鋼構造物の設計 (2)

1.2 構造部材の形と力学的な考察

・構造物、構造部材の形は
力学的に決まるもの

・構造力学＋構造材料＝
構造物の形状と
構造部材の断面形状

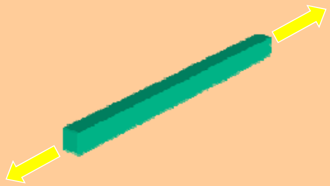
Eiffel Tower (1889)

構造部材の力学

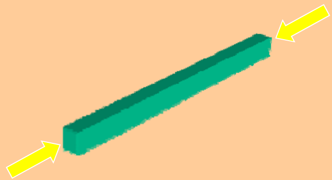
構造部材に作用する力

Types of Forces in Structural Components

引張　Tension



圧縮　Compression



作用する力は複雑
支配的な力に対して部材耐力を決める。これが断面設計

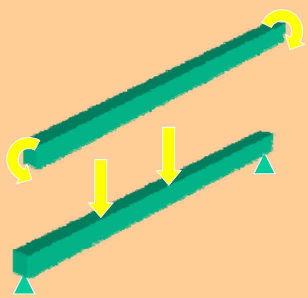
構造部材に作用する力

Types of Forces in Structural Components

引張　Tension　Or　圧縮　Compression

＋

曲げ　Bending

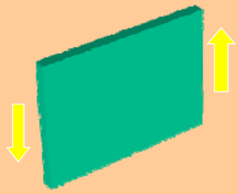


構造部材に作用する力

Types of Forces in Structural Components

ねじれ　Torsion

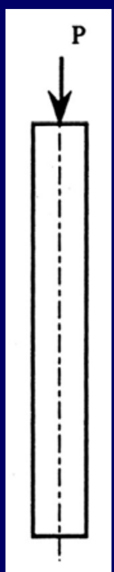
せん断　Shear



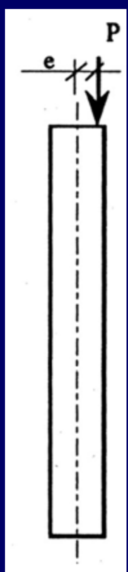
引張 or 圧縮　+ 曲げ + せん断 + ねじれ

柱部材における偏心荷重

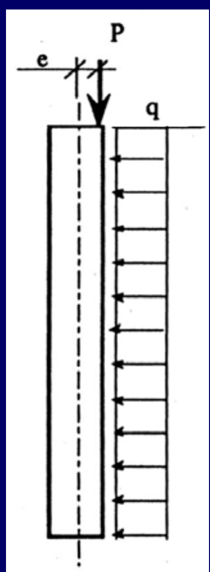
A Column with Eccentric Load



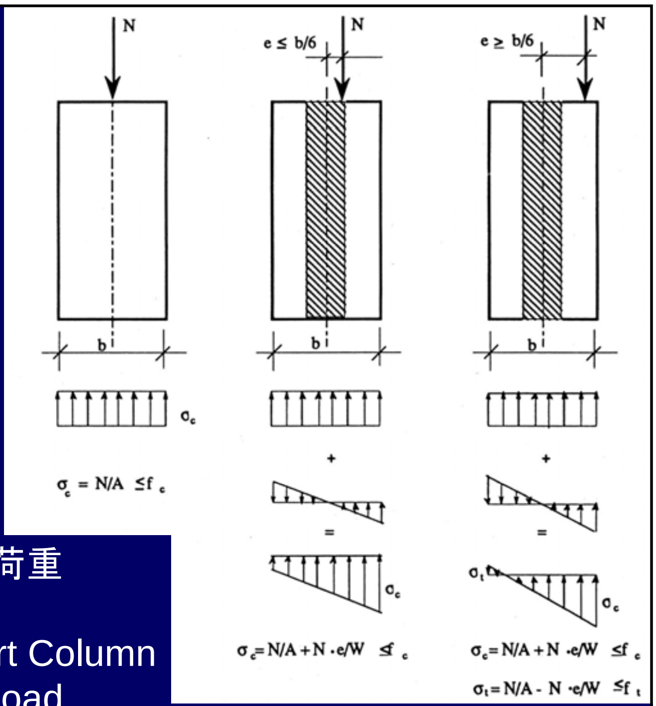
Concentric Load



Eccentric Load

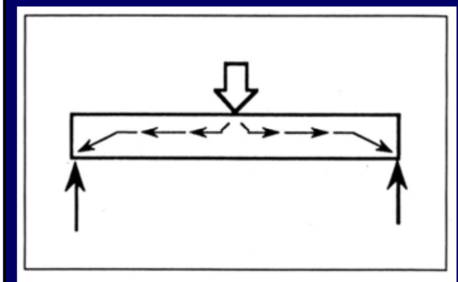


