Materi Struktur Baja 1

Minggu ke-	Materi
1	Pengenalan bahan baja sebagai material struktur
2	Elemen struktur tarik
3	Elemen struktur tarik
4	Elemen struktur tekan penampang simetris ganda dan tunggal
5	Elemen struktur tekan penampang siku dan dobel siku
6	Contoh aplikasi
7	UTS
8	Alat-alat sambung pada baja
9	Baut terhadap gaya aksial
10	Baut terhadap gaya eksentrisitas
11	Sambungan baut untuk lentur
12	Las terhadap gaya aksial
13	Las terhadap gaya eksentrisitas
14	Sambungan las untuk lentur
15	Contoh aplikasi
16	UAS

Tugas 1 : Elemen tarik dan elemen tekan

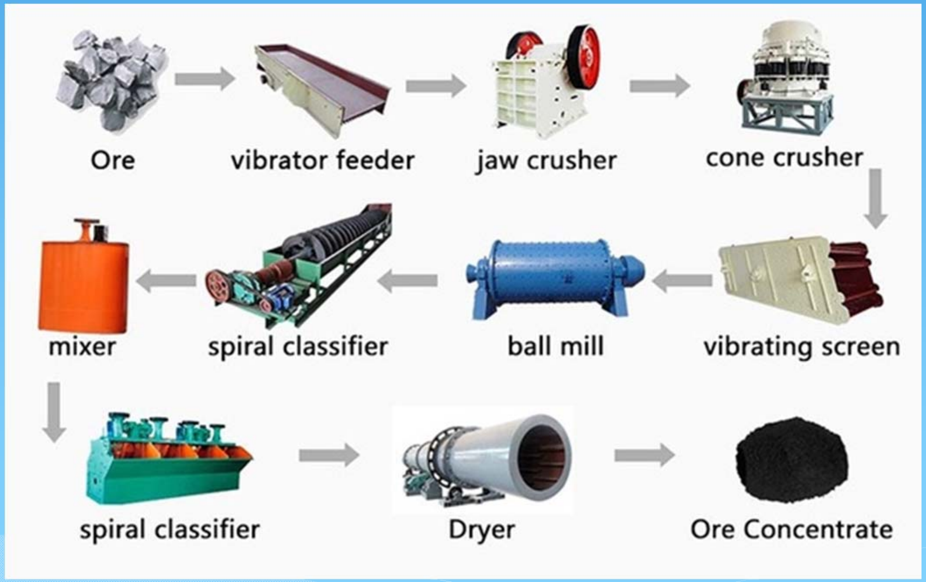
Tugas 2 : Baut dan las

Tugas besar : dari prodi

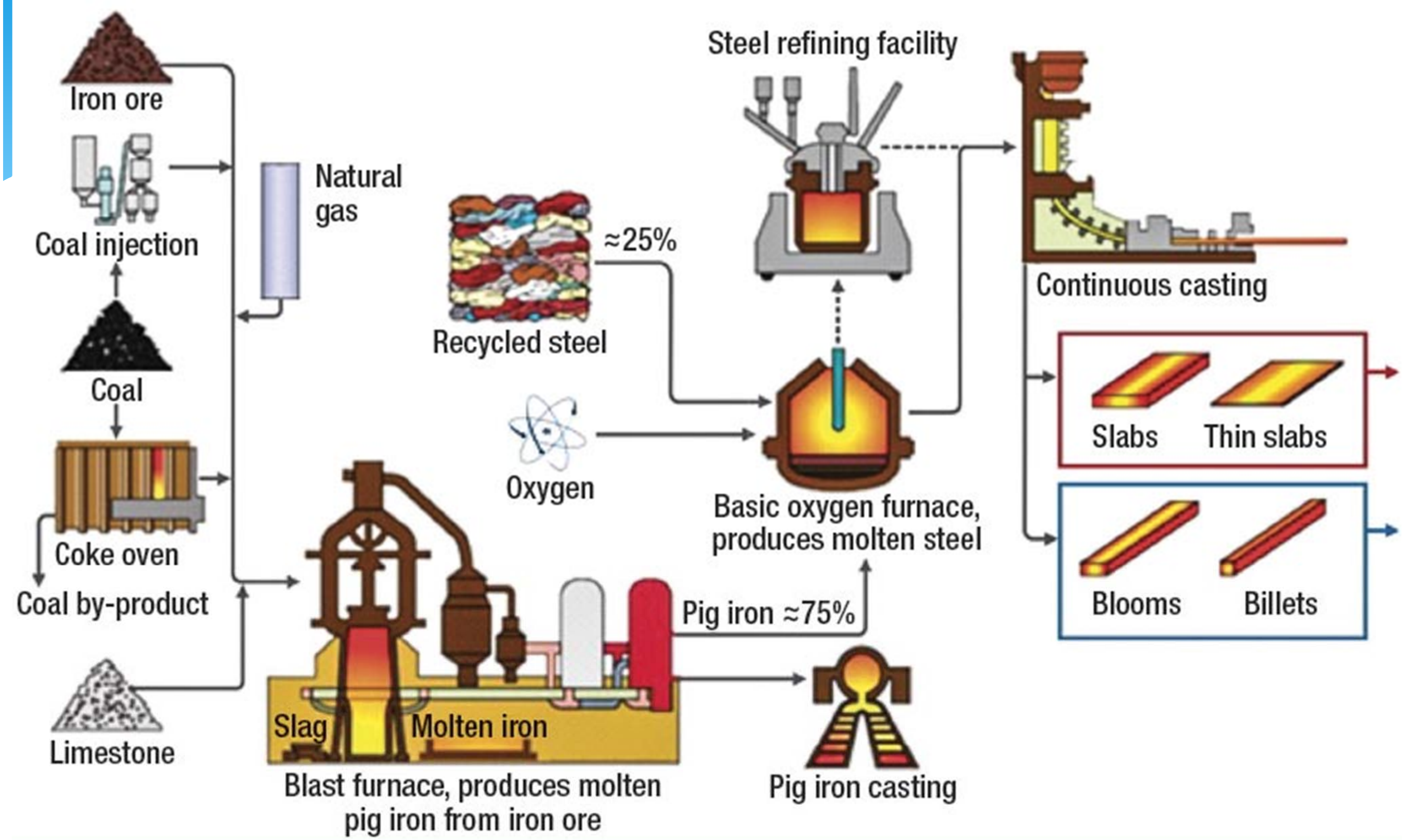
Buku referensi :

