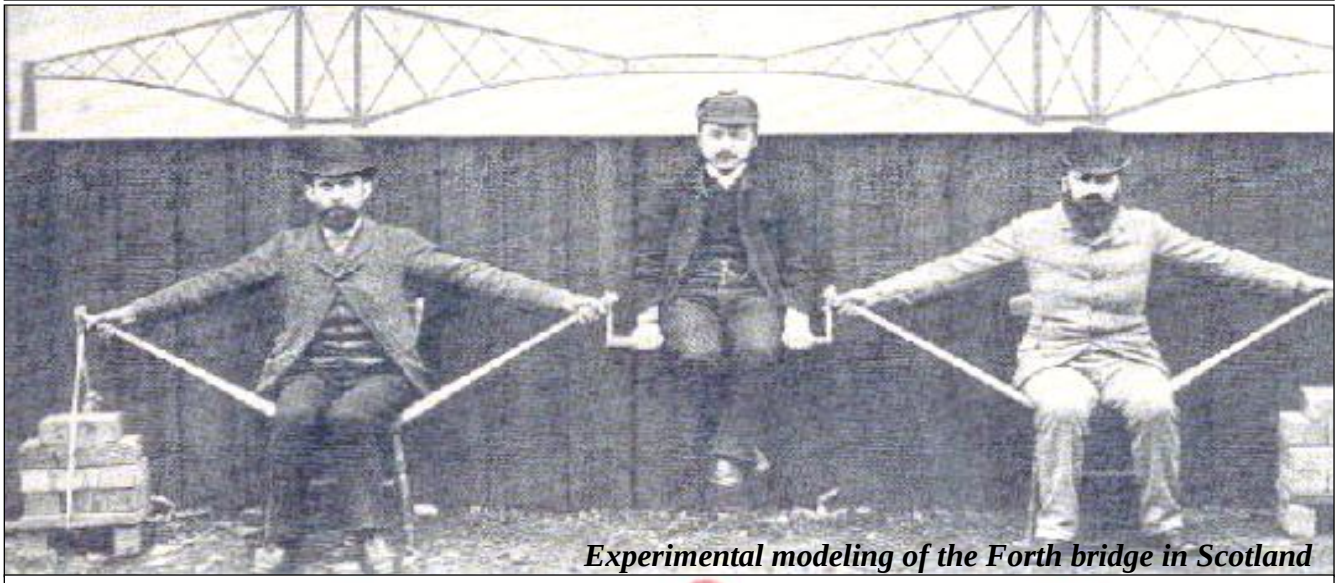
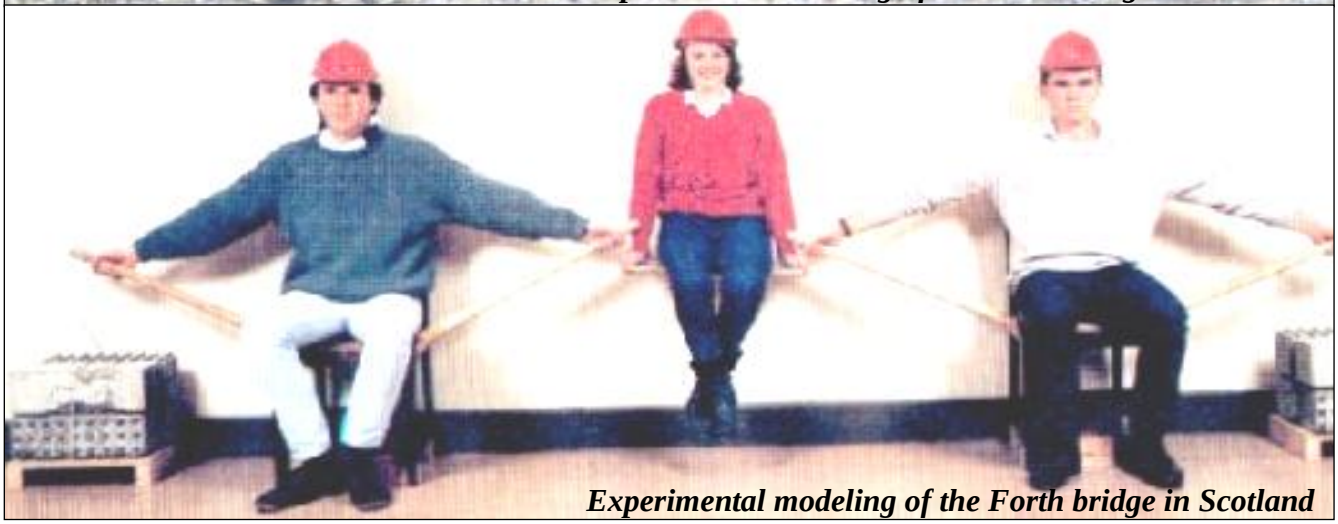
Chapter 1



