Chapter 1

INTRODUCTION TO STRUCTURE

Bambang Prihartanto;
Shahrul Niza Mokhatar

1.1 STRUCTURE & STRUCTURAL ANALYSIS

- A structure is defined to a system of connected/fabricated parts used to support a load or creature's activities. Eg; building, bridge, towers, ship, tanks, aircraft frames, ___________________________________.

- The area of structural engineering should cover four important aspects :
  - Planning
  - Analysis
  - Design
  - Construction

- Process which included the 4 above aspects named as STRUCTURAL / ENGINEERING DESIGN.

- When designing a structure, the engineer must account for its :
  - Utility / Serviceability
  - Safety
  - Economy / Cost
  - Aesthetic / Beauty
  - Material / Available
  - Environmental Constraints

- Thus, structure can be defined as a part of construction which has one or more element is subjected to various loads that it must resist without either collapsing or deforming excessively

1.2 STRUCTURAL FORM & TYPES OF STRUCTURE

A. Tension & Compression Structure

- column, strut (compression)
- cable-supported structure (tension)
- arch (compression)
- truss (compression & tension)

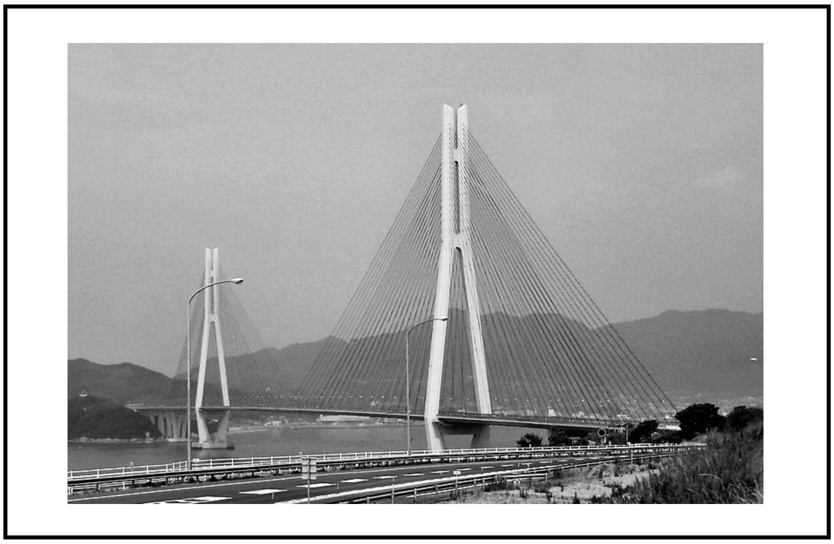


Figure 1.1: Tatara Ohashi Bridge,Japan

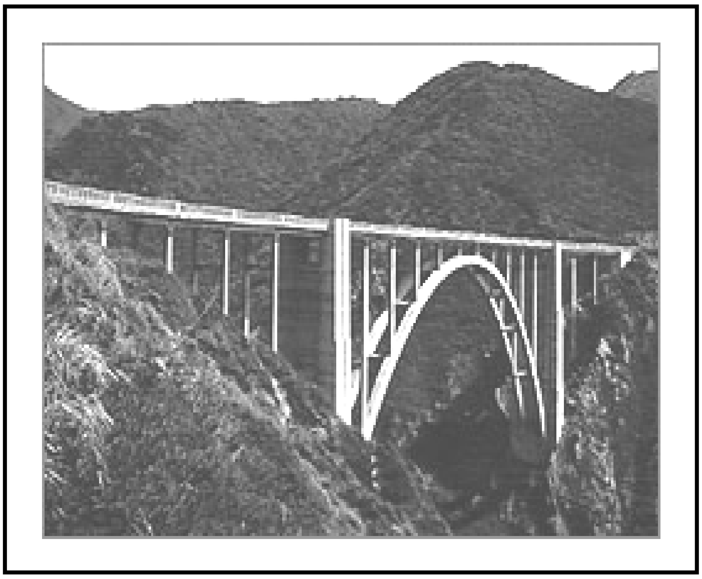


Figure1.2: Arch Bridge Bixby Creek, Monterey, CA.

- Figure1.2 shows the arch bridges are one of the oldest types of bridges and have great natural strength.

B. Flexural Beam & Frame Structure

- beam
- frame
- combination structure (bridges, building)

C. Surface Structures

- slabs
- folded plates
- shells
- domes
- skin-type structures
- inflatable members

Figure 1.3: Millenium Dome, England.

- Figure 1.3 shows the dome as simply a series of arches which is set on a circular base. Like the arch, this is predominantly a compression structure.

<u>EXERCISE 1.1:</u>

Give the difference between the suspension cable bridge and the cable-stayed bridge.

Give two of the example for any types of structures mentioned above. Eg. Jambatan Pulau Pinang.

1.3 ANALYSIS

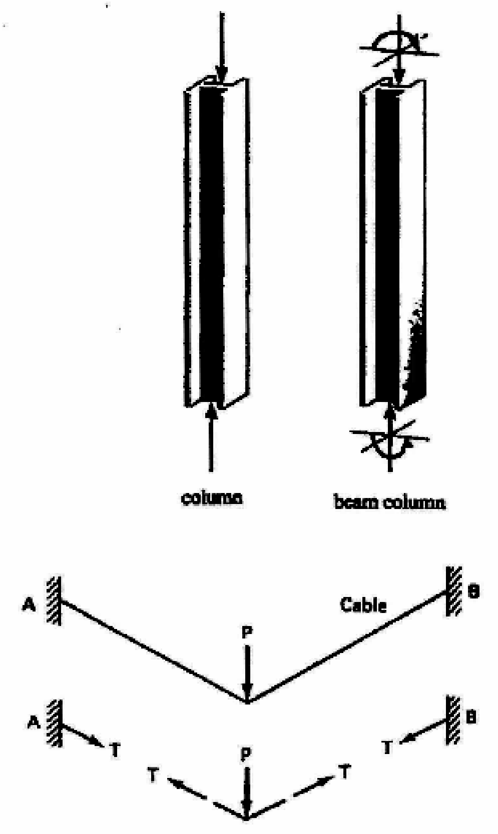
- Structural analysis is a process in determining the reaction of the structure under the specified loads or actions. The reactions usually measured by establishing the forces and deformations throughout the structure.