1. Salmon, C.G., Johnson, J.E., Malhas, F.A., “Steel Structures Design and Behaviour”, 5th edition, Pearson Prentice Hall.
2. Segui, W.T., “Steel Design”, 5th edition, Cengage Learning.
3. Dewobroto, W., “Struktur Baja”, Lumina.
4. SNI 1729:2015, Spesifikasi untuk Bangunan Gedung Baja Struktural, Badan Standardisasi Nasional.
5. Setiawan, A., “Perencanaan Struktur Baja dengan Metode LRFD”, Erlangga, Jakarta.

Bijih besi

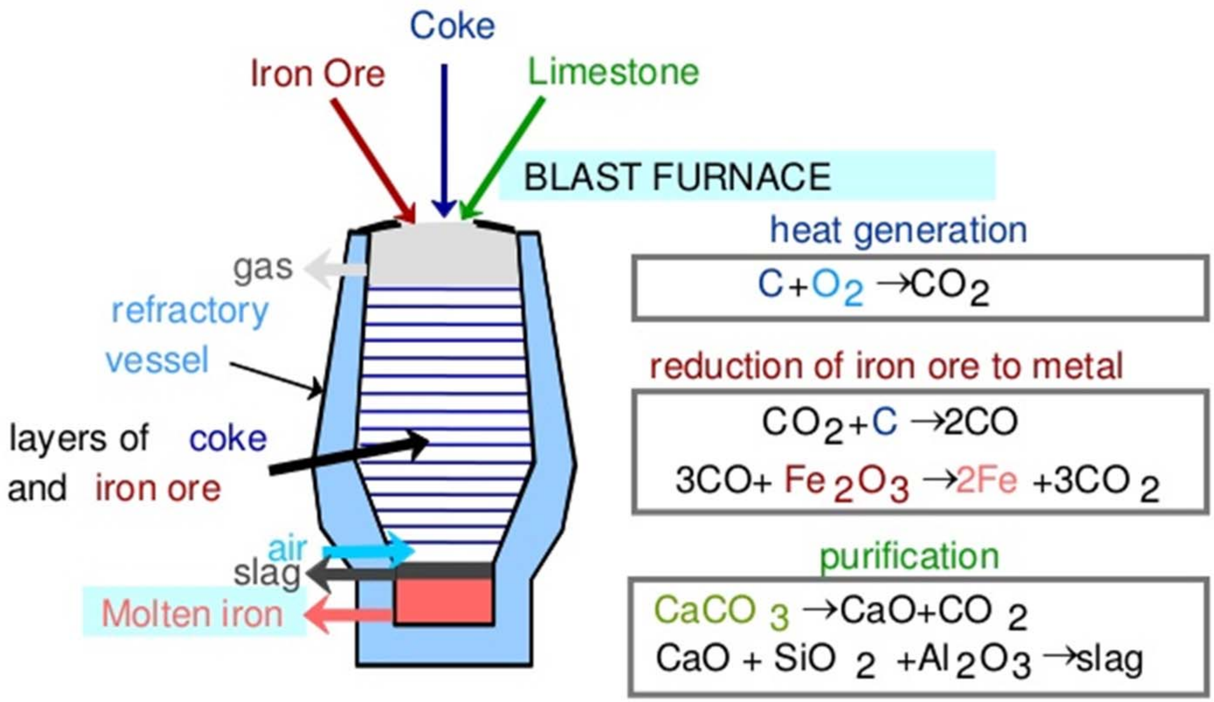


Proses pengolahan bijih besi



Pengolahan bijih besi menjadi baja

Process: Iron Ore → Steel



CARBON STEEL

Carbon Steel adalah baja yang terdiri dari elemen-elemen yang prosentase maksimum selain bajanya sebagai berikut:

- 1. 70% Carbon
- 1. 65% Manganese
- 0. 60% Silicon
- 0. 60% Copper

Carbon dan Manganese adalah bahan pokok untuk meninggikan tegangan (strength) dari baja murni.
Baja dikategorikan berdasarkan material, ialah dari *Ingot Iron* (baja bongkah) tanpa Carbon sama sekali, sampai *Cost Iron* (baja tuang) yang mempunyai Carbon sekurang-kurangnya 1.70%.
Baja ini dibagi menjadi 4 kategori (berdasarkan Carbon yang dikandung):

1. Low Carbon (mengandung Carbon kurang dari 0,15%)
2. Mild Carbon (mengandung Carbon 0,15%-0,29%)
3. Medium Carbon (mengandung Carbon 0,30%-0,59%)
4. High Carbon (mengandung Carbon 0,60%-1,70%)

Structural Carbon Steel (Baja Carbon untuk konstruksi) adalah termasuk kategori Mild Carbon.

Penambahan prosentase Carbon akan mempertinggi Yield Stress tetapi akan mengurangi daktilitasnya *(ductility)*. Pengurangan daktilitas akan menambah problem-problem pada pengelasan. Pengelasan akan ekonomis dan memuaskan bila baja mengandung Carbon tidak lebih dari 0,30%.
A36 : Structural Steel (Fy = 36 ksi) ≈ 2500 kg/cm^2.