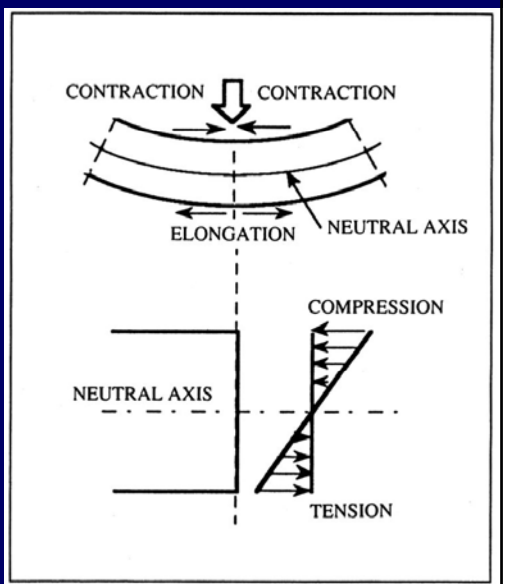
Eccentric Load + Bending



短柱における偏心荷重
による応力
Stresses in A Short Column
due to Eccentric Load

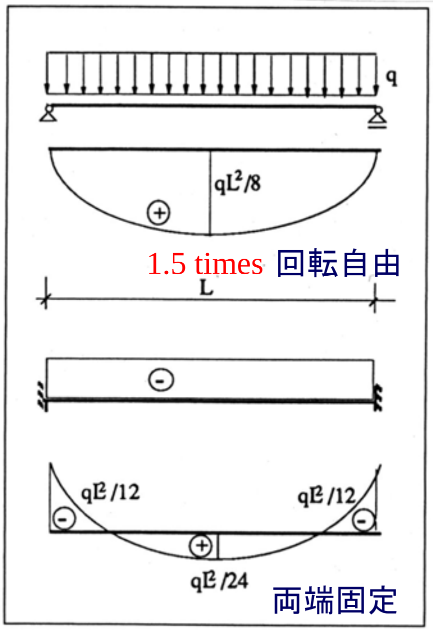
はりの曲げ　Bending of A Beam Element





分布荷重を受けるはり 境界条件の影響

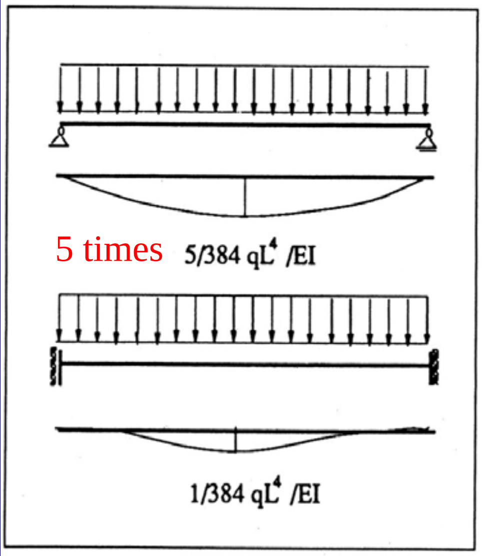
A Beam with distributed Load
with Various Boundary Conditions



Bending-Moment-Diagram

分布荷重を受けるはり境界条件の影響

A Beam with distributed Load
with Various Boundary
Conditions

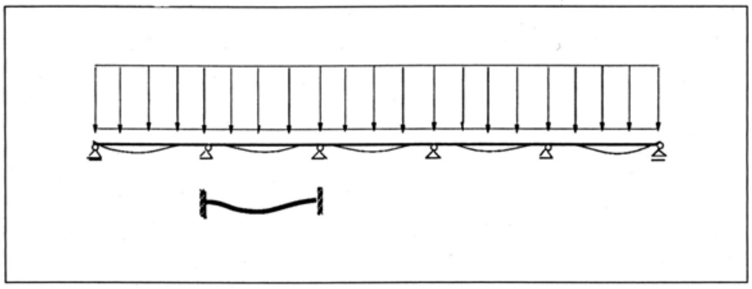


Deflection

分布荷重を受ける多径間連続はり 境界条件の影響

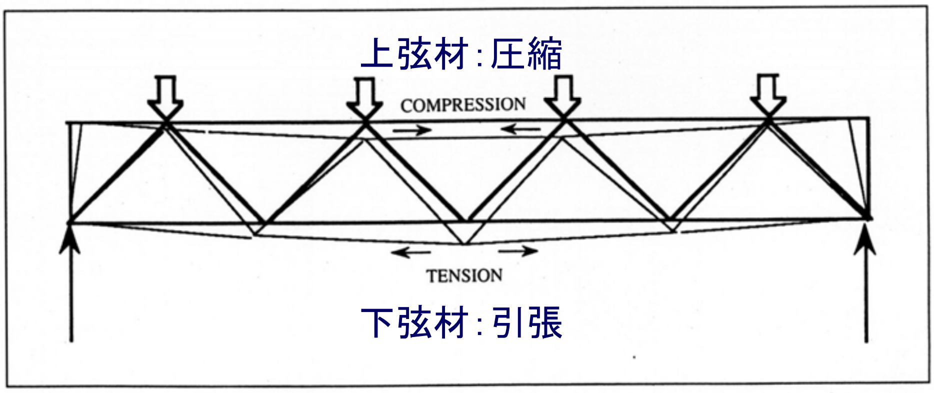
A Continuous Multi-Span Beam with distributed Loads

Continuous beam over several equal spans. With uniformly distributed load over the whole beam, an inner span will be prevented from rotating at the ends. These will therefore be subjected to bending moments equal to the beam with two fixed ends.