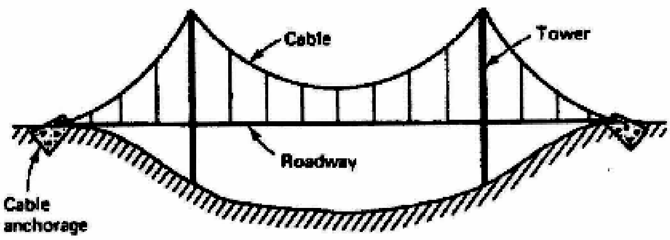
- Once a preliminary design of structure is proposed, the structure must be analyzed to ensure that it has its required strength and rigidity.

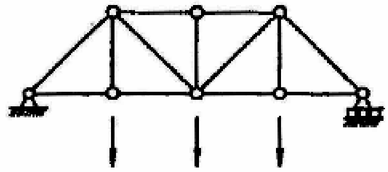
- To analyze a structure properly, certain idealizations must be made as to how the members are supported and connected together.

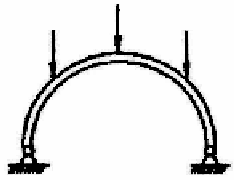
- The loadings are determined from codes and local specifications and the forces in the members and their displacements are found using the theory of structural analysis.

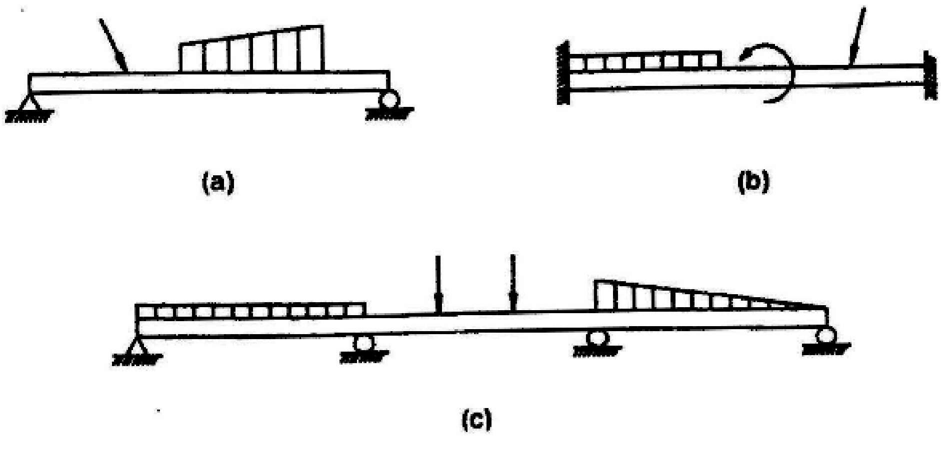
- From the results, it can be used to redesign the structure.