Baja konstruksi ini menggantikan A7 sejak tahun 1960. Baja A36 mempunyai Carbon maksimum antara 0,25% - 0,29%. A36

Spesifikasi baja yang ada

* ASTM (American Standard and Testing Method)
* CEN (Comite Europeen de Normalisation)
* DIN (Deutsches Institut fur Normung)
* JIS (Japan Industrial Standard)
* AS/NZS (Australian/ New Zealand Standard)
* SNI 1729:2015 mengacu pada ASTM
* SNI 03-1729-2002 masih dipergunakan di pasaran Indonesia

Spesifikasi Baja SNI 1729 : 2015

1a. Acuan ke ASTM

Material *baja struktural* yang sesuai dengan satu dari spesifikasi ASTM berikut yang disetujui untuk digunakan dalam Spesifikasi ini:

(1) Profil struktur canai panas

ASTM A36/A36M
ASTM A529/A529M
ASTM A572/A572M
ASTM A588/A588M
ASTM A709/A709M
ASTM A913/A913M
ASTM A992/A992M
ASTM A1043/A1043M

(2) Tabung struktur

ASTM A500
ASTM A501
ASTM A618/ASTM618M
ASTM A847/A847M

(3) Pipa

ASTM A53/A53M, Gr. B

(4) Pelat

ASTM A36/A36M
ASTM A242/A242M
ASTM A283/A283M
ASTM A514/A514M
ASTM A529/A529M
ASTM A572/A572M
ASTM A588/A588M
ASTM A709/A709M
ASTM A852/A852M
ASTM A1011/A1011M
ASTM A1043/A1043M

(5) Batang tulangan

ASTM A36/A36M
ASTM A529/A529M
ASTM A572/A572M
ASTM A709/A709M

(6) Lembaran baja

ASTM A606/A606M
ASTM A1011/A1011M SS, HSLAS, dan HSLAS-F

ASTM	Keterangan
A36	*Carbon Structural Steel* Catatan : jenis baja karbon yang umum dipakai untuk konstruksi.
A242	*High-Strength Low-Alloy Structural Steel* Catatan : baja tahan cuaca (*weathering steels*), bisa dipakai tanpa pengecatan.
A441	*High-Strength Low-Alloy Structural Manganese Vanadium Steel* Catatan : sudah tidak berlaku dan telah digantikan A572.
A514	*High-Yield Strength, Quenched and Tempered Alloy Steel Plate Suitable for Welding* Catatan : baja mutu tinggi untuk struktur jembatan dengan las
A529	*High-Strength Carbon-Manganese Steel of Structural Quality* Catatan : jenis baja karbon-mangan untuk konstruksi.
A572	*High-Strength Low-Alloy Columbium-Vanadium Steel* Catatan : baja mutu tinggi dengan lima grade mutu (42, 50, 55, 60 dan 65), adapun grade 50 setara dengan baja A992 yang lebih baru.
A588	*High-Strength Low-Alloy Structural Steel, up to 50 ksi [345 MPa] Minimum Yield Point, with Atmospheric Corrosion Resistance* Catatan : baja tahan cuaca (*weathering steels*), bisa dipakai tanpa pengecatan.
A633	*Normalized High-Strength Low-Alloy Structural Steel Plates* Catatan : cocok untuk temperatur rendah, −50°F [−45°C] ke atas.
A709	*Carbon and High-Strength Low-Alloy Structural Steel Shapes, Plates, and Bars and Quenched-and-Tempered Alloy Structural Steel Plates for Bridges* Catatan : baja pelat untuk struktur jembatan
A852	*Quenched and Tempered Low-Alloy Structural Steel Plate* Catatan : baja mutu tinggi untuk struktur jembatan dengan las, punya ketahanan korosi yang tinggi, tetapi tahun 2010 ditarik lagi karena tidak populer.
A871	*High-Strength Low-Alloy Structural Steel Plate With Atmospheric Corrosion Resistance* Catatan : baja tahan korosi untuk pipa atau tiang (pole)
A913	*High-Strength Low-Alloy Steel Shapes of Structural Quality, Produced by Quenching and Self-Tempering Process (QST)* Catatan : baja mutu tinggi mutu Grade 50, 60, 65 dan 70 , karena karakter proses pembuatannya maka tipe ini tidak boleh dipanasi lebih dari 600°C
A992	*Steel for Structural Shapes for Use in Building Framing* Catatan : spesifikasi baru (1998) profil baja *hot-rolled* setara A572 Gr.50 untuk bangunan tahan gempa, dimana ratio $F_y / F_u \leq 0.8$ untuk menjamin daktilitasnya. Populer digunakan sebagai pengganti baja karbon A36 (Zoruba dan Grubb 2003).
A1026	*Alloy Steel Structural Shapes for Use in Building Framing* Catatan : ratio $F_y / F_u \leq 0.8$, tidak boleh galvanis dan dipanasi lebih dari 400°C
A1043	*Structural Steel with Low Yield to Tensile Ratio for Use in Buildings* Catatan : material baru untuk struktur bangunan dengan ratio $F_y / F_u \leq 0.8$
A1077	*Standard Specification for Structural Steel with Improved Yield Strength at High Temperature for Use in Buildings* Catatan : spesifikasi baru (2012), material baja tahan api (*fire resistant steel*) untuk struktur bangunan gedung tanpa perlu tambahan lapisan *fire proofing*, karena mempunyai kuat leleh yang ditingkatkan pada temperatur tinggi.