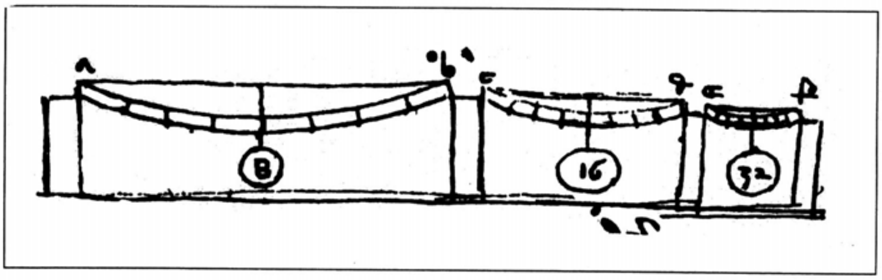
単純支持されたトラス

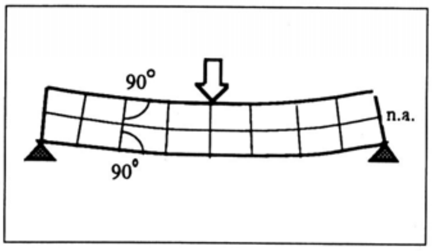
A simply supported truss structure



トラス桁 (Truss) ⇔ プレートガーダー (girder)
応力の流れは同様

Leonardo da Vinciによるはり耐力の考え方





Perpendicular cross sections of the beam will also be perpendicular after the beam is bent.

力学的に形状が決定される構造例(1)

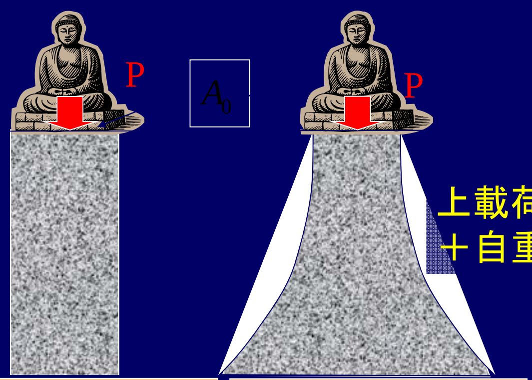
Determination of Shapes of Structural Components Based on Mechanics

Eiffel Tower (1889)

Tokyo Tower

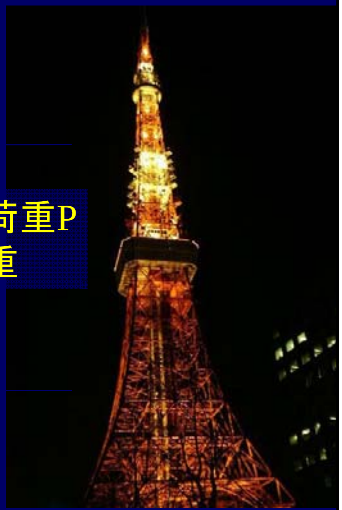
力学的に形状が決定される構造例(1)

Determination of Shapes of Structural Components Based on Mechanics



$$A(x) = A_0 = const.$$
$$\sigma(x) = \sigma_0 + wx$$

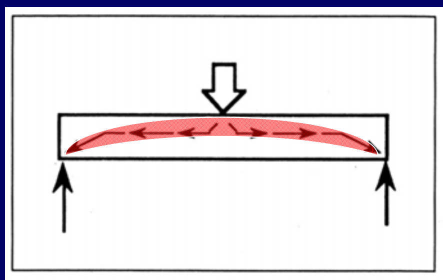
$$A(x) = A_0 \exp(\frac{w}{\sigma_0} x)$$
$$\sigma(x) = \sigma_0 = const.$$



Tokyo Tower

力学的に形状が決定される構造例(3)