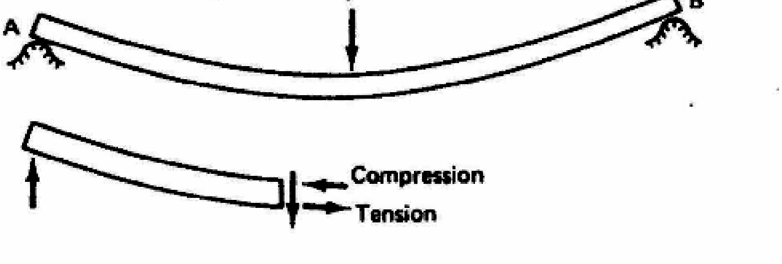


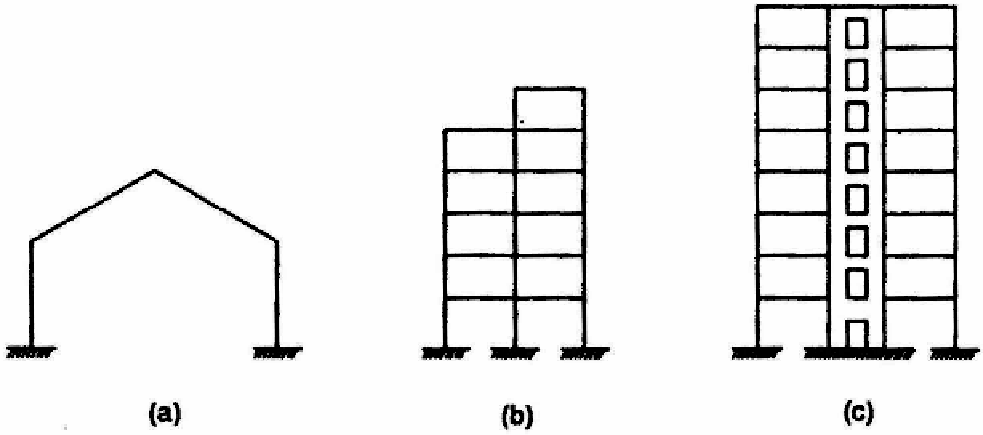

Cable
Tower
Roadway
Cable anchorage



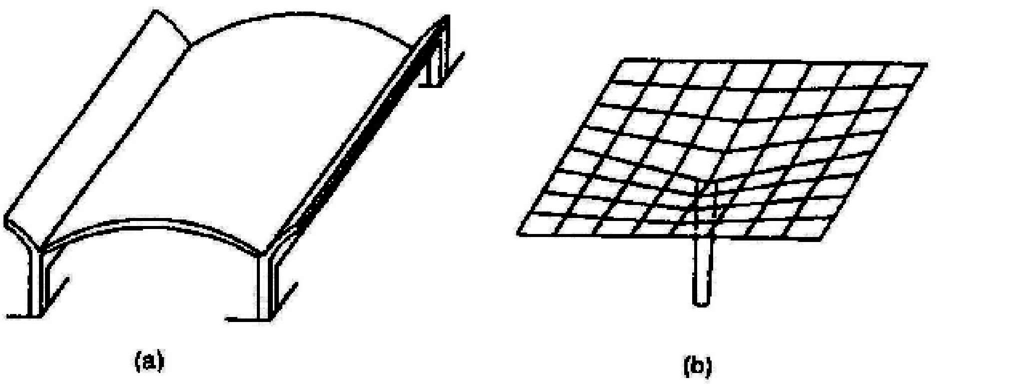


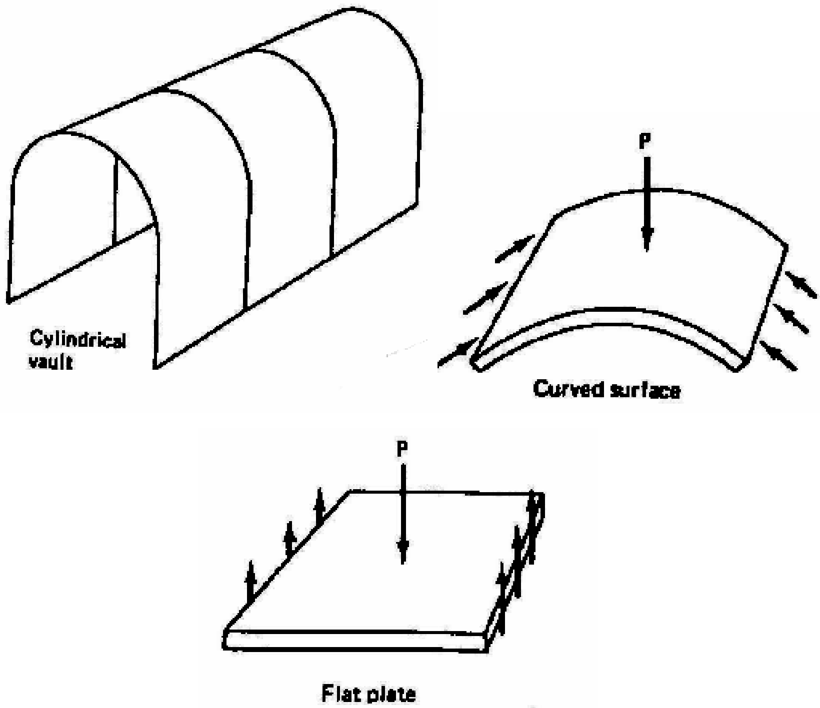

(a)
(b)
(c)


P
A
B
Compression
Tension



Types of frames: (a) Industrial frame, (b) Multi-storey building frame, (c) Building frame with shear wall