Spesifikasi baja di pasar Indonesia

* SNI 03-1729-2002
  * BJ34 Fy= 210 MPa Fu= 340 MPa
  * BJ37 Fy= 240 MPa Fu= 370 MPa
  * BJ41 Fy= 250 MPa Fu= 410 MPa
  * BJ50 Fy= 290 MPa Fu= 500 MPa
  * BJ55 Fy= 410 MPa Fu= 550 MPa

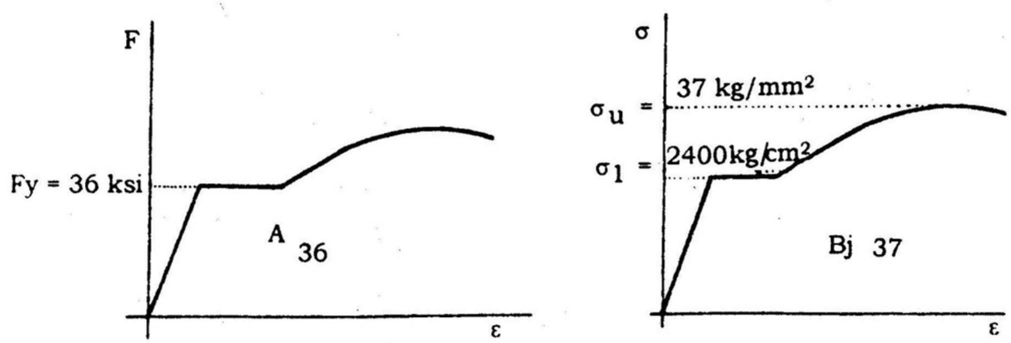
PERBANDINGAN ANTARA A36 DENGAN Bj 37

Dapat dilihat pada Tabel 1 halaman 6 PPBBI, besarnya tegangan leleh untuk Bj 37 = 2400 kg/cm².

Dibanding dengan tegangan leleh A36 yang terletak di antara 2200-2500 kg/cm², tampak bahwa harga σ_l Bj 37 terletak dalam range tegangan leleh A36, sehingga A36 dan Bj 37 ≈ sama.

Perlu diketahui bahwa yang dimaksud dengan baja A36 ialah bahwa baja tersebut 0 mempunyai tegangan leleh σ_l = 36 ksi, sedangkan Bj 37 mempunyai tegangan ultimate σ_u = 37 kg/mm² = 3700 kg/cm² (σ_u = tegangan ultimate).

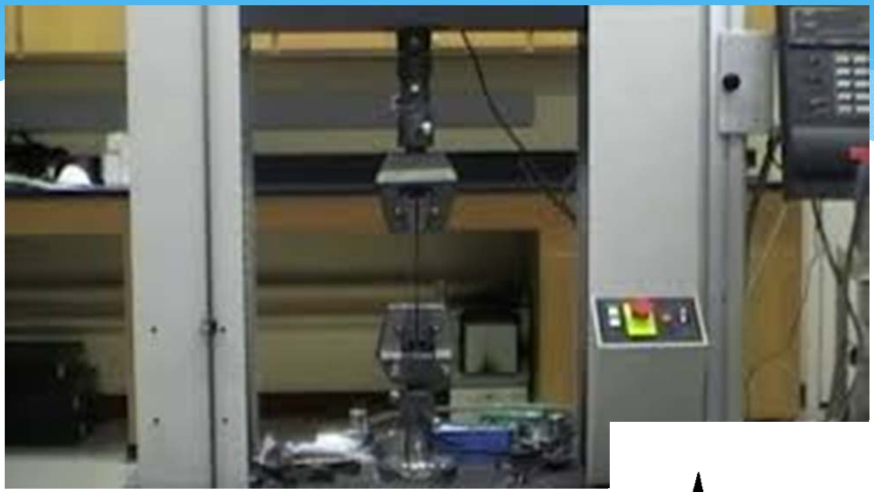
Perbandingan diagram tegangan-tegangan antara kedua macam baja ini dapat dilihat sebagai berikut:

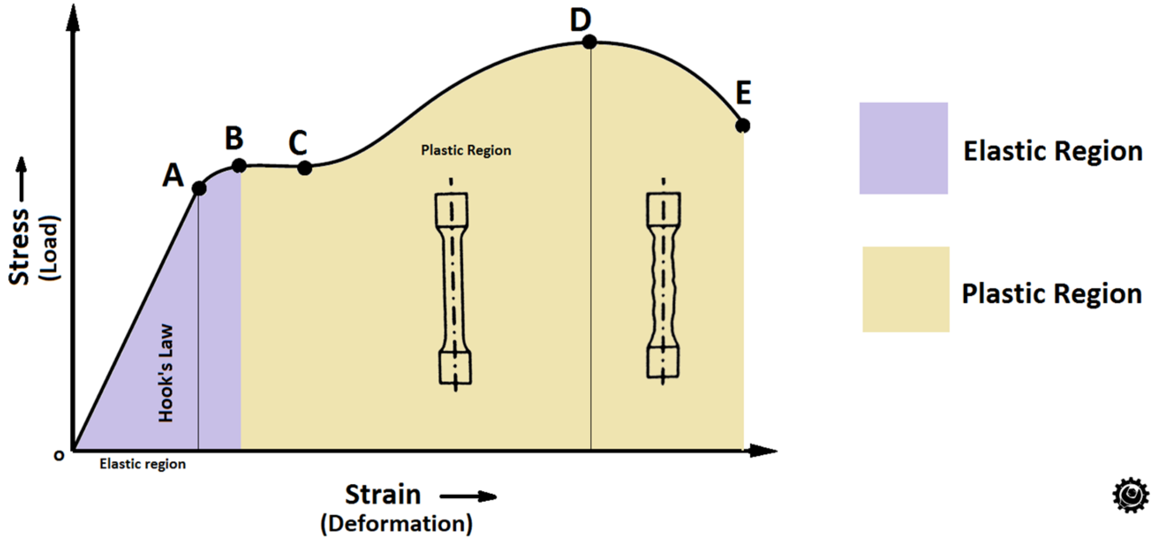


Gambar 1.1

Pada umumnya, di Indonesia, baik untuk bangunan gedung maupun jembatan, banyak dipakai Bj 37 ini. Jelasnya A36 mempunyai σ_l = 36 ksi dan Bj 37 mempunyai σ_u = 37 kg/cm².