Determination of Shapes of Structural Components Based on Mechanics



アーチ構造，ドーム構造

石造で長スパンを考えると
アーチになる

通潤橋（1854）

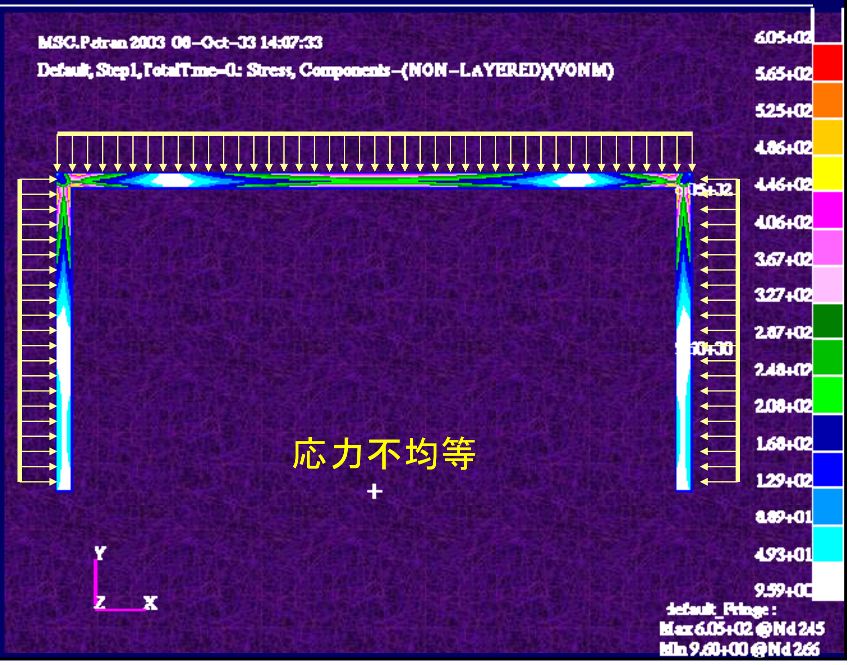
力学的に形状が決定される構造例(2)

Determination of Shapes of Structural Components
Based on Mechanics

なぜアーチ形状？
車両の形に合せたら？

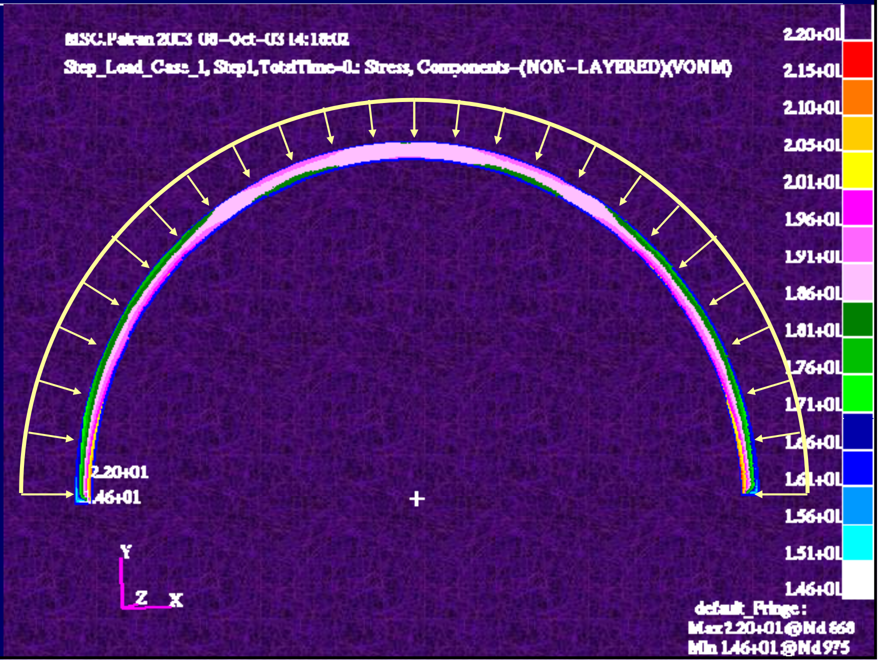
Tunnel

トンネルの形状が箱形だったら・・・

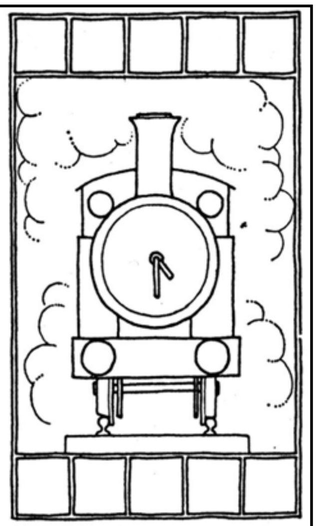


応力不均等

トンネルの形状がアーチ形の場合

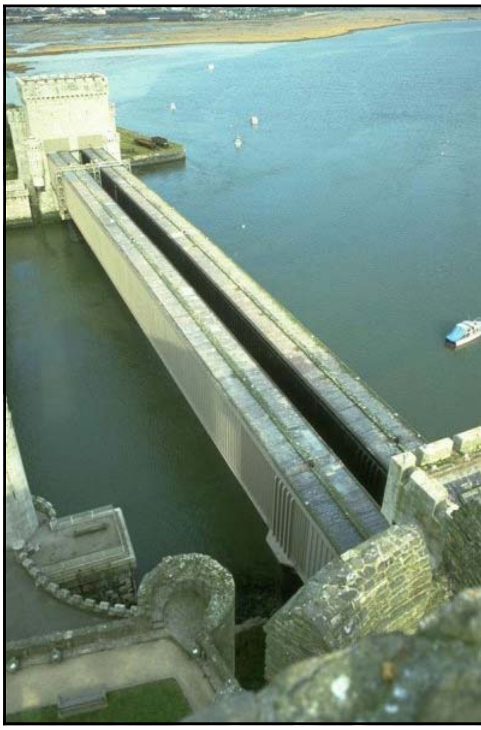


Britannia Bridge



Britannia bridge: tubular box beam.