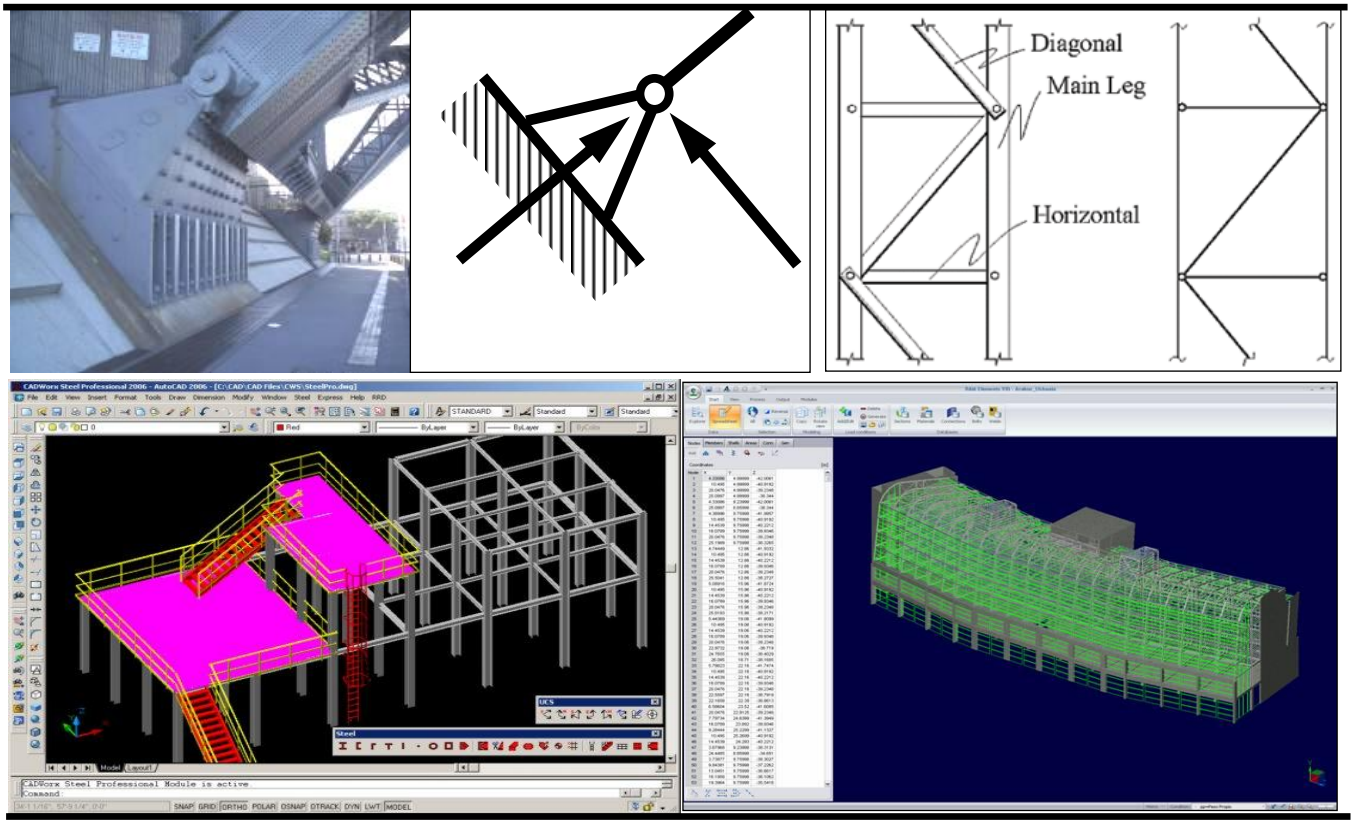
Experimental modeling of the Forth bridge in Scotland