Menentukan mutu baja





Canai Panas VS Canai Dingin

LOTOS TV

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Produk penampang baja

- Canai panas → penampang baja dibentuk dalam keadaan panas

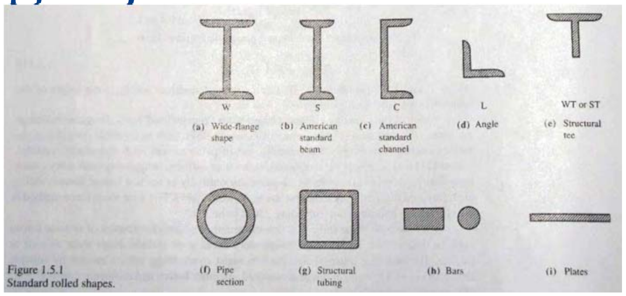


Figure 1.5.1
Standard rolled shapes.

- Canai dingin → penampang baja dibentuk dalam keadaan dingin

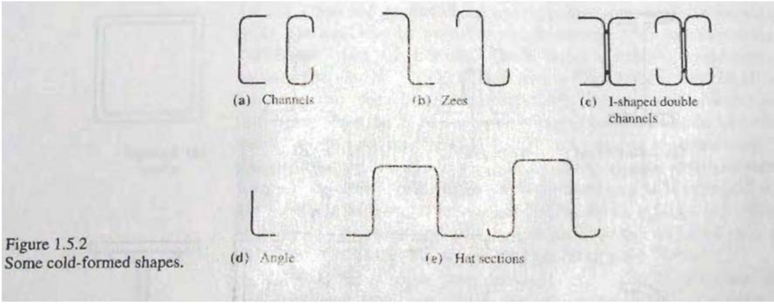
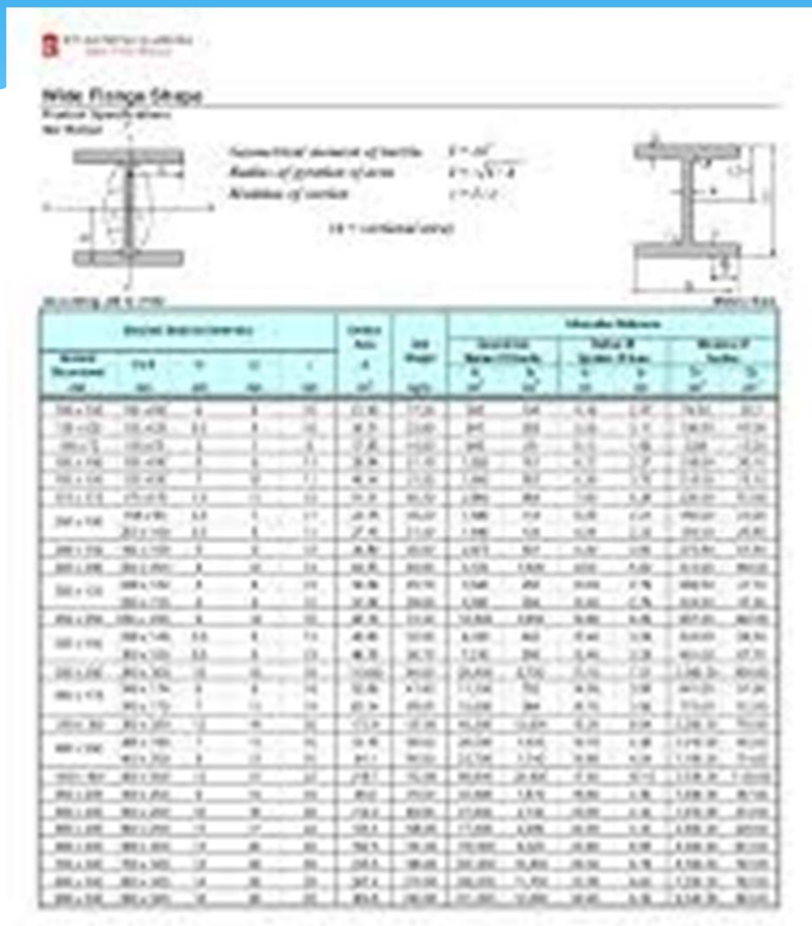


Figure 1.5.2
Some cold-formed shapes.

Produk-produk baja canai panas


Wide Flange Shape

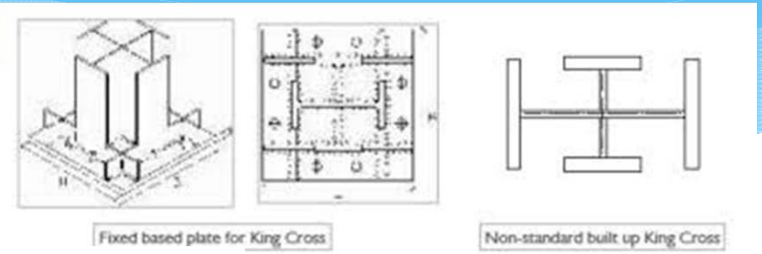
Disajikan dalam bentuk tabel-tabel

Tiap-tiap produsen baja mempunyai penamaan yang berbeda.

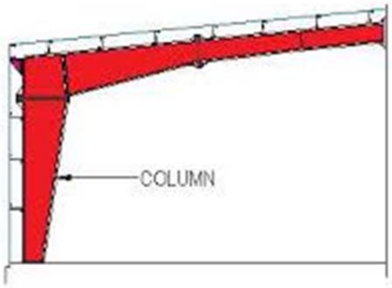
Penting diingat sebelum memutuskan untuk mempergunakan suatu profil dikonfirmasikan dahulu ketersediaannya

Variasi dari penampang baja

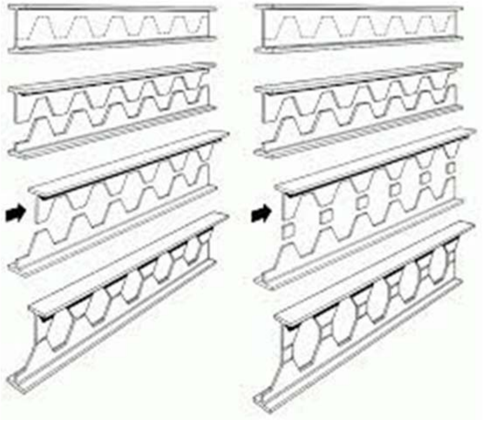
* Built-up (tersusun)



* Tappered



* Castelated



Alat-alat sambung

* Pasak
* Paku keling (sudah tidak dipergunakan)
* Rivet
* Sekrup (untuk baja ringan)
* Baut (non-struktural)
* Baut mutu tinggi (untuk struktur)
* Las (untuk struktur)

Bab 1. Introduction

1.1 Perencanaan Struktur

Structural design may be defined as a mixture of art and science, combining the experienced engineer's intuitive feeling for the behavior of a structure with a sound knowledge of the principles of statics, dynamics, mechanics of materials, and structural analysis, to produce a safe, economical structure that will serve its intended purpose.