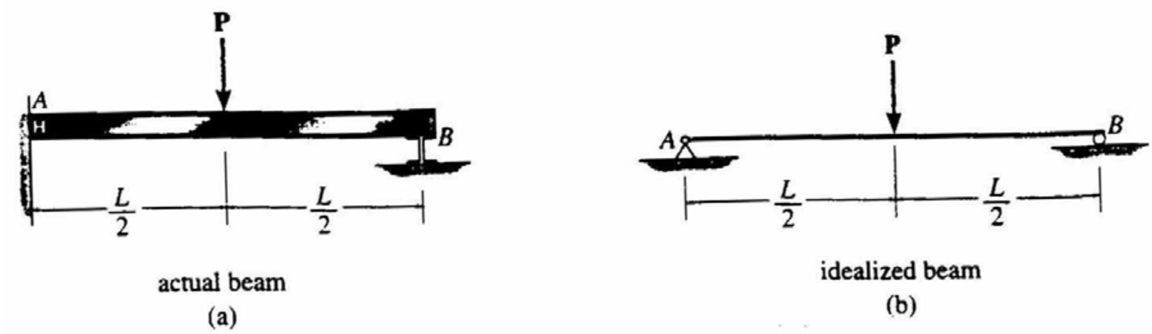


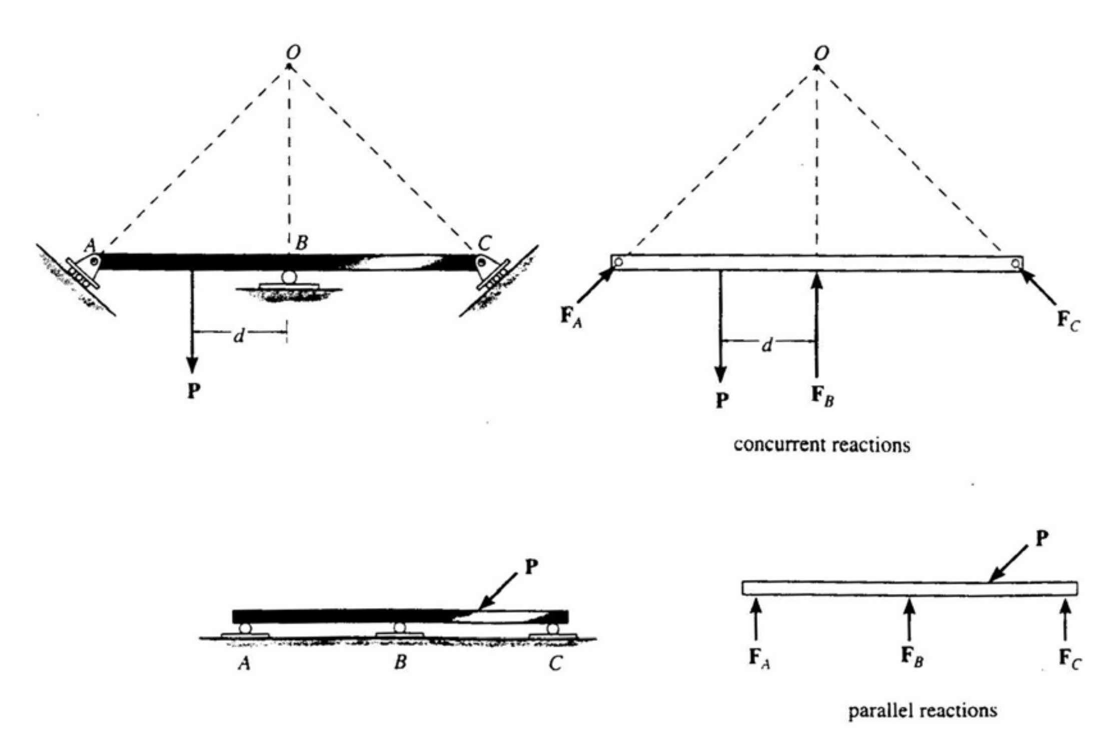


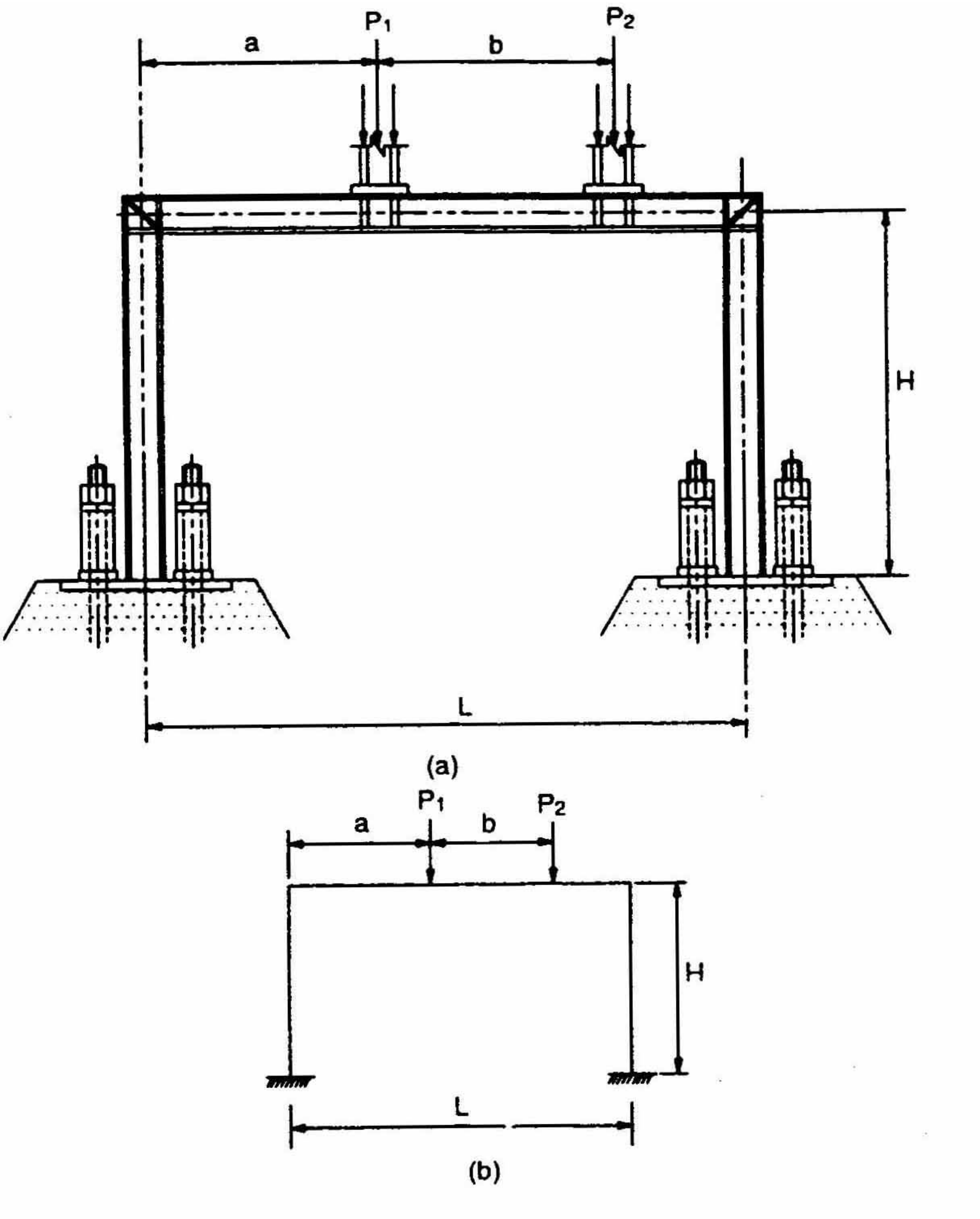
1.4 IDEALIZATION OF STRUCTURES

- In the process of analysis, the real structure has to redraw again in the form of line diagram. The line diagram must be tempered with judgment to ensure that the results do not depart drastically from those in the real structure. This process is called Idealization Of Structures.

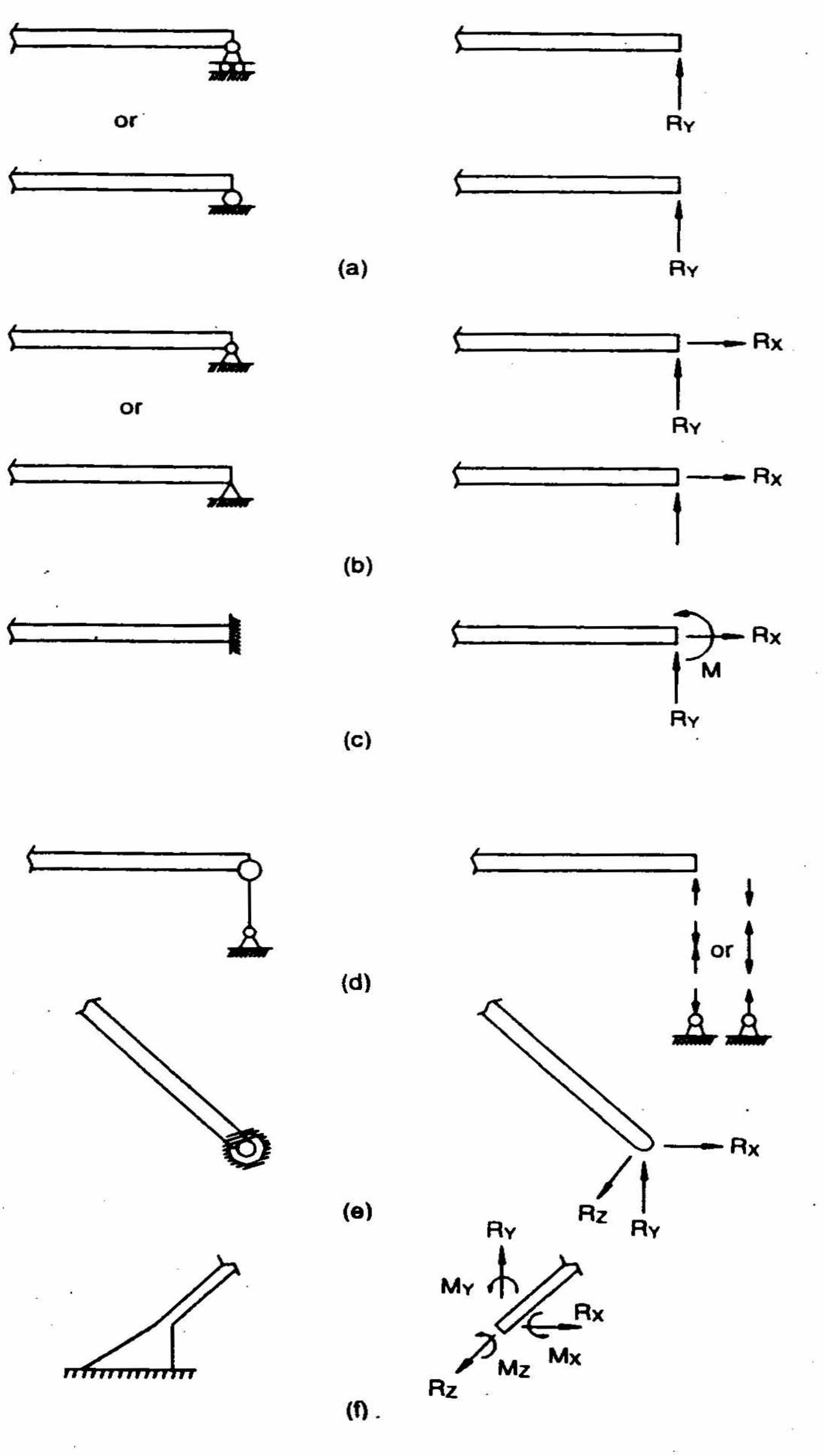
- Generally, most of the structure in 3 dimensional can be idealized in 2 dimensional.