たわみをおさえるために桁高が大きくなり,
吊橋 → 箱断面桁橋

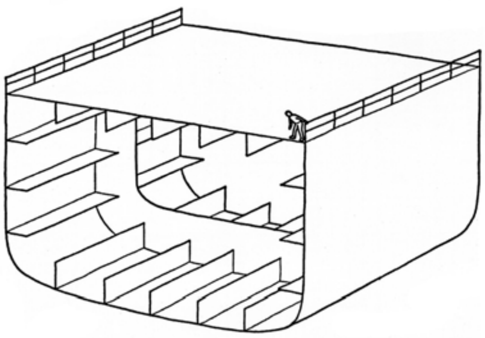


Conway Bridge

日本丸

- ■総トン数／21,903トン
- ■全長／166.6m
- ■全幅／24.0m
- ■客室数／202室
- ■乗客数／600名
- ■就航年：1990年

断面の構成は
箱断面の桁橋と同じ



Engineering shell structures such as ships and aircraft generally use both stringers and ribs or bulkheads. This is a diagram of the Isherwood construction often used in oil tankers.

1.3 鋼構造物の限界状態と破壊事例

1940 Tacoma Narrows Bridge Collapse

失敗の積み重ねにより工学は進歩

http://www.enm.bris.ac.uk/research/nonlinear/tacoma/

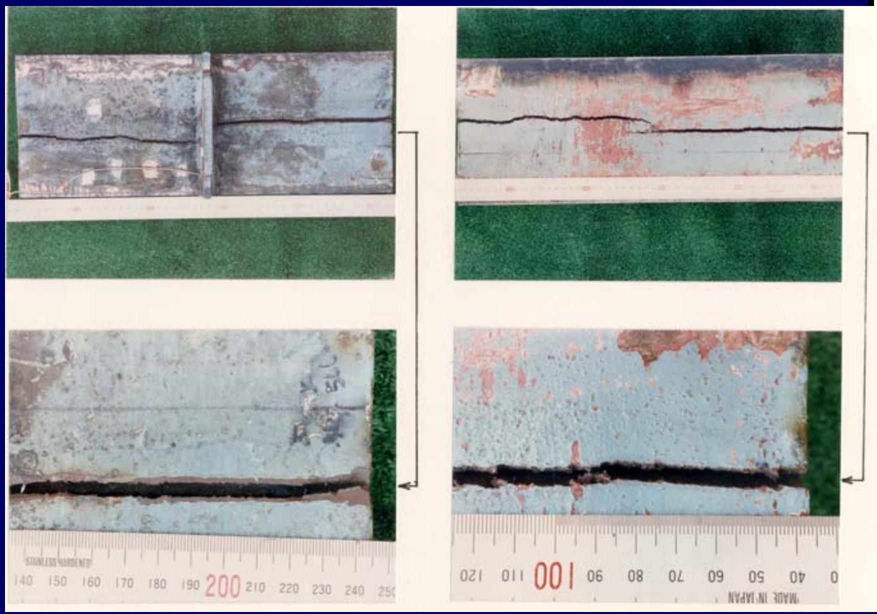
2000 Brittle Fracture In Hoan Bridge

損傷事例と原因

- Yielding
  Material Properties
- Structural Instability
  Vibration induced by wind or pedestrian
  Unexpected lateral movement during erection
  Buckling
- Fracture
  Fatigue
  Earthquakes

Fatigue and Fracture

Imperfect butt-welding of bottom flanges

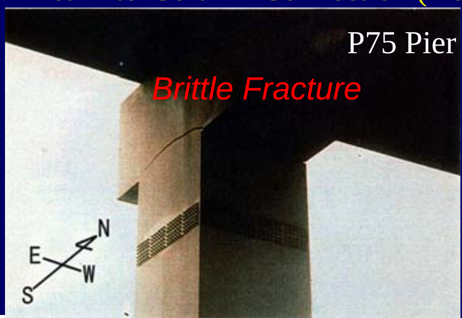


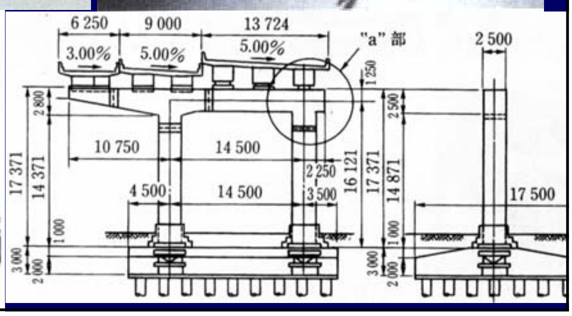
Damage Cases in Hyogo-ken Nanbu Earthquake

