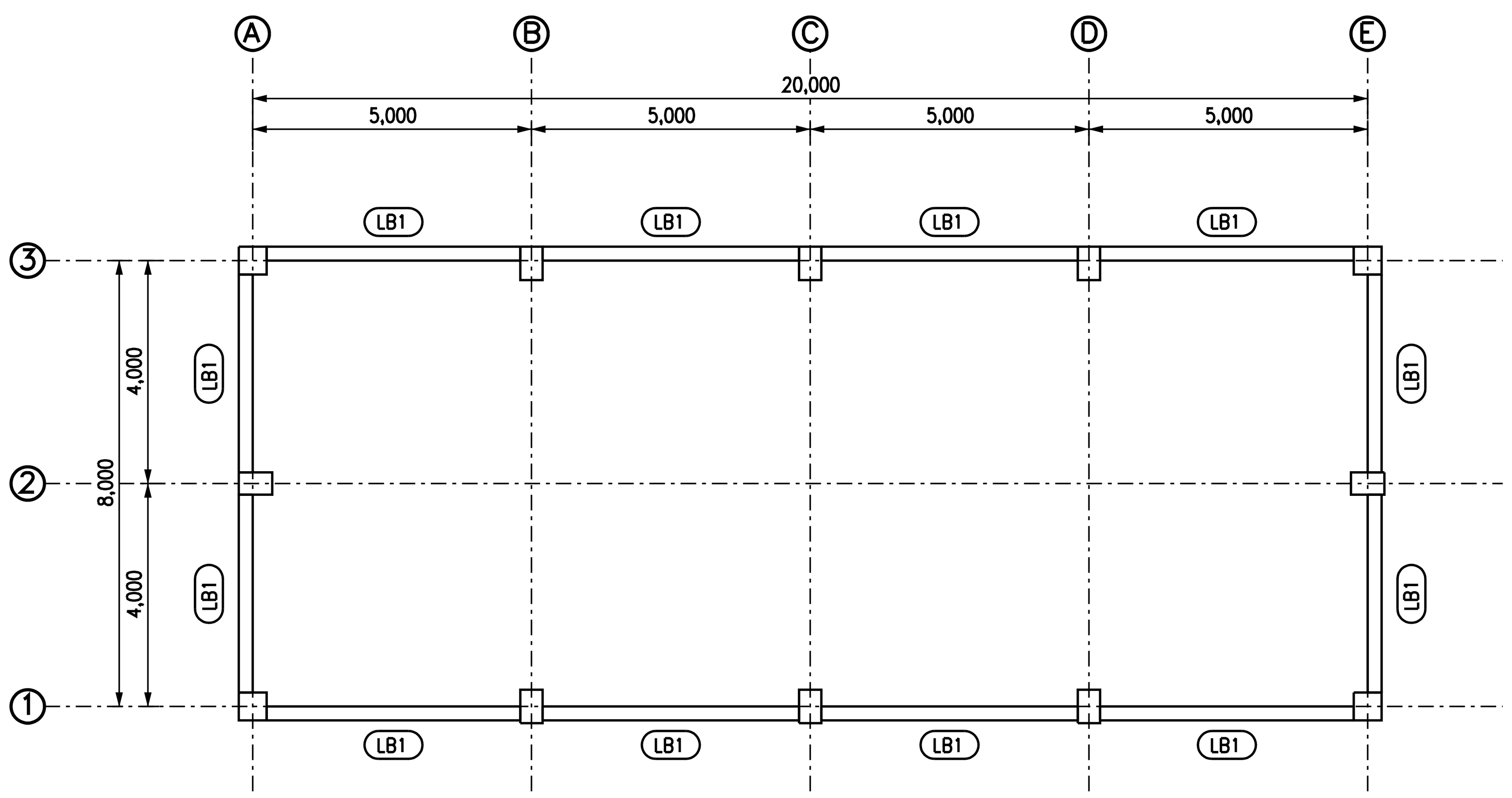
The structural details for beam, column and foundation have been attached.