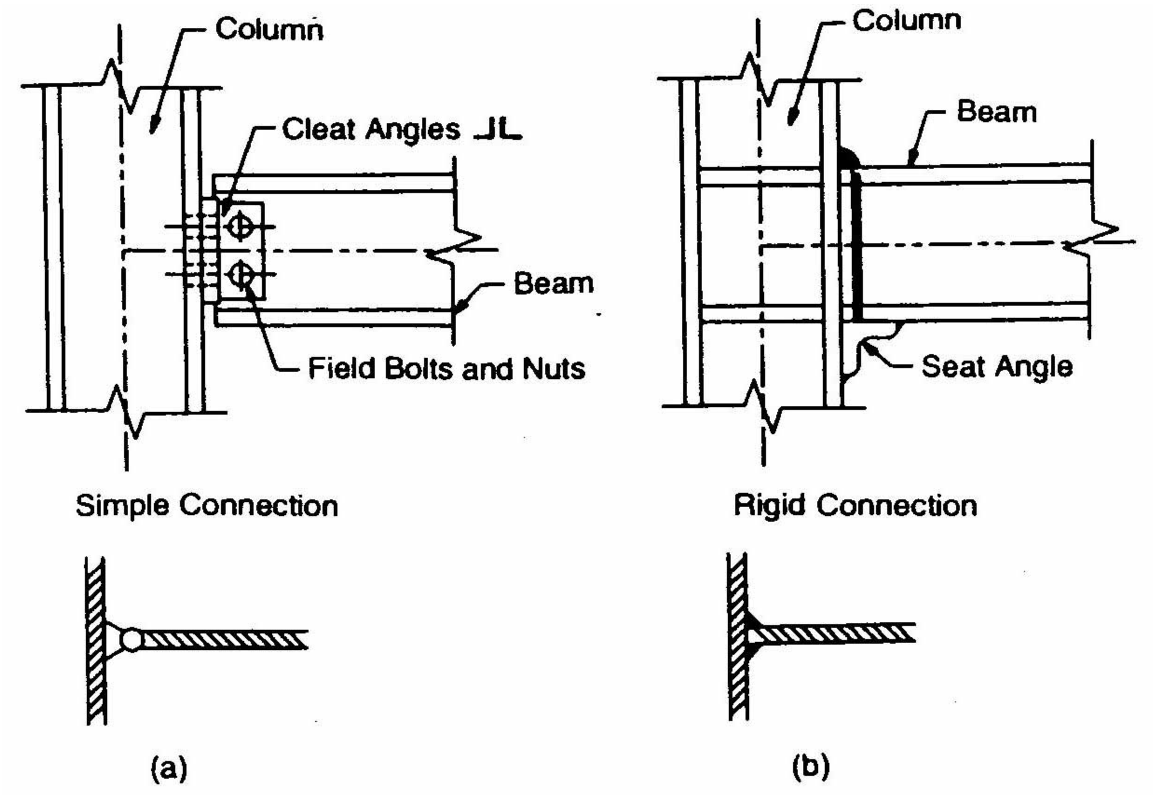




Idealization of structure: (a) Actual structure, (b) Idealized structure

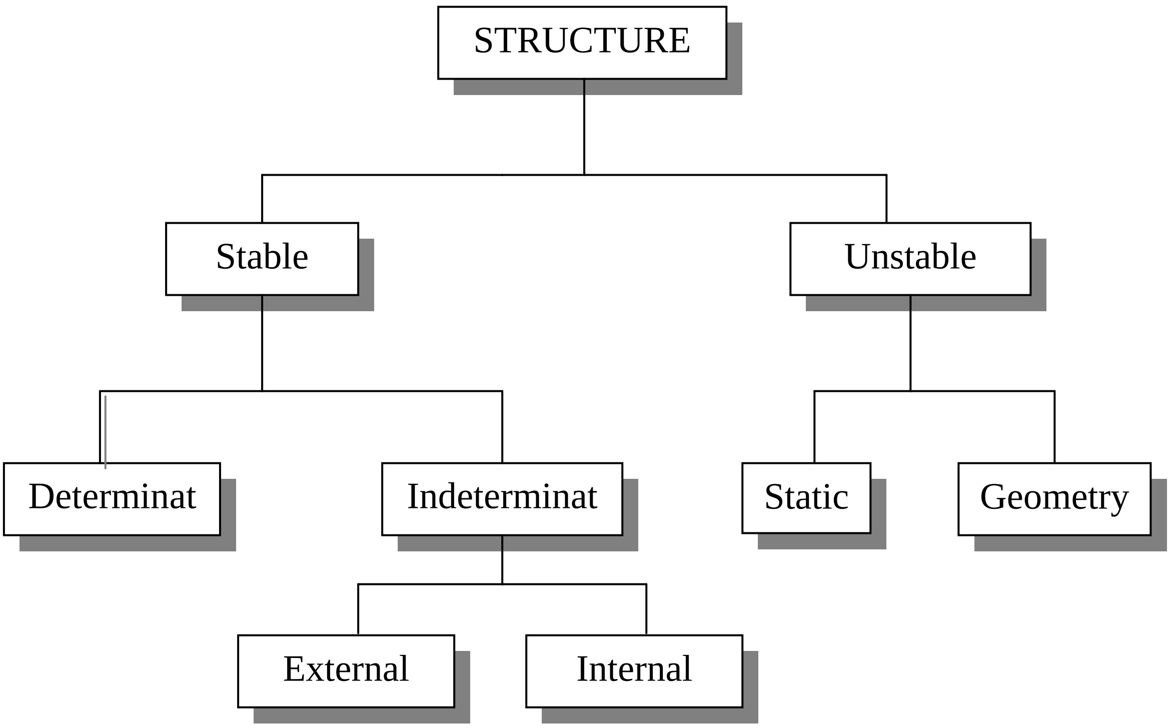


Types of supports: (a) Roller support, (b) Hinged support, (c) Fixed support, (d) Link support, (e) Ball and socket, (f) Rigid support in space



(a) Idealized hinge, (b) Idealized rigid joint

1.5 STRUCTURAL PROBLEMS



- The analysis method can be classical methods or modern matrix methods. Although matrix methods have become the foundation of modern structural analysis as it is employed in the practice of structural engineering, classical methods continue to play a vital role in the educational process because they introduce the fundamentals of structural analysis.