Damage Cases in Hyogo-ken Nanbu Earthquake

Damage Cases in Hyogo-ken Nanbu Earthquake

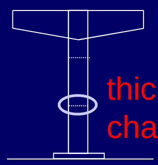
Beam-to-Column Connection (Kobe Harbor Highway)





Damage Cases in Hyogo-ken Nanbu Earthquake

3. Circular Pier



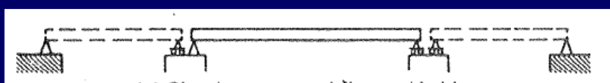
thickness
changing point

→Material Tests

1. 橋の形式　　Bridge Types

(1) 単純桁　Simply Supported flexural bridge

- 最も単純な形式
- 圧延部材，圧延部材+カバープレート
- プレートガーダ，ボックスガーダ



(a) Simply supported flexural bridge

(2) カンチレバー桁　Cantilever flexural bridge

- 二径間以上，主桁に回転自由なヒンジを入れ静定化

(b) Cantilever flexural bridge

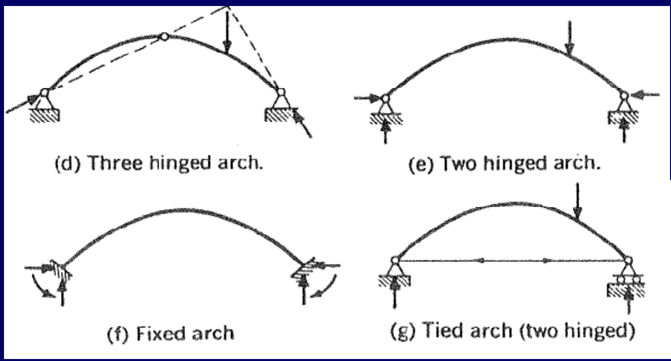
(3) 連続桁　Continuous girder bridge

- 二径間以上，不静定構造
- 剛性高い

1. 橋の形式　Bridge Types

(4) アーチ橋　Arch bridge

- 石造，コンクリート，鋼
- アーチ部は圧縮力が支配的

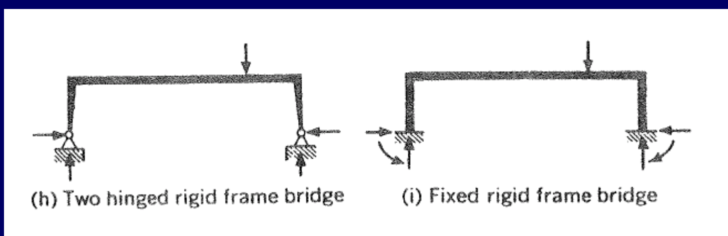


以上のほか，アーチ系の橋として
ランガー橋，ローゼ橋

1. 橋の形式　Bridge Types

(5) ラーメン橋　Rigid frame bridge

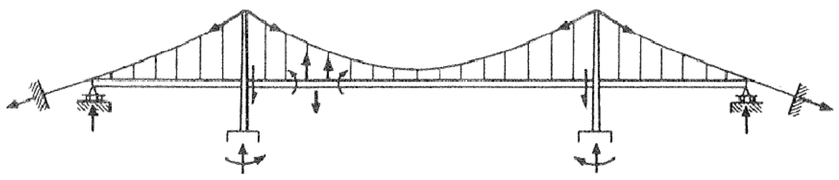
- 不静定次数の高い構造



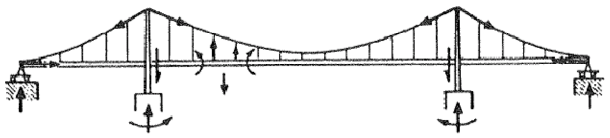
1. 橋の形式　Bridge Types

(6) 吊橋　Suspension bridge

- 長径間の橋
- ケーブルが最重要，桁はハンガーでケーブルに吊られている
- 無補剛(中，小吊橋) 補剛



(j) Suspension bridge (earth anchored)

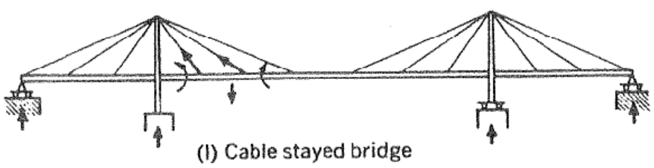


(k) Suspension bridge (self anchored)