Experimental modeling of the Forth bridge in Scotland

Introduction to Structural Modeling

Experimental models

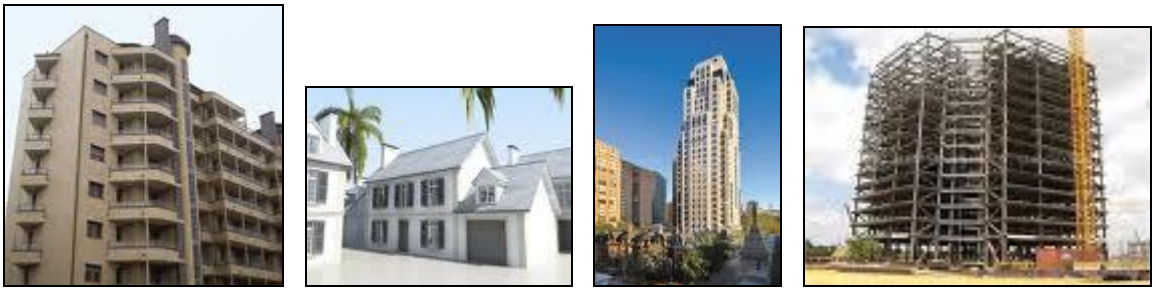


Theoretical models

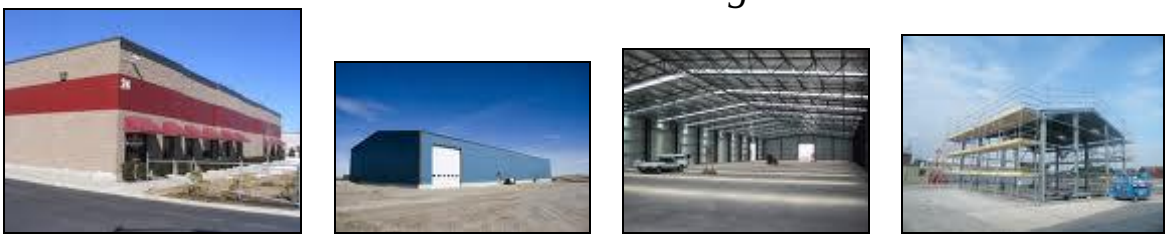
Chapter 1
Introduction to Structural Modeling

1.1 Introduction

A *structure* can be defined as a rigid body that resists external effects (e.g.; loads, temperature changes and support settlements) without excessive deformation. Typical structures such as residential buildings, industrial buildings, halls, towers, bridges, dams, tanks, channels and pavements are of interest to civil engineers (Fig.1.1). Airplane, missile and satellite structures are of interest to the aviation engineers. Ships are interesting for a naval engineers. A machine engineers should be able to design machine parts.



Residential buildings



Industrial buildings

Halls

Figure 1.1 *Civil engineering structures*

Towers

Bridges

Dams

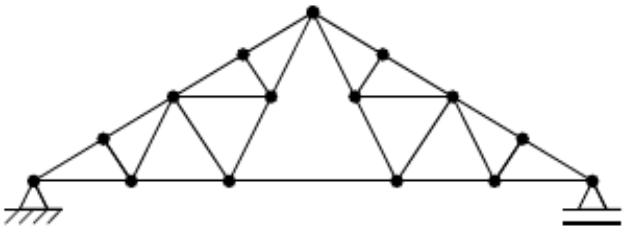
Tanks

Channels

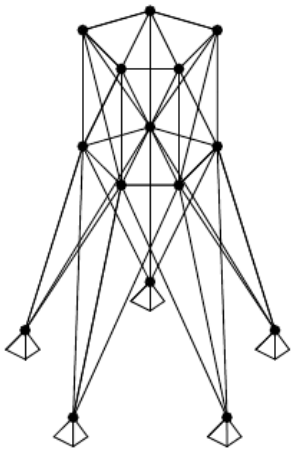
Pavements

Figure 1.1 *Civil engineering structures (Continue)*

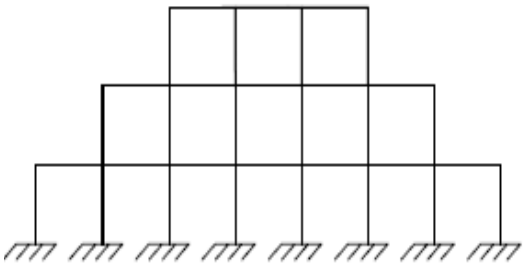
A structure can also be considered to be an assemblage of members and nodes. Structures with clearly defined members are known as *skeletal structures*. Planar and space frames, planar and space trusses, single- and double-layer grids are examples of skeletal structures (Fig.1.2).



