

Computer Aided Structural Design of Multistorey Buildings

Pasala Dayaratnam and Nischala P. Dayaratnam

Indian Institute of Technology
Kanpur - 208 016, U.P., (INDIA)

KEYWORDS

Tall Buildings, Computer Aided Design, Data Generation, Trusses

ABSTRACT

A compact dedicated computer program for analysis and design of multistorey building frames, and industrial frames and sheds is presented. A pre-Processor, generates geometry of the frames, fixed and live loads at joints and on beams. Only the architectural information such as number of storeys, number of bays in each storey, width of the bays and offsets if any are to be read-in to generate the total geometry of the frame. Types of members, slabs, cross and longitudinal beams and walls are also to be read-in to generate the load distribution from beams and slabs. Numbering of joints and members, computation of fixed and live loads as per the codal recommendations and a banded stiffness matrix are generated with the least architectural data. The seismic model analysis is also carried out to give the seismic coefficients. The analysis for displacements is carried out for three basic load conditions namely fixed loads, live loads and seismic or wind loads. Any sets of load combinations can be preassigned to give the results of the combined load effects. There are several built-in control devices to control the input, output and the analysis. Separate subroutines are provided to do the design of members. A number of sets of friendly outputs can be called by the control devices.

Dessein de structure des bâtiments à plusieurs étages à l'aide de ordinateur

Pasala Dayaratnam and Nischala P. Dayaratnam

Indian Institute of Technology
Kanpur - 2080 016, U.P., (INDIA)

Key words

Hauts bâtiments dessein à l'aide de ordinateur, engendrer les données, fermes

Sommaire

On présente un programme à ordinateur, compact et dédié pour l'analyse et le dessein du châssis des bâtiments à plusieurs étages et d'halls industriels. Un pré-processeur engendre la géométrie des châssis, des charges fixes aussi bien que actifs aux joints et sur les flèches. Pour engendrer la géométrie totale du châssis on n'utilise que les informations architecturales telles que le nombre de bays à chaque étage, largeur des bays et des réssauts. On a besoin de connaissance de type des membres, des tranches, des flèches transversales et longitudinales et des parois pour engendrer la distribution de charge sur le châssis à partir de celle sur les flèches et les tranches. Le numérotage des joints et des membres, calcul des charges fixes et actifs selon les recommandations codifiées et une matrice bandée de rigidités sont engendrés à l'aide de très peu de données architecturales. L'analyse du modèle sismique a aussi été affectuée pour obtenir les coefficients sismiques. L'analyse pour les déplacements est affectuée pour trois cas de conditions de chargement, viz. charge fixe, charge actif et charge sismique c.à.d. charge à cause du vent. Une combinaison quelconque des charges peut être assignée pour obtenir le charge total désiré. Il y a plusieurs paramètres pour contrôler les données, l'analyse et les résultats. Une variété de sous-routines est fournie pour le dessein de différents membres. A l'aide du contrôle (des paramètres) on peut obtenir plusieurs résultants aimables.

INTRODUCTION

Use of digital computers in analysis of tall buildings has been in practice for decades. Many powerful general purpose computer programmes using finite element method have been developed and most of them are available for application to tall buildings. Meyer (1)⁺ in his paper describes different aspects of many of the general purpose programs such as SAP, FINITE, STRUDL, ADINA, NASTRAN, ANSYS, ASKA, BERSAFE, EASE, ELAS, MARC, NONSAP, SUPERB etc. These programs even though versatile and applicable to the analysis of tall building but they are not the direct methods to minimize the input information, and the computer CPU and memory requirements. Special purpose computer program dedicated to the analysis and design of tall buildings has some advantages besides that it can be used on mini-computer systems or even on micro-computers in case of not so tall buildings. Structural design is often code dependent therefore, the dedicated programs can easily be updated to the changing needs of the national codes.

Tall buildings have rectangular bays, a set of types of loads and load distribution along the floors and bays for the purpose of analysis. A limited number of types of members based on architectural and practical considerations can be used in the dimensions, even if the number of members is large.

ORGANIZATION OF THE COMPUTER PROGRAM

The computer program and the developmental work consists of the following phases :

- (a) Idealization of the building into ordered plane frames,
- (b) Generation of frame geometry, numbering of the nodes and members and member connectivities,
- (c) Identification of member types,
- (d) Generation of banded stiffness matrix,
- (e) Seismic Coefficient analysis,
- (f) Generation of loads at joints and on beams, and special loads if acting,
- (g) Frame analysis for displacements under basic loads,
- (h) Load combinations and force analysis,
- (i) Equilibrium check from backward substitution and total load computations,
- (j) Choice of friendly outputs and
- (k) Member design subroutines.