Until about 1850, structural design was largely an art relying on intuition to determine the size and arrangement of the structural elements. Early man-made structures essentially conformed to those which could also be observed in nature, such as beams and arches. As the principles governing the behavior of structures and structural materials have become better understood, design procedures have become more scientific.

Computations involving scientific principles should serve as a *guide* to decision making and not be followed blindly. The art or intuitive ability of the experienced engineer is utilized to make the decisions, guided by the computational results.

1.2 Prinsip Perencanaan

- Prosedur desain :
  - Functional design ➔ arsitek
  - Structural framework design ➔ civil engineer
- Prosedur desain ➔ iterasi
  - Perencanaan
  - Preliminary konfigurasi struktur
  - Penentuan pembebanan yang diperlukan
  - Preliminary pemilihan elemen-elemen struktur
  - Analisa
  - Evaluasi
  - Redesain
  - Final desain

1.2 Prinsip Perencanaan

- Perencanaan → optimum solution
- Optimum pada struktur :
  - Minimum cost
  - Minimum weight
  - Minimum construction time
  - Minimum labor
  - Minimum cost of manufacture of owner's product
  - Maximum efficiency of operation to owner

1.3 Sejarah Struktur Baja

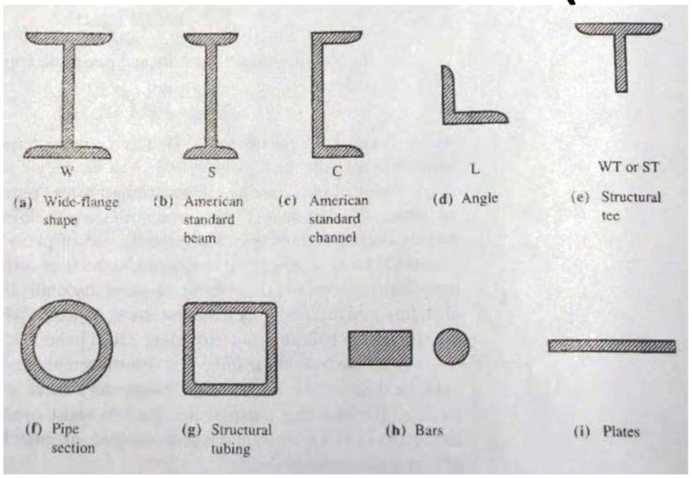
- Inggris (1777-1779) ➔ Cast iron
- 1780 – 1820 ➔ jembatan cast iron
- \- 1840 ➔ chain links, suspension bridge
- Sesudah 1840 ➔ wrought iron
  - Brittania Bridge, Wales (1846-1850)
- 1870 ➔ I-shapes for rails
- 1890 ➔ steel

1.4 Pembebanan

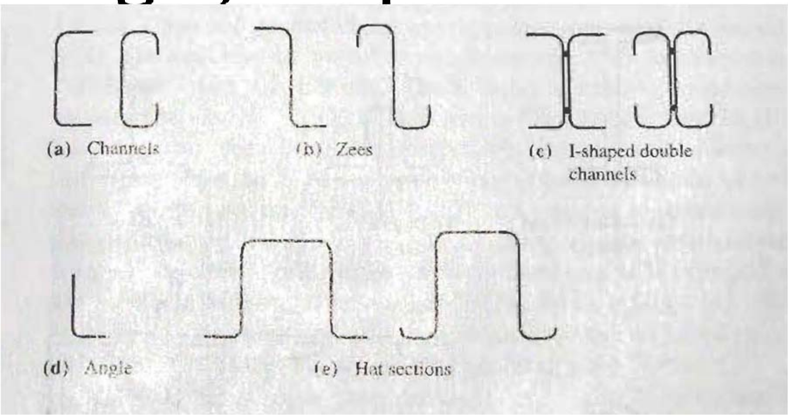
- Beban mati
- Beban hidup
- Beban hidup lalu lintas
- Beban kejut
- Beban salju
- Beban angin
- Beban gempa