1. 橋の形式　Bridge Types

(7) 斜張橋 Cable stayed bridge

- 新しい形式
- 桁をケーブルで支持

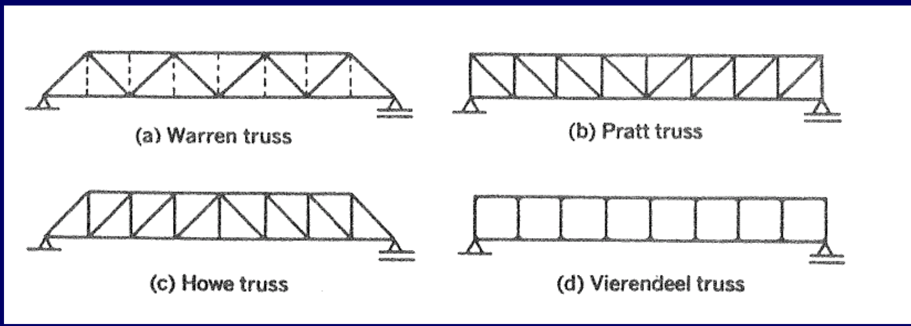


(l) Cable stayed bridge

1. 橋の形式　Bridge Types

(8) トラス構造　Truss

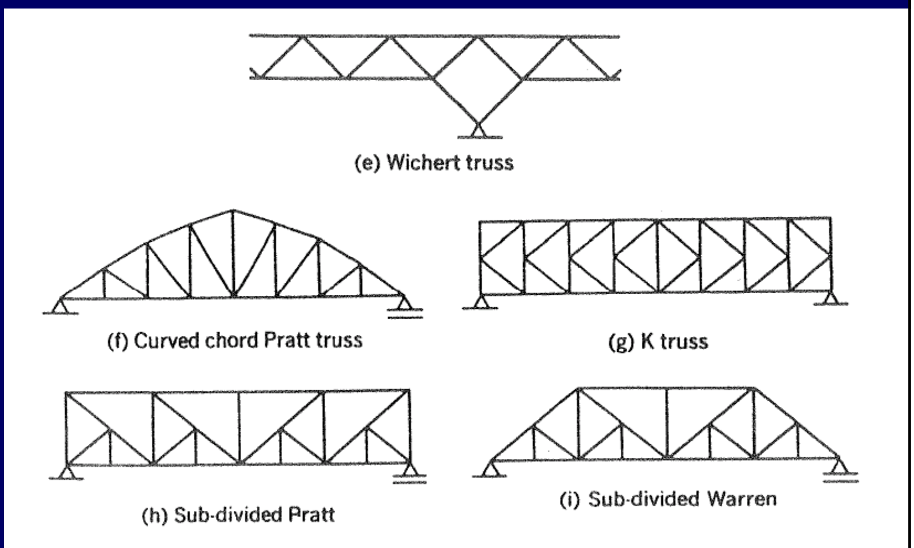
- トラス構造の橋への最初の応用は木橋
  (引張部材のみ鋳鉄棒，あるいは鋼棒)
- 斜材の組みかたにより種々の形式
- 単純桁，ゲルバー桁，連続桁，アーチ橋，吊橋，斜張橋



次スライドに続く

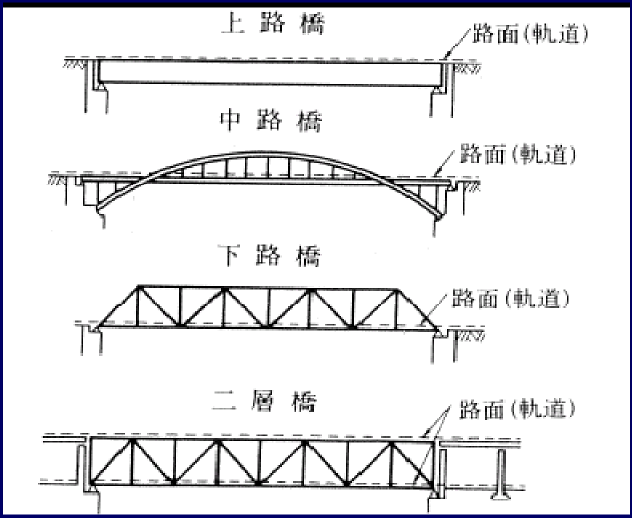
1. 橋の形式　Bridge Types

(8) トラス構造(続き)　Truss (Continued)