Computer program even though can handle a spatial structural analysis, the size of the banded stiffness matrix is going to be large even for 20 storey and 4 bays buildings. Such a largematrix cannot be handled directly by most of the computers presently

⁺ The numerals in the paranthesis refers to the reference numbers given at the end of the paper.

available in India. Further the three dimensional analysis may not be needed for a many multistorey structures. Hence this program is developed for idealized plane frames rather than spatial ones. However, a modified version of this program is available for checking the member forces in the spatial situation.

PRE- PROCESSOR

Numbering of joints and members, member connectivities and the digram for the frame are developed by a program using the architectural data. Joint and member locations with respect to the floors are also developed. In case, the height of all the floors is same and similarly the width of all bays is same then one has to read in only four quantities namely number of floors, number of bays and height and width of the bays. In majority of the buildings there are many variations, such as height of floors need not be same or number of bays could be different and so on with different combinations. Fig. 1 illustrate a flow chart of this subroutine.

ELEMENT TYPES

Sizes of the following members or elements are needed either for load computations for structural analysis :

- (a) Frame members; Beams and Columns;
- (b) Slabs,
- (c) cross beams from either side,
- (d) Cross walls, and
- (e) Longitudinal walls.

The loads from all these elements have to be computed and transferred to the appropriate joints or beams. Instead of reading the sizes of all the members and elements, all of them are grouped into a number of types and are identified by member type. There may be several hundred members in a building, but when they are grouped into types, then the number of types reduces to only a fraction of the number of members, walls, slabs etc. It is far easier to read integer numbers corresponding to the member types and further, any modification if needed in the design, it can be affected easily. Dimension requirement is also reduced considerably. The sizes of the basic types can be read in either in widths and depths in case of rectangular sections or areas and inertii in case of rolled sections; thickness in case of slabs and walls.

GENERATION OF LOADS

Four basic types of loads are generated and they are :

- (a) Dead loads from elements such as beams, columns, cross beams, walls and slabs on to joints and beams,
- (b) Live loads from slabs on joints and beams,
- (c) Special loads such as lift, water tanks etc. are read in and
- (d) Seismic coefficients.

A subroutine generates the dead and live loads separately and distributes them to the appropriate joints and beams. Further it also computes the seismic loads from the seismic coefficients and load factors in the seismic load combination. All the loads are then classified into three basic loads namely :

- (a) Dead loads,
- (b) Live loads and
- (c) Seismic loads.

A small subroutine computes the total basic loads in each direction and lists them so as to have an equilibrium check, and a comparison from backward substitution. The load computation, member generation, member type notations are some of the strong points of the program.

STRUCTURAL ANALYSIS AND DESIGN

The structural analysis is of standard stiffness method using properties of member types and semi-band inverse subroutine. Analysis is carried out for the three basic load conditions and the corresponding deformations are stored for different load combinations. The joint deformations are suitably combined with appropriate load factors to obtain the member forces in each load combination. The program is designed both for frame and truss analysis. Separate subroutines for design of RCC elements and different type of steel members both for frames and trusses are developed incorporating the codal provisions.

CONCLUSIONS

There are variety of computer programs exist for analysis and design. The present program may appear similar to some of the existing programs but it aims at the following :

- (a) Use of minimum possible memory space to enable even the mini-computers to solve reasonably large problems. Small consulting offices can solve the problems on their computers and not be burdened by computer charges.
- (b) Input data, often causes boredom and typing errors leading to unnecessary problems. The program minimizes the input data to the barest minimum based on architectural dimensions. Further it also provides for wider spectrum of architectural and structural specifications.
- (c) The dimensional requirement is also optimized by assigning integer numbers to members and then inter-relating to sets or types of members.
- (d) Read in control devices enable the preparation of input data to suit a number of problems. In case of rectangular sectioned elements which are common in RCC construction, one can read in only the sizes of the types of members, whereas in case of rolled sections, areas and inertii can be read in. Similarly print out has options of printing either sizes or actual areas etc.
- (e) The program even though code biased but not code dependent.

One has to read in the coefficients or intensities of loads from the code. Computation of loads and their distributions are generated automatically as per the input codal coefficients. The program has dimensional independency in analysis, input and output.