1.6 STABILITY & DETERMINACY

- Before starting analysis any structure, it is necessary to establish the stability and determinacy of the structure.

- Stability,

  There are two types of structural unstability:

  (i) Kinematics Unstable (Partial Constraints)
  - a structure where the number of reaction at the support or number of the member is less than the minimum requirement.
  - In some cases a structure or one of its members may have fewer reactive forces than equations of equilibrium that must be satisfied. The structure then becomes only partially constrained.

  (ii) Geometry Unstable (Improper Constraints)
  - This occur when the location or the arrangement of the support or member are improper.

- Determinacy,

  1) Beam

If	$r < n + 3$	:	Statically Unstable
	$r = n + 3$	:	Determinate (only if geometrically stable)
	$r > n + 3$	:	Indeterminate

  2) Frame

If	$3m + r < 3j + n$	:	Statically Unstable
	$3m + r < 3j + n$	:	Determinate (only if geometrically stable)
	$3m + r > 3j + n$	:	Indeterminate

3) Plane Truss

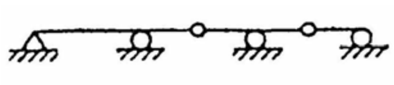
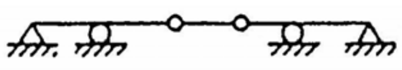
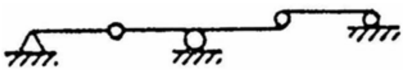
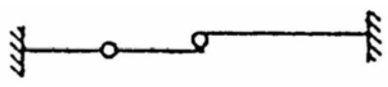
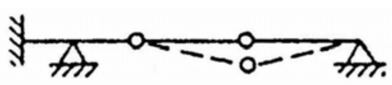
If	$m < 2j - r$	:	Statically Unstable
	$m = 2j - r$	:	Determinate (only if geometrically stable)
	$m > 2j - r$	:	Indeterminate

4) Space Truss

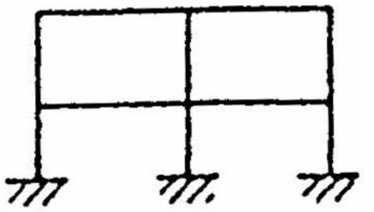
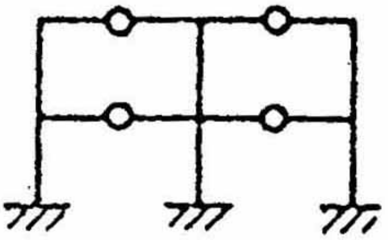
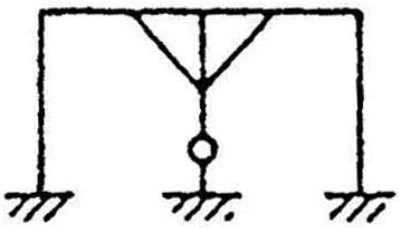
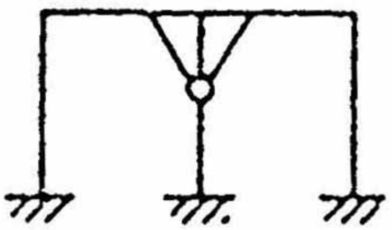
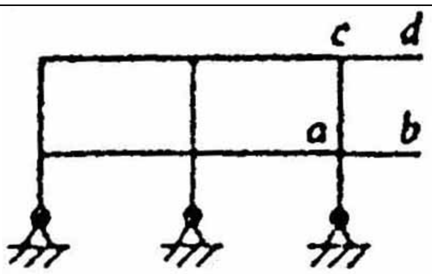
If	$m < 3j - r$	:	Statically Unstable
	$m = 3j - r$	:	Determinate (only if geometrically stable)
	$m > 3j - r$	:	Indeterminate

where,	n	=	number of internal hinge
	r	=	number of reaction
	m	=	number of member
	j	=	number of joint

Stability & Determinacy Of Beam Structures

Beam	r	n	$r \le = \ge n + 3$	Classification
	5	2	5 = 5	Determinate, Stable
	6	2	6 > 5	Indeterminate, 1^{st} deg.,Stable
	5	2	5 = 5	Geometrically Unstable
	4	3	4 < 6	Unstable
	6	3	6 = 6	Determinate, Stable
	7	2	7 > 5	Geometrically Unstable

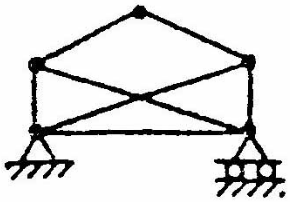
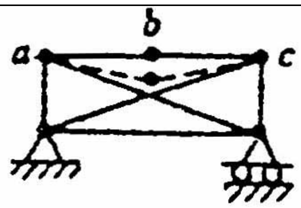
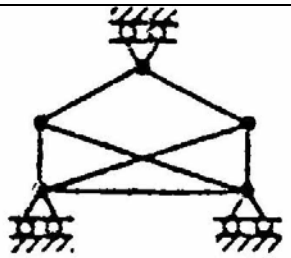
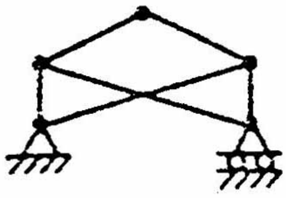
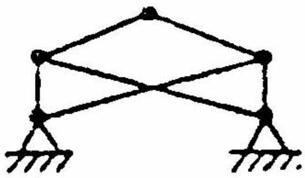
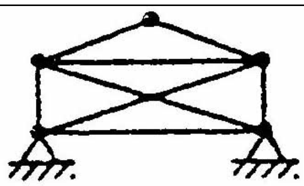
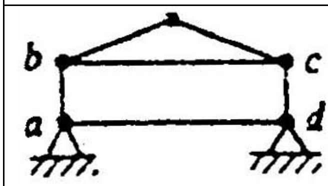
Stability & Determinacy Of Frame Structures