1.5 Elemen-elemen Struktur Baja

- Standard rolled (canai panas) shapes

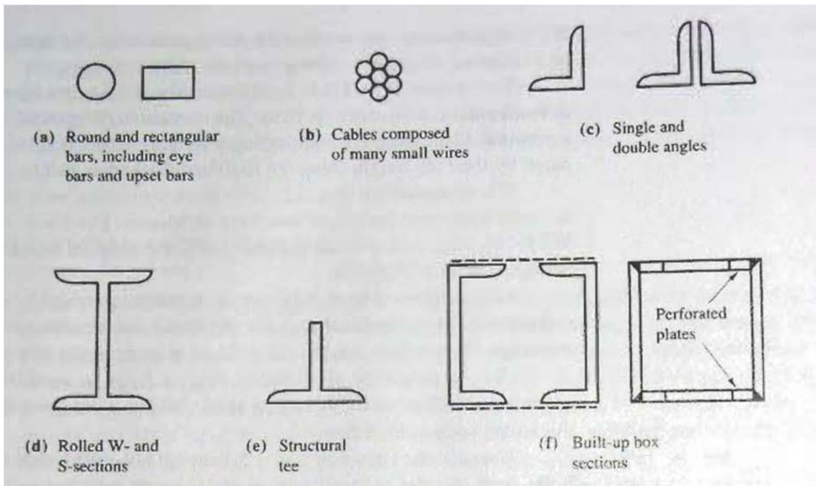


- Cold-formed (canai dingin) shapes

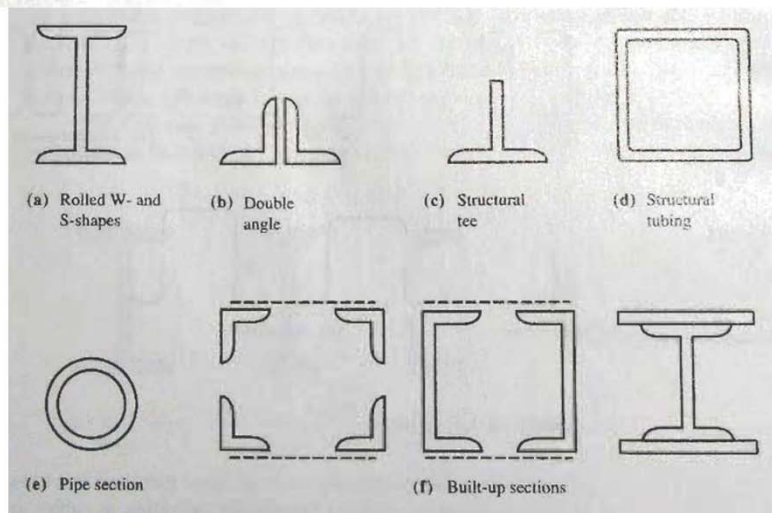


1.5 Elemen-elemen Struktur Baja

- Elemen tarik

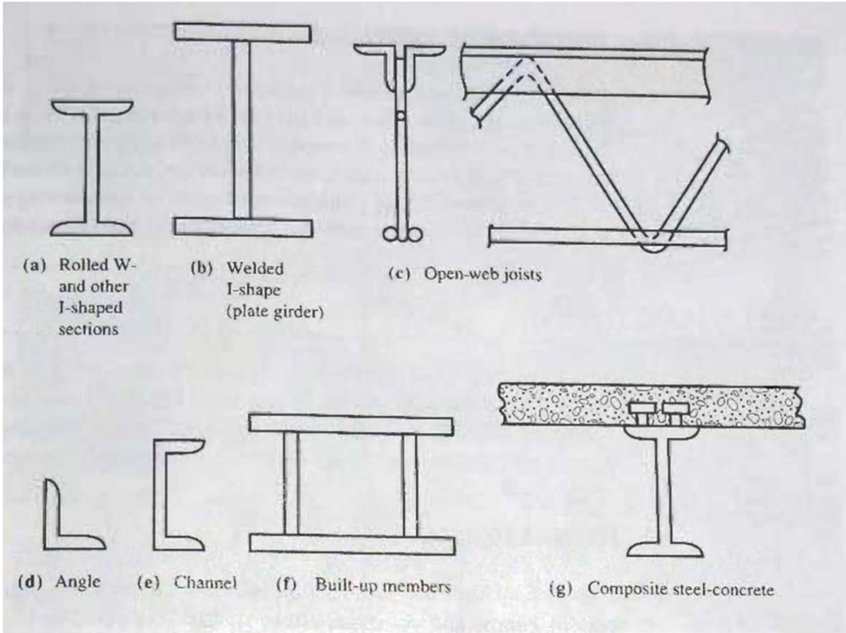


- Elemen tekan



1.5 Elemen-elemen Struktur Baja

- Balok (elemen lentur)



- Elemen lentur dan aksial

1.6 Struktur-struktur Baja

- Framed structures (rangka)

FIGURE 11.57
A 10-story steel frame nears completion. The lower floors have already been decked with corrugated steel decking. *(Courtesy Vulcraft Division of Nucor)*

FIGURE 11.80
The steel rigid frames of this industrial building carry steel purlins that will support the roof deck and girts to support the wall cladding. The depth of each frame varies with the magnitude of the bending forces and is greatest at the eave connections, where these forces are at a maximum. *(Courtesy of Metal Building Manufacturers Association)*

1.6 Struktur-struktur Baja

- Suspension-type structures (kabel)

- Shell-type structures (cangkang)
  - Fasad bangunan
  - Badan pesawat, mobil, dst

1.7 Spesifikasi dan "Building Codes"

SNI 1727:2013

Beban Minimum untuk Perancangan Gedung dan Struktur Lain

SNI 1726:2012

Tata Cara Perencanaan Ketahanan Gempa untuk Struktur Bangunan Gedung dan non Gedung

SNI 1729:2015

Spesifikasi untuk Bangunan Gedung Baja Struktural

1.8 Filosofi Desain

- AISC – Load and Resistance Factor Design (LRFD)

$$\phi R_n \geq [R_u = \Sigma \gamma_i Q_i]$$

$$1.4D \quad (1.8.2)$$

$$1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R) \quad (1.8.3)$$

$$1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (0.5L \text{ or } 0.8W) \quad (1.8.4)$$

$$1.2D + 1.3W + 0.5L + 0.5(L_r \text{ or } S \text{ or } R) \quad (1.8.5)$$

$$1.2D \pm 1.0E + 0.5L + 0.2S \quad (1.8.6)$$

$$0.9D \pm (1.3W \text{ or } 1.0E) \quad (1.8.7)$$

where the nominal *service loads* indicated by Eqs. 1.8.2 through 1.8.7 are

D = dead load (gravity load from the weight of structural elements and permanent attachments)
L = live load (gravity occupancy and movable equipment load)
L_r = roof live load
W = wind load
S = snow load
E = earthquake load
R = rainwater or ice load