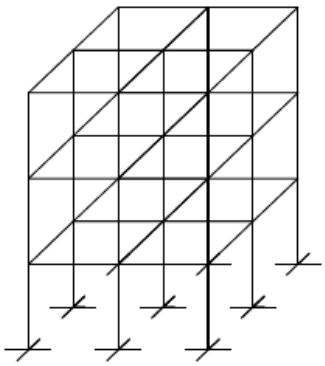
(a) Planar truss



(b) Space truss

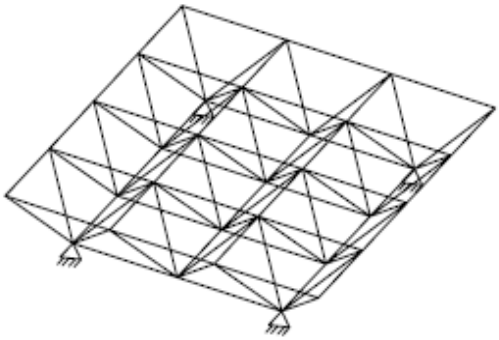


(c) Planar frame



(d) Space frame

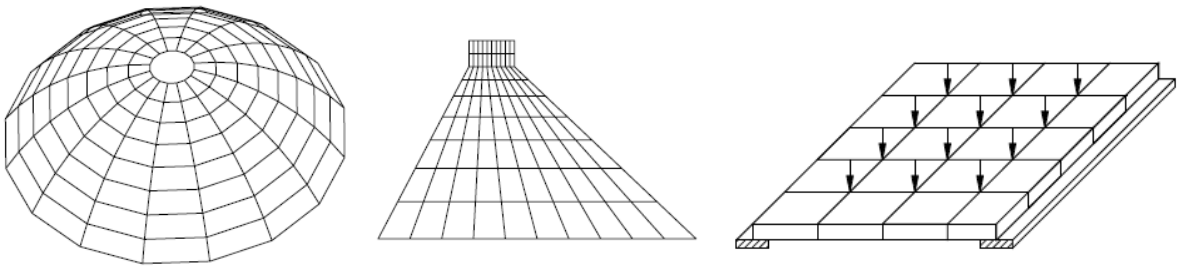
(e) Single-layer grid



(f) Double-layer grid

Figure 1.2 *Examples of skeletal structures*

Structures that may be artificially divided into members (elements) are called *continua*. Concrete domes, dams, plates and pavements are examples of continua; see Figure 1.3.



(a) Dome *(b) Dam* *(c) Plate*

Figure 1.3 *Examples of continuum*

Structural analysis is the determination of the response of a structure to external effects such as loads, temperature changes and support settlements. *Theories of structure* may be classified from different points of view as follows: static or dynamic, and if static, statically determinate or statically indeterminate, planar or space, linear or non-linear. Only, linear static analysis of statically determinate structures will be discussed here.