Frame	m	r	j	n	3m+r ≤ = ≥ 3j+n	Classification
	10	9	9	0	39 > 27	Indeterminate, 12^{th} deg.,Stable
	10	9	9	4	39 > 31	Indeterminate, 8^{th} deg.,Stable
	10	9	9	1	39 > 28	Indeterminate, 11^{th} deg.,Stable
	10	9	9	3 *	39 > 30	Indeterminate, 9^{th} deg.,Stable
	10 **	6	9	0	36 > 27	Indeterminate, 9^{th} deg.,Stable

* If hinge occur in frame, generally, n calculates as number of member connected to the joint and minus 1. For this case, n = 4-1 = 3

** Cantilever parts not consider as number of members

Stability & Determinacy Of Plane Truss Structures

Plane Truss	m	R	j	m+r ≤ = ≥ 2j	Classification
	7	3		10 = 10	Determinate, Stable
	7	3	5	10 = 10	Unstable *
	7	3	5	10 = 10	Unstable **
	6	3	5	9 < 10	Unstable
	6	4	5	10 = 10	Determinate, Stable
	8	4	5	12 > 10	Indeterminate, 2^{nd} deg.,Stable
	6	4	5	10 = 10	Unstable ***

* Geometrically unstable due to the hinge in one straight line

** Geometrically unstable due to parallel reactions (horizontally unrestrained)

*** Statically unstable due to insufficient member to brace panel a-b-c-d in horizontally movement

External Statical Classification of Structures with Condition Equations

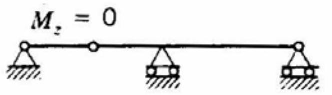
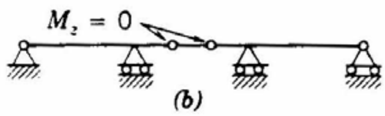
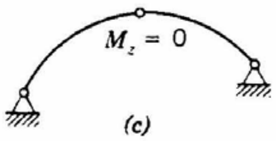
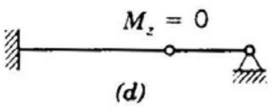
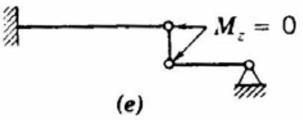
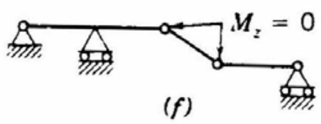
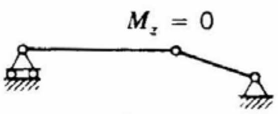
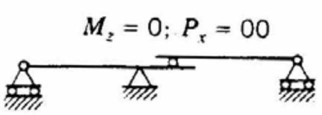
Structure	Indep. React. Comps. r_a	Numb. of Conditions n	Req'd. React. Comps. $r = 3 + n$	Classification
 (a)	4	1	$3 + 1 = 4$	$r_a = r$; determinate, stable
 (b)	5	2	$3 + 2 = 5$	$r_a = r$; determinate, stable
 (c)	4	1	$3 + 1 = 4$	$r_a = r$; determinate, stable
 (d)	5	1	$3 + 1 = 4$	$r_a > r$; indeterminate, stable
 (e)	5	2	$3 + 2 = 5$	$r_a = r$; determinate, stable
 (f)	4	2	$3 + 2 = 5$	$r_a < r$; unstable
 (g)	3	1	$3 + 1 = 4$	$r_a < r$; unstable
 (h)	4	2	$3 + 2 = 5$	$r_a < r$; unstable

Table 5.1 Statical Classification of Beam and Frame Structures

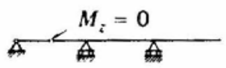
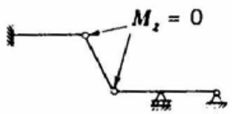
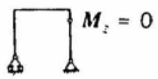
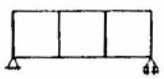
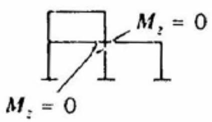
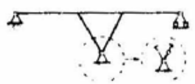
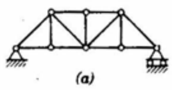
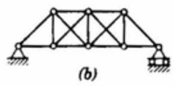
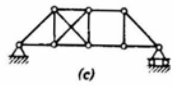
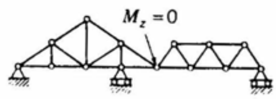
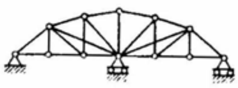
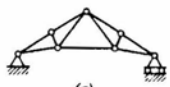
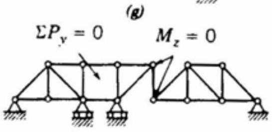
Structure	Structure Characteristics				External Classification		Overall Classification		
	j	n	m_a	r_a	$r = 3 + n$	Classification	$(3m_a + r_a)$	$(3j + n)$	Classification
 (a)	4	1	3	4	$3 + 1 = 4$	$4 = 4$ Determinate, stable	$(9 + 4) = 13$	$(12 + 1) = 13$	$13 = 13$ Determinate, stable
 (b)	5	2	4	6	$3 + 2 = 5$	$6 > 5$ Indet., 1st degree, stable	$(12 + 6) = 18$	$(15 + 2) = 17$	$18 > 17$ Indet., 1st degree, sta- ble
 (c)	4	1	3	3	$3 + 1 = 4$	$3 < 4$ Unstable	$(9 + 3) = 12$	$(12 + 1) = 13$	$12 < 13$ Unstable
 (d)	8	0	10	3	3	$3 = 3$ Determinate	$(30 + 3) = 33$	$(24 + 0) = 24$	$33 > 24$ Indet., 9th degree, stable
 (e)	8	3 2 (Ext)	8	9	$3 + 2 = 5$	$9 > 5$ Indet., 4th degree, stable	$(24 + 9) = 33$	$(24 + 3) = 27$	$33 > 27$ Indet., 6th degree, stable
 (f)	5	1 0 (Ext)	5	5	3	$5 > 3$ Indet., 2nd degree, stable	$(15 + 5) = 20$	$(15 + 1) = 16$	$20 > 16$ Indet., 4th degree, stable