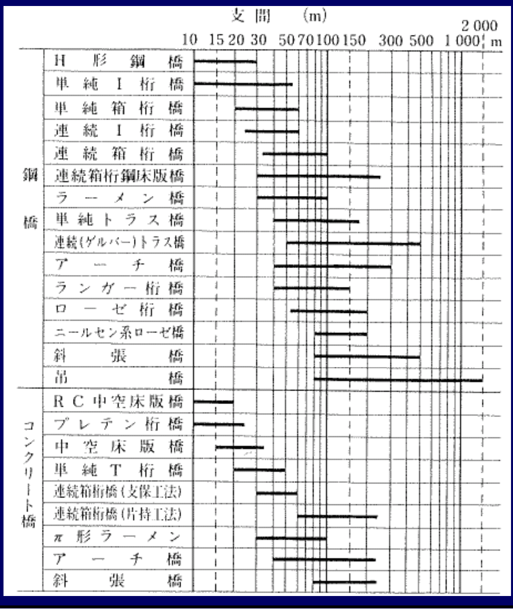
1. 橋の形式　Bridge Types

(9) 橋の走行位置による分類
Classification of bridges by deck position

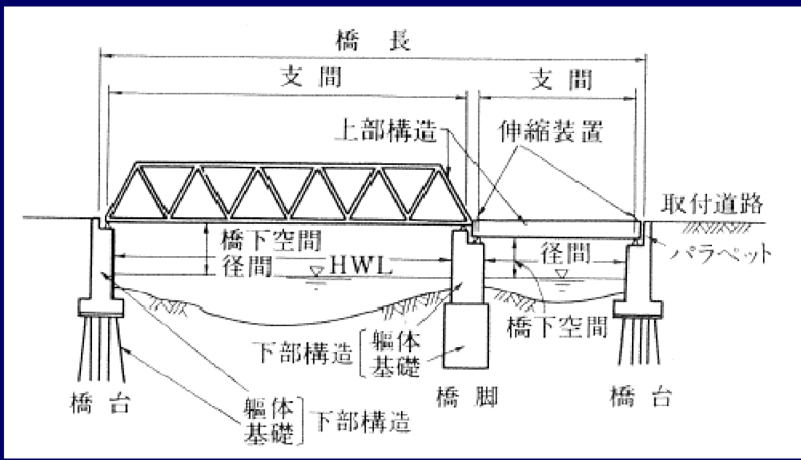


2. 橋梁形式別適用支間

Normal ranges of span length by bridge type

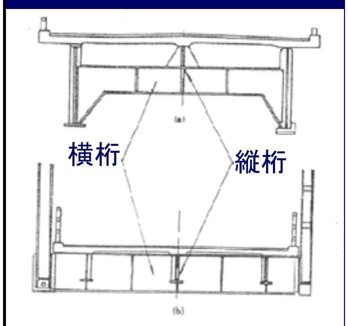


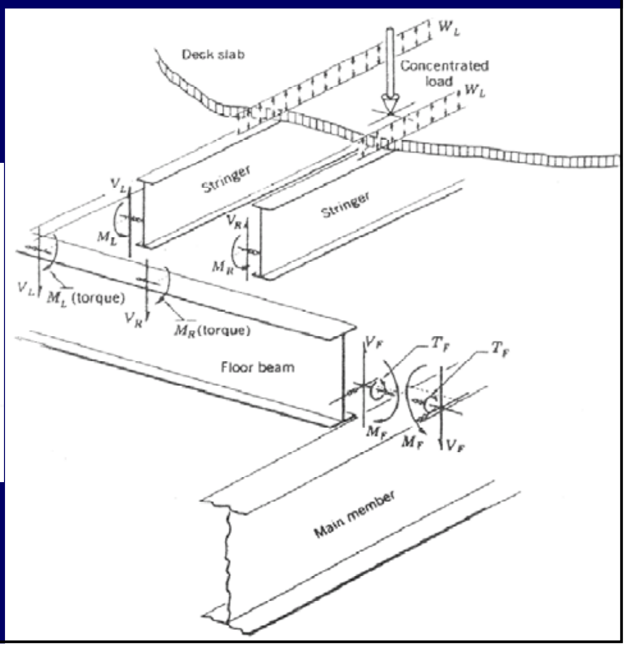
3. 橋梁各部の名称



3. 橋梁各部の名称

縦桁と横桁
Floor beam
and stringer

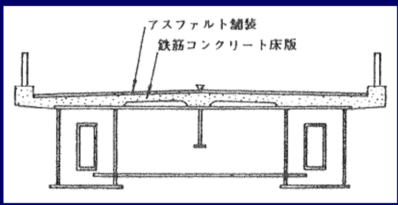




3. 橋梁各部の名称

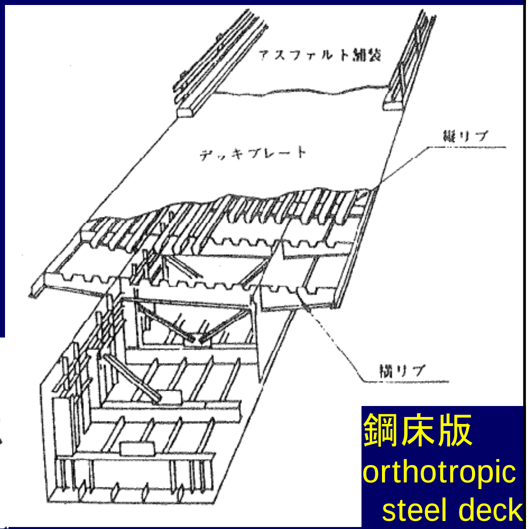
床版の構造(箱桁の例)

Orthotropic steel deck (Ex. of box girder)

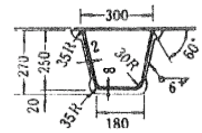


鉄筋コンクリート床版

RC deck



縦リブの例



鋼床版

orthotropic steel deck