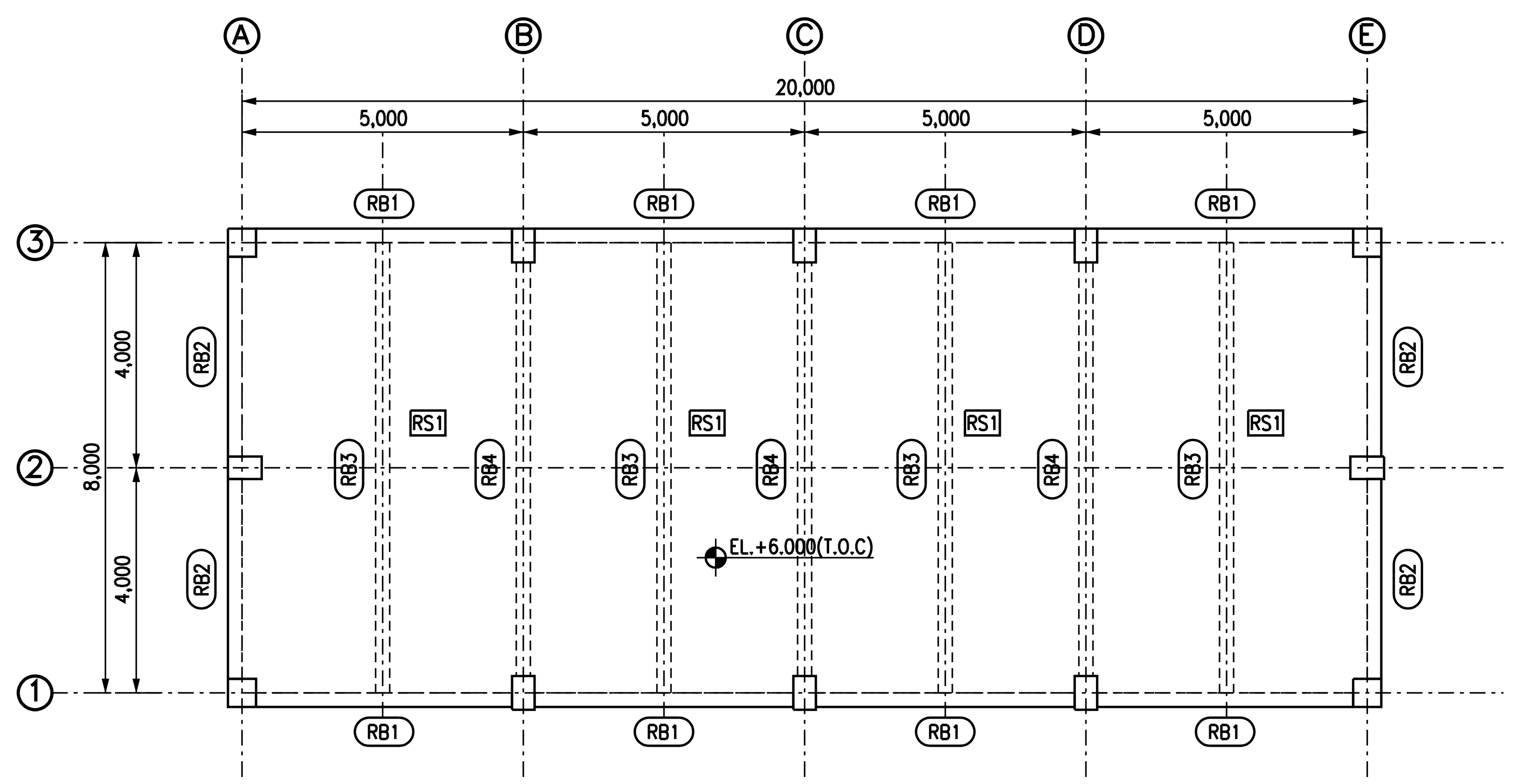
1 FOUNDATION, COLUMN AND TIE GIRDER ARRANGEMENT
SCALE 1:100



2 GRADE SLAB PLAN
SCALE 1:100



3 LINTEL LEVEL FRAMING PLAN
SCALE 1:100



4 ROOF FRAMING PLAN
SCALE 1:100

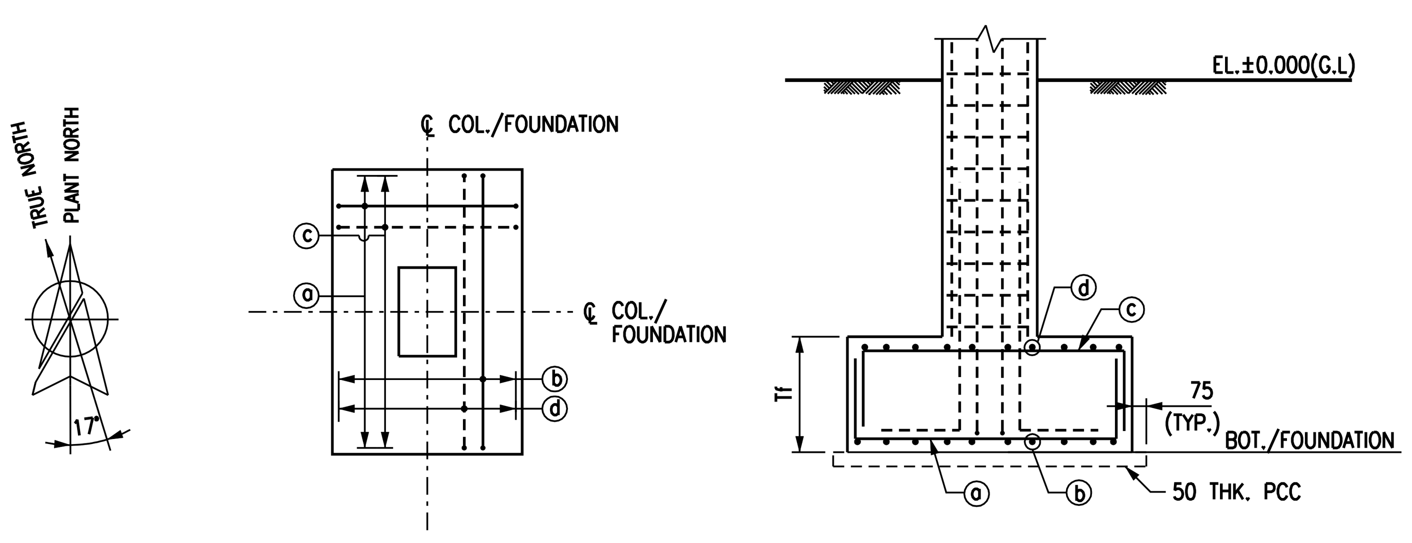
NOTES:

1. ALL DIMENSIONS ARE IN MM AND ELEVATIONS ARE IN M UNLESS OTHERWISE NOTED.
2. THE MINIMUM YEILD STRENGTH OF DEFORMED BAR IS Fy=415 N/mm^2
3. THE CHARACTERISTIC STRENGTH OF CONCRETE IS Fck=25 N/mm^2

Project					PC
	Date	Name	Scale	1/100	Type
Drawn	07-DEC-07		Title: STRUTURAL FRAMING PLANS		Contents Code
Checked	07-DEC-07				Reg.No
Approved	07-DEC-07				Rev.
Drawing No.					Page-No. 1 of 1

A1(841x594mm)

Drawing No



TYPICAL FOUNDATION DETAIL

NOTE : REINFORCEMENT AT BOTTOM LAYER OF FOUNDATION, LONGER SIDE BARS SHALL BE PLACED IN BOTTOM MOST LAYER

SCHEDULE OF FOUNDATION

FOUNDATION MKD	SIZE Tf	BOT./FOUNDATION	REINFORCEMENT DETAILS AT BOTTOM (a)	REINFORCEMENT DETAILS AT BOTTOM (b)	REINFORCEMENT DETAILS AT TOP (C)	REINFORCEMENT DETAILS AT TOP (d)	REMARKS
F1	350	EL.-3.000	16 @200	16 @200	12 @200	12 @200	
F2	450	EL.-3.000	16 @200	16 @200	12 @200	12 @200	
F3	400	EL.-3.000	16 @200	16 @200	12 @200	12 @200	

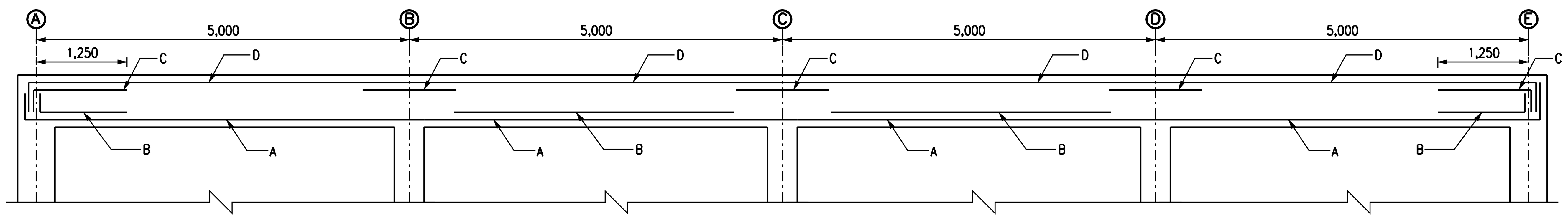
SCHEDULE OF COLUMNS

MARK	C1	C2	C3
SIZE	500 X 500	400 X 600	600 X 400
SECTION			
REINF.	8-25	16-20	8-25
TIES	8 @250	8 @250	8 @250

SCHEDULE OF BEAMS

	PB1	PB2	LB1	LB2	RB1	RB2	RB3	RB4
SIZE	250 X 600	250 X 450	250 X 600	250 X 450	250 X 700	250 X 700	250 X 700	250 X 700
SHAPE								
D	2-12	2-16	2-16	3-16	2-16	2-16	3-12	2-16
C	2-12	2-10	2-10	2-12	2-10	2-10	2-16	2-10
B	2-16	2-16	2-16	2-20	2-12	2-12	-	2-16
A	3-12	3-16	3-16	2-20	3-16	3-16	3-20	3-12
STIRRUP	8 @150	8 @150	8 @150	8 @150	8 @150	8 @150	8 @150	8 @150

LONGITUDINAL SECTION OF BEAM (RB1)



NOTES:

1. ALL DIMENSIONS ARE IN MM AND ELEVATIONS ARE IN M UNLESS OTHERWISE NOTED.
2. THE MINIMUM YEILD STRENGTH OF DEFORMED BAR IS Fy=415 N/mm^2
3. THE CHARACTERISTIC STRENGTH OF CONCRETE IS Fck=25 N/mm^2

Project					PC
	Date	Name	Scale 1/20		Type
Drawn	07-DEC-07		Title RE-BAR DETAILS		Contents Code
Checked	07-DEC-07				Reg. No
Approved	07-DEC-07				Rev.
Drawing No.					Page-No. 1 of 1

A1(841x594m/m)