DESIGN OF R.C.C. BUILDINGS USING STAAD PRO V8i
WITH INDIAN EXAMPLES

STATIC AND DYNAMIC METHODS

T.S. SARMA
Design of R.C.C. Buildings using Staad Pro V8i with Indian Examples
Utmost care has been taken to avoid mistakes and errors in this book. But some human errors may still be present in spite of vigorous checks. The author has no responsibility on the correctness of reader’s own designs, done as per the procedures explained in this book. The reader should confirm the correctness of his/her designs on his/her own before implementation. Readers are advised to get their designs and drawings checked by experienced structural engineers initially. The author will not spare his time to explain the doubts to the readers of this book. However, the readers and experts may give suggestions for improvement of the book. The opinions/ contents expressed in this book are solely of the author and do not represent the opinions/ standings/ thoughts of Educreation.
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Static and Dynamic Methods

By

T.S. Sarma

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Preface

This book is intended to be read by Indian students who want to learn the structural design of R.C.C. Buildings as per Indian codes.

Initially, the author thought of writing a book covering most of the topics in design such as underground, and overhead water tanks, industrial sheds with and without cranes, pipe racks, watch towers etc., But it seems that writing such a book takes lot of time and it becomes voluminous also. The cost of the book also would be far reach of Indian students. So, it is felt that, writing books covering only specific areas found to be more convenient than writing a single book covering all the topics. In this series, the author’s next book will be on design of steel structures which covers industrial sheds with and without cranes. The portal type and truss type structures will be included.

In this book, the analysis and design procedure of RCC framed structures, is explained by taking a practical example such that it will be understood very easily by the learners. The details of load calculations, load combinations etc., have been explained with reference to code provisions. Most of the practical aspects are discussed such that the reader will learn the design of Reinforced Concrete Buildings in most practical way and can develop confidence to practice.

Both static analysis and dynamic analysis methods have been covered in this book. The difference between static analysis and dynamic analysis was discussed with same example problem, such that the reader can understand the difference easily.

I sincerely thank my wife T. Sudha, and my daughter T. Tejaswi for assisting and encouraging me in writing this book. I thank A. Sulochana, my junior, for assisting me in preparation of drawings and images in this entire book. I also thank my internship students M.K.J. Bhavani, S. Sridevi, Sk. Shahanaz from Rajiv Gandhi University of Knowledge and Technologies, Nuzvid, A.P for participating in composing of two chapters in this book. I thank my engineering classmates for their sustained encouragement and for their advices.

Author
Dedicated to my eldest brother

T. Venkateswarlu

Former Vice-President
Mysore Petrochemicals
Raichur
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Chapter 1
Introduction

Topics covered in this chapter

- Scope of the book
- Staad environment
- Global Coordinate System
- Local Coordinate System
- Geometric Modeling
- Staad input file system
- Methods of analysis
Staad Pro V8i is the world’s most popular and reliable structural analysis and design software which was accepted and approved by many countries. This is well known for its 3D model generation and multi-material design. It is a versatile software for design of RCC and steel structures. This software is developed by Research Engineers Intl Headquarters, Bentley Solutions Center, USA. The author of this book assumes that the reader already knows the software content and commands. So detailed steps were not presented regarding software. Anyhow it is more relevant to touch some fundamental aspects of the software. In case of problems with the software commands application, the designer can approach the support center. The details of support centers can be viewed in Help menu in software. The help desk support will be available only after purchasing the license from Bentley.

The readers, who do not have the knowledge of software content and commands, are advised to go through the book “Staad Pro V8i for beginners – with Indian Examples” by this author, to learn the process of creating a geometrical model, applying loads, analyzing and getting design results.

For understanding the Indian code provisions, code references were provided at appropriate places. The readers are advised to refer and go through the mentioned clauses, understand them clearly before applying in Staad model.

Staad Environment
It has a powerful user-friendly GUI, Graphical use interface, visualization tools and analyzing and design facilities. There are basically two modes—Modeling and Post processing. The post processing mode will be active after the analysis only. There are some other modes called Interactive Design Mode, Bridge Deck Preprocessor and Page control. Only modeling and post processor modes are in the scope of this book.

Global Coordinate System
Most important thing in Staad Pro is to understand the coordinate system. There are different coordinate systems. There are 3 axes in the global coordinate system. By default the vertical axis is Y axis as shown in figure 1-1. We can change the Z axis as vertical axis if necessary.
Local Co-ordinate System

One more coordinate system which is associated with each member is called the local coordinate system. This system will also have 3 axes. The member’s self axis is fixed always as X axis. The following figures show how Staad considers the local axes.
The Staad Screen has four major parts as shown in figure 1-2:

**Menu bar** in the top of the screen. Just below that few rows are occupied by **tool bar**. Middle white part of the screen is the **main window**. **Page control** command buttons are arranged in the left by default and the right part of the screen is known as **Data Area**. The details of each item are explained in Staad pro help in: Technical reference: Overview of Staad environment: Staad Pro screen organization.