Table 4.1 Statical Classification of Trusses

Structure	Structure Characteristics			External Classification		Internal Classification	
	j	m_a	r_a	r	Classification	$m = 2j - r$	Classification
 (a)	8	13	3	3	$r_a = r$, deter. stable	$13 = 16 - 3$	$m_a = m$, deter. stable
 (b)	8	15	3	3	$r_a = r$, deter. stable	$13 = 16 - 3$	$m_a > m$, indet. stable
 (c)	8	13	3	3	$r_a = r$, deter. stable	$13 = 16 - 3$	$m_a = m$, but unstable
 (d)	7	9	4	3	$r_a > r$, indet. stable	$11 = 14 - 3$	$m_a < m$, unstable
 (e)	14	24	4	$3 + 1 = 4$	$r_a = r$, deter. stable	$24 = 28 - 4$	$m_a = m$, deter. stable
 (f)	12	23	4	3	$r_a > r$, indet. stable	$21 = 24 - 3$	$m_a > m$, indet. stable
 (g)	7	11	3	3	$r_a = r$, deter. stable	$11 = 14 - 3$	$m_a = m$, deter. stable
 (h)	14	22	6	$3 + 3 = 6$	$r_a = r$, deter. stable	$22 = 28 - 6$	$m_a = m$, deter. stable

TUTORIAL 1

1 Classify each of the structures in Figure 1(a)–(d) as statically determinate, statically indeterminate, stable or unstable. If indeterminate, specify the degree of indeterminacy.

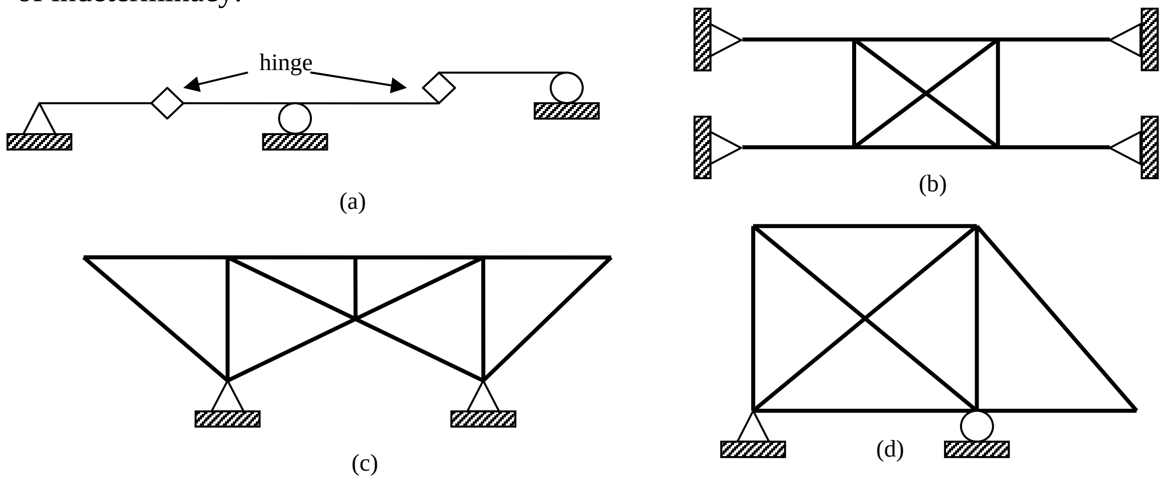


Figure 1

2 Figure 2(a)-(e) shows the pinned connected truss, determine;
(i) the degree of indeterminacy
(ii) classification of indeterminate truss

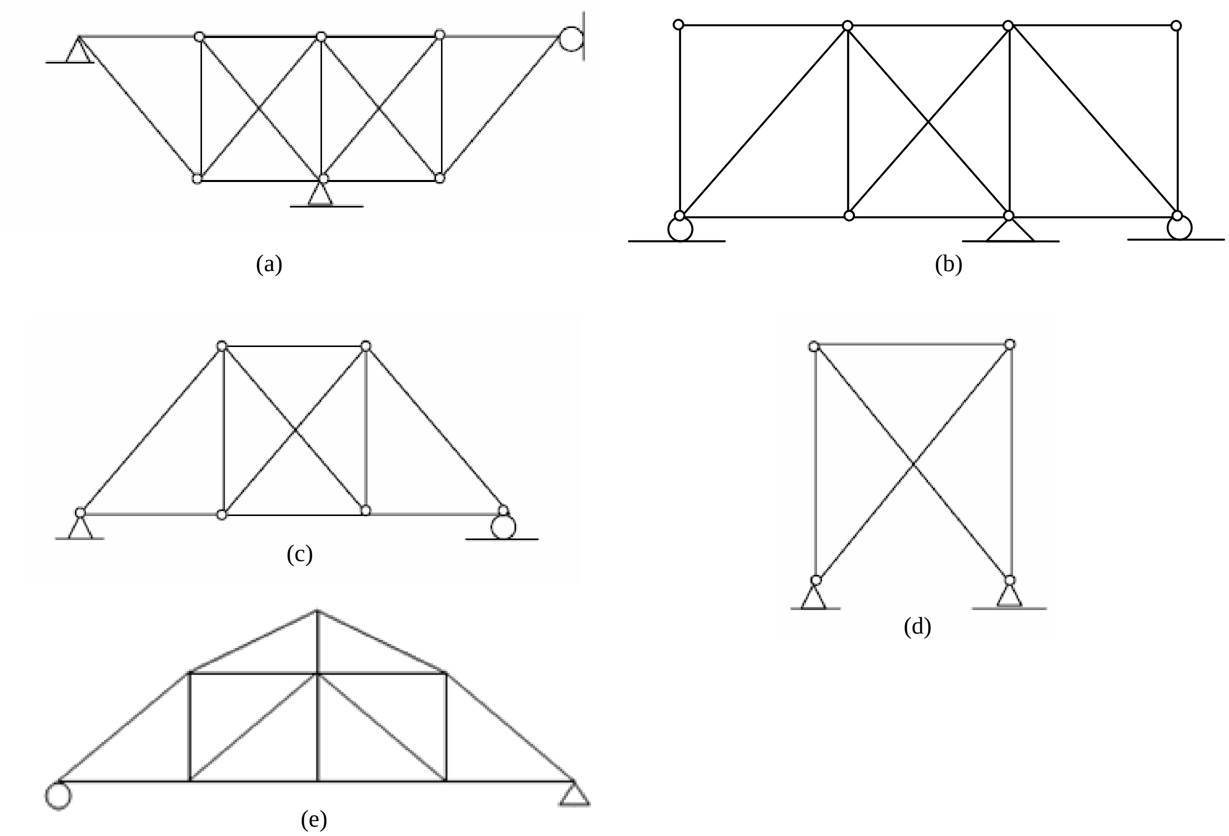


Figure 2