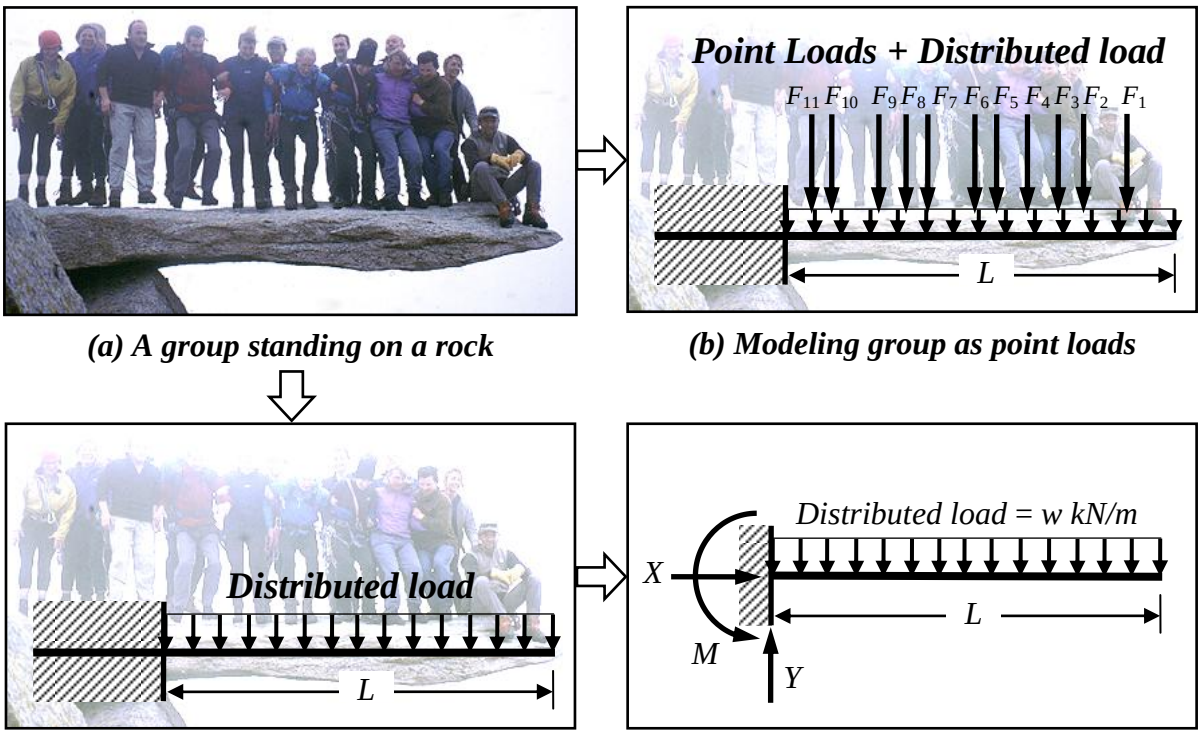
Structural design is the selection of a suitable arrangement of members, and a selection of materials and member sections, to withstand the stress resultants (internal forces) of a specified set of loads, and satisfy the specified displacement constraints.

In this book, basic definitions, concepts and theorems of structural analysis are presented. The solution to the basic equations of the theory of structures and the analytical determination of the distribution of internal forces, under static and moving loads will be discussed in the next chapters.

1.2 Free-body diagram

The free-body diagram (FBD) is an aid for solving structural problems. It is a graphic representation of the structure (structural element or segment of an element) in which all connecting parts have been removed. In this diagram a structural element is represented by a line. Each connection is represented by a node or joint with certain properties (type of fixation and a set of forces and moments) which represent the action at that connection. Internal forces which would be found at the nodes can be replaced by external forces where that structural element connects with the other parts. Loads are represented as force systems.

The following example illustrates how to convert a real problem to structural problem and analyze it. The aim of analysis is the determination of the reactions at the fixed end for the rock carrying a group of people shown in Fig.1.4a that acts as a cantilevered beam.



(a) A group standing on a rock ***(b) Modeling group as point loads***

(c) Modeling group as a distributed load ***(d) Free-body diagram***

Figure 1.4 *Free-body diagram of a rock*

To convert a real problem (the rock that carrying a group of people, Fig. 1.4a) to a structural problem you should know the following.

- **Properties:** The first step is to identify the necessary properties (especially weights) of the rock and people.

- **Drawing center line:** identify the center of the rock and draw it (straight line in this case).

- **Representation of loads:** The loads applied on the rock are the rock weight itself and the weight of the people, the rock weight is represented (drawn) as a uniformly distributed load while the weight of the people is represented as point (concentrated) forces as indicated in Fig.1.4b. Or as shown in Fig.1.4c, the weight of rock and people together is represented as a uniformly distributed load (this is an approximation to reduce the calculation).

- **Supports:** The rock is cut from its fixation place and replace it with the forces that were supporting the beam at that fixed end before it was cut.

- **Determination of reactions:** The next step is to determine the unknown forces required at the support to maintain equilibrium. These unknown forces (*X*, *Y*, and *M* in Fig.1.4d) are the internal forces in the rock at the fixation place. They can be determined by applying the principles of equilibrium on the free-body diagram.

The above problem shows the need to know the types of loads acting on the structures and how to represent them in the free-body diagram. Also the need to know how the structural elements are supported and the types of supports.