- (f) Several check read in data at critical locations is provided with error messages. In case the input data is inadequate or wrongly typed, the program will type or write messages about the error in the input and exit without going further beyond the error. The program types out some messages during the execution giving an indication of the stage of processing and also some critical check values.
- (g) Reverse equilibrium check of the analysis is also carried out from the final result. The analysis is carried out for basic loads and the final results are of the load combinations. Beginning from the final members forces, the equilibrium at all joints is verified. The total reactions of the supports are also cross checked with the total loads generated earlier. Weight of members and load per floor area are also printed for quick reading of the design efficiency.
- (h) Friendly and versatile outputs is one of the aims of the program. There are six output control devices to enable the program to printout detailed generated input and or results of the basic load conditions and or the combined load analysis or a limited output with or without displacements or suppressing information of some member of not of much importance etc. In case of large frames, the number of members are too many and printing, pages after pages will be of no use. The printout is arranged floor wise with identification of floors loads etc. along with member forces and the sizes. The formats are beautifully arranged with complete descriptions easy to read and explanatory notes.
- (i) The program can also handle design of roof trusses in which typical roof truss geometries are generated along with loads. Here again only the dead, live, wind and permeability coefficients can be read from which the total analysis carried out.
- (j) Many structures such as multistorey offices, apartment and commercial buildings, TV and microwave towers and industrial buildings were designed and constructed based on this program. It is well tested not only for accuracy but also versatility and friendliness.

REFERENCES

1. C. Meyer, "Computer Analysis and Design of Structures", J. Tech. Div. ASCE, V 107, No. TC 1, PP 73-94 (1981).
2. P. Dayaratnam, "Users Manual on Computer Aided Design of Tall Buildings", IIT Kanpur, (1984).

NOTE

Some structures either analysed or designed by the program are :

(Acknowledgements are due to them)

- (a) Multistorey buildings : (1) Water Works Building at Kanpur for UP Jal Nigam, (2) Judge Court Building at Kanpur for UPRNN, (3) Megdoot Hotel extension at Kanpur, (4) Yojana Bhavan at Lucknow for FWD, (5) Chitwapur Commercial Complex at Lucknow for Lucknow Development Authority (LDA); (6) La-Place Apartment Tower for LDA, (7) Kailash Kunj Commercial Complex, Lucknow for LDA.
- (b) Towers : (1) TV Towers at Kanpur, Lucknow, Madras, Hyderabad Bangalore, Calcutta and Missoorie for Triveni Structural Ltd. Allahabad, (2) Microwave Tower for P&T department (3) Oil Rig Mast for BHEL, Hyderabad, (4) 75t Crawler Crane Boom 50' X 150' for Hindustan Motors, Calcutta.
- (c) Industrial Buildings and Sheds : (1) Converter Building, Bookaro Steel Plant, (2) Catalyst plant and Uria Storage Shed for IEL Ltd. Kanpur, (4) Sheds for Vijay Engineering Works Kanpur and (5) Factory Buildings.
- (d) Narainpur Pumphouse in Ganges River (25m below HFL) for UP Irrigation department.

APPENDIX A : PROGRAM CAPABILITIES AND CONTROLS

(A) READ IN VARIATIONS : PREPROCESSOR

- (1) Geometry of Multistorey Frames or Trusses or Frames :
- Generates for standard type of trusses and all Multistorey frames,
 - Read if the trusses are odd shape or Gable frames,
- (2) Member classification or properties :
- Into types,
 - Sizes (width and depths), or area or inertia,
 - For trusses read : Segments, size, shape, thickness, etc.
 - For truss design read shape.
- (3) Loads :
- Generate : Dead, Live, Wind or Seismic loads and read special loads in Multistorey and standard roofs,
 - Read : Loads in odd trusses and Gable frames.

(B) MAIN PROGRAM

- Analyse for basic loads or sets of load combination,
- Design members.

(C) OUTPUT VARIATIONS

Any combination of the following outputs can be called for :

- Vital dimensions and specifications,
- Member weights etc.

- Weight of members and loads per unit plinth, total loads,
- Generated or read in geometry shape and details,
- Generated or and read in loads,
- Joint Information : coordinates, loads, displacements in each basic load or load combinations,
- Member information in each basic load or load combination: location, type, size, properties, joint forces including mid span moments & loads, slenderness, stress etc.
- Equilibrium check : From backward substitution, the equilibrium of joints and reactions.

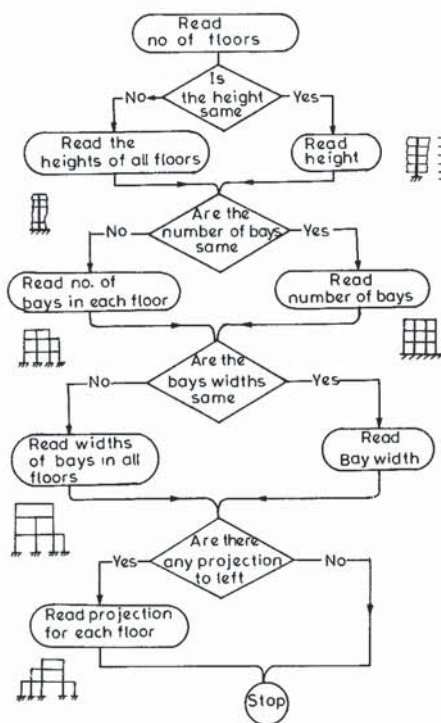


Fig.1 Typical flow chart of a preprocessor