**Geometrical Modeling**

Geometrical model can be created and loads, conditions can be applied in two ways. First one is by using Command file and the second one is by using **GUI** (Graphical User Interface).

The command file looks like text file and contains commands and data. This command file can be created by directly typing in Staad input editor, or it can be first created in any text editor like Notepad, wordPad or MS word.
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In the graphical method of model creation, graphical tools are utilized in modeling mode. Assigning material properties, creation and applying loads etc., can be done through GUI using different menus and dialogue boxes of the mode.

The model shown in figure 1-3, can be created by typing the text given in the box.

Notes:
- It is general practice to call columns and beams as BEAMS in staad except in design commands.
- Nodes are termed as JOINTS in input file
- Beams and Columns are termed as MEMBERS in input file.

Figure 1-3

```
STAAD SPACE
START JOB INFORMATION
ENGINEER DATE 28-Sep-08
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
1 0 0 0; 2 0 5 0; 3 6 5 0; 4 6 0 0; 5 0 0 8; 6 0 5 8; 7 6 5 8; 8 6 0 8;
9 3 5 0; 10 3 5 8; 11 6 5 4; 12 0 5 4; 13 3 5 4;
MEMBER INCIDENCES
1 1 2; 2 2 9; 3 3 4; 4 5 6; 5 6 10; 6 7 8; 7 3 11; 8 2 12; 9 9 3; 10 10 7;
11 11 7; 12 12 6; 13 9 13; 14 12 13; 15 13 10; 16 13 11;
DEFINE MATERIAL START
ISOTROPIC CONCRETE
E 2.17185e+007
POISSON 0.17
DENSITY 23.5616
ALPHA 1e-005
DAMP 0.05
END DEFINE MATERIAL
MEMBER PROPERTY INDIAN
1 TO 12 PRIS YD 0.6 ZD 0.3
13 TO 16 PRIS YD 0.3 ZD 0.3
CONSTANTS
MATERIAL CONCRETE ALL
SUPPORTS
1 4 5 8 FIXED
LOAD 1 LOADTYPE None TITLE DEAD LOAD
SELFWEIGHT Y -1 LIST 1 TO 16
FLOOR LOAD
YRANGE 4.9 5.1 FLOAD -50 GY
PERFORM ANALYSIS
FINISH
```
Staad Space

Figure 1-4

The use of commands is explained with same Staad input file.

**STAAD SPACE**
The above line shows that the structure is a space frame or a three dimensional structure.

**START JOB INFORMATION**
**ENGINEER DATE 28-Sep-08**
**END JOB INFORMATION**
The above lines give the job information like name of the engineer, date of creating of file

**INPUT WIDTH 79**
It defines that the width of input file is 79. If any text is available after 79 columns, it will be ignored by Staad Pro. However it gives error message while running the file.

**UNIT METER KN**
The above line implies that the force units are defined as Kilo Newtons and length units as Metres.
JOINT COORDINATES
1 0 0 0; 2 0 5 0; 3 6 5 0; 4 6 0 0; 5 0 0 8; 6 0 5 8; 7 6 5 8; 8 6 0 8;
9 3 5 0; 10 3 5 8; 11 6 5 4; 12 0 5 4; 13 3 5 4;

There are four numbers in each set. First number represents node number and second, third, fourth numbers are X,Y,Z co-ordinates of that node respectively. Each set of numbers are separated by a semi-colon.

Note that Joints and Nodes are same.

MEMBER INCIDENCES
1 1 2; 2 2 9; 3 3 4; 4 5 6; 5 6 10; 6 7 8; 7 3 11; 8 2 12; 9 9 3; 10 10 7;
11 11 7; 12 12 6; 13 9 13; 14 12 13; 15 13 10; 16 13 11;

There are three numbers in each set. First number represents beam number, second and third numbers represent starting and ending nodes of that beam. Each set of numbers are separated by semi-colon.

DEFINE MATERIAL START
ISOTROPIC CONCRETE
E 2.17185e+007
POISSON 0.17
DENSITY 23.5616
ALPHA 1e-005
DAMP 0.05
END DEFINE MATERIAL

In the above lines material properties are defined. Material is defined as isotropic concrete with Elastic modulus $2.17185 \times 10^7$ kN/m$^2$.

[Code reference: As per clause 6.2.3.1 of IS 456-2000, the Elastic Modulus of concrete is given by $E_{c,con} = 5000 \sqrt{f_{ck,con}}$ Where $E_{c,con}$ Elastic Modulus in N/mm$^2$ and $f_{ck,con}$ characteristic strength of concrete in N/mm$^2$. The calculated value can be substituted for the default value]

The next lines assigns the value of Poissons ratio as 0.17, Density as 23.5616 kN/m$^3$, Coefficient of thermal expansion as $1 \times 10^{-5}$, Damping Ratio as 0.05 (or 5%) and the last line represents end of material definition.

MEMBER PROPERTY INDIAN
1 TO 12 PRIS YD 0.6 ZD 0.3
13 TO 16 PRIS YD 0.3 ZD 0.3

0.6m x 0.3m prismatic section was assigned to beams 1 to 12
0.3m x 0.3m prismatic section was assigned to beams 13 to 16.
CONSTANTS
MATERIAL CONCRETE ALL
Material concrete was assigned to all structural members. (Beams and Columns)

SUPPORTS
1 4 5 8 FIXED
Fixed supports were assigned to nodes 1, 4, 5 and 8.

LOAD 1 LOADTYPE None TITLE DEAD LOAD
Load 1 was named as Dead Load

SELFWEIGHT Y -1 LIST 1 TO 16
Self weight was applied to members from 1 to 16. Y Represents vertical axis and the minus sign represents downward direction.

FLOOR LOAD
YRANGE 4.9 5.1 FLOAD -50 GY
Floor load was applied to the floor which is in 4.9m to 5.1m height range. 50 kN/m² floor load was applied vertically downwards. GY represents global Y axis and minus sign represents downward direction.

PERFORM ANALYSIS
The above command performs the analysis.

FINISH
This command implies the end of the project.

There are different methods of analysis with static and dynamic loads. Static loads varies very slowly and the acceleration of the load is negligible. Loading due to earthquake on a given structure induces ground motions, defined as a variation in the ground acceleration, resulting in inertial forces acting on the masses of the structure. Those forces depend on the characteristics of the structure, earthquake and other geological factors. To design a structure capable to withstand the effect of an earthquake, the forces acting on the structure must be specified. However, each earthquake can lead to different type of ground motions and acceleration even within a same site, the resulting forces which will affect the structure within a given prone seismic region cannot be specified accurately. The simplest way to estimate the maximum forces is using the “equivalent static lateral force method even though its uses are limited by various conditions in this method. A seismic coefficient is applied to the mass of the structure to produce the lateral force that is approximately equivalent in effect to the dynamic motion of the expected earthquake. A dynamic analysis is relied on inertia force developed by a structure when subjected to dynamic loads applied suddenly (ex: wind, earthquake) Dynamic loads change quickly with time. The structural response needs to be calculated at every time instant in comparison to the structure natural frequency.
Pseudo Static Method

This method is a combination of static and dynamic method of analysis in which both static and dynamic seismic loads are applied. As we observe the deflection in both the methods, the deflection in static methods is more than that of in dynamic method. In fact the static loads are not generally applied in combination loads. The static loads are used for measuring maximum deflection.

The general format of the Pseudo static method is
1. Pseudo static load is X direction
2. Pseudo static load Z direction
3. Dead load
4. Live load
5. Other load 1
6. Other load 2
7. Other load 3
8. Other load 4

Load combinations.

Analysis

Design

The scope of this book is to explain the procedure to design Reinforced Concrete buildings with earthquake loads as per IS 1893 (Part 1) -2002/2016. The IS 1893 (part1) has been revised recently. But the procedure adopted in Staad will be similar. In addition to the normal dead loads and live loads, earthquake loads are considered in design. The earthquake loads referred to as short term loads as they exist for very short period on any structure. Note that the procedures explained in this book are some of the methods available and the reader may try other methods also.

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This book is intended to give a basic knowledge of design of R.C.C buildings using Staad Pro V8i, to those who already have some knowledge in working in this software. This is highly useful for Civil Engineering Students who want to develop design skills in R.C.C. by using Staad Pro. Indian Code references were given where ever necessary and many snapshots of working example are inserted in almost every page of the book so that the reader can understand easily. This book is highly suitable for Indian Civil Engineers, as all the examples are in Indian Code methods. This will greatly benefit practicing engineers and students in India as this is the first detailed book on R.C.C building design using Staad Pro, with Indian Examples. Static method and Dynamic method of analysis has been explained by taking the same example problem, so that the reader can understand the differences in those methods.

About the author
The author has vast experience in designing concrete and steel structures. He has worked in various Indian and multi-national companies, where he was involved in the design of power plant structures, refineries, commercial buildings etc. Now he is the chief advisor to a structural design company in Andhra Pradesh and deals with design projects.

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