1.8 Filosofi Desain

- AISC – Allowable Strength Design (ASD)

$$\left[\frac{\phi R_n}{\gamma} = \frac{R_n}{\Omega}\right] \geq \left[R_a = \Sigma \gamma_i Q_i\right]$$

$$D \quad (1.8.9)$$

$$D + L \quad (1.8.10)$$

$$D + L + (L_r \text{ or } S \text{ or } R) \quad (1.8.11)$$

$$D + (W \text{ or } 0.7E) + L + (L_r \text{ or } S \text{ or } R) \quad (1.8.12)$$

$$0.6D + W \quad (1.8.13)$$

$$0.6D + 0.7E \quad (1.8.14)$$

1.9 Faktor Keamanan Metode ASD dan Metode LRFD

Comparison of LRFD with ASD for Tension Members

The original LRFD Specification values were calibrated to the 1978 ASD Specification at a live load to dead load ratio of 3. To determine the relationship between φ and Ω, the nominal strengths from ASD and LRFD are equated. Using the live load and dead load combinations, with $L = 3D$, the required nominal strength can be expressed as follows:

From ASD: $$\frac{R_n}{\Omega} = D + L = D + 3D = 4D$$

$$R_n = 4D\Omega$$

From LRFD: $$\phi R_n = 1.2D + 1.6L = 1.2D + 1.6 \times 3D = 6D$$

$$R_n = \frac{6D}{\phi}$$

Equating and solving for Ω: $$\Omega = \frac{6D}{\phi} \times \frac{1}{4D} = \frac{1.5}{\phi}$$

Therefore, for $\phi = 0.9$, the value of $\Omega = 1.67$ and for $\phi = 0.75$, $\Omega = 2.00$.
A similar method was used to determine all the Ω values throughout the Specification.

The comparison of safety obtained for tension members designed by the two AISC methods is indicative of the general result expected. Direct comparisons have become easy for all types of members since the nominal strength in both methods is the same.

For tension members acted upon by gravity dead and live loads, the resistance factor $\phi = 0.90$, and using Eq. 1.8.3 gives for LRFD

$$1.2D + 1.6L = 0.90R_n \qquad [1.8.3]$$

$$1.33D + 1.78L = R_n \qquad \text{LRFD}$$

1.9 Faktor Keamanan Metode ASD dan Metode LRFD

In ASD the factor of safety $\Omega = 1.67$ for axial tension, which gives from Eq. 1.8.8 where (γ/ϕ is the factor of safety)

$$R_n/1.67 = \Sigma Q = D + L \qquad [1.8.8]$$

or

$$1.67D + 1.67L = R_n \qquad \text{ASD}$$

Next, dividing Eq. 1.8.3 by Eq. 1.8.8 gives

$$\frac{\text{LRFD}}{\text{ASD}} = \frac{1.33D + 1.78L}{1.67D + 1.67L} = \frac{0.8 + 1.07(L/D)}{1 + (L/D)} \qquad (1.9.6)$$

Since this is a gravity load comparison, Eq. 1.8.2 must also be used as L/D approaches zero. Thus, Eq. 1.8.2 gives

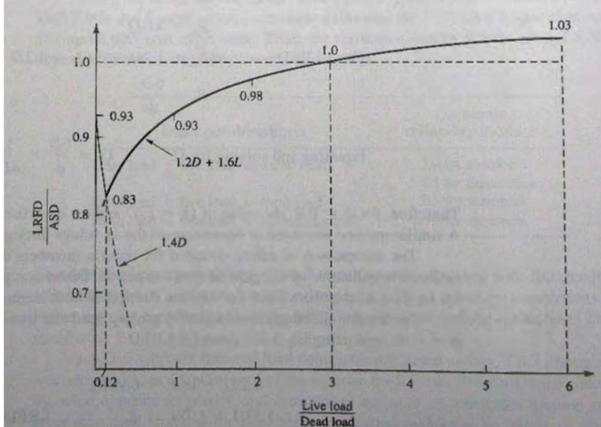
$$1.4D = 0.90R_n \qquad [1.8.2]$$

$$1.56D = R_n \qquad \text{LRFD}$$

Dividing LRFD by ASD gives

$$\frac{\text{LRFD}}{\text{ASD}} = \frac{1.56D}{1.67D + 1.67L} = \frac{0.93}{1 + (L/D)} \qquad (1.9.7)$$

Equations 1.9.6 and 1.9.7 are shown plotted in Fig. 1.9.1. The design of tension members will be about the same in both LRFD and ASD when the live load to dead load ratio (L/D) is about 3. As the L/D ratio becomes lower (that is, dead load becomes more predominant) there will be economy in using LRFD. With L/D ratio larger than 3, ASD will be slightly more economical, but rarely by more than about 3%.



1.10 Mengapa Metode LRFD?

1. LRFD is another "tool" for structural engineers to use in steel design. Why not have the same tools (variable overload factors and resistance factors) available for steel design as are available for concrete design?

2. Adoption of LRFD is not mandatory but provides a flexibility of options to the designer. The marketplace will dictate whether or not LRFD will become the sole method.

3. ASD is an approximate way to account for what LRFD does in a more rational way. The use of plastic design concepts in ASD has made ASD such that it no longer may be called an "elastic design" method.

4. The rationality of LRFD has always been attractive, and becomes an incentive permitting the better and more economical use of material for some load combinations and structural configurations. It will also likely produce safer structures in view of the arbitrary practice under ASD of combining dead and live loads and treating them the same.

5. Using multiple load factor combinations should lead to economy.

6. LRFD will facilitate the input of new information on loads and load variations as such information becomes available. Considerable knowledge of the resistance of steel structures is available. On the other hand, our knowledge of loads and their variation is much less. Separating the loading from the resistance allows one to be changed without the other if that should be desired.

7. Changes in overload factors and resistance factors ϕ are much easier to make than to change the allowable stress in ASD.

8. LRFD makes design in all materials more compatible. The variability of loads is actually unrelated to the material used in the design. Future specifications not in the limit states format for any material will put that material at a disadvantage in design.

9. LRFD provides the framework to handle unusual loads that may not be covered by the Specification. The design may have uncertainty relating to the resistance of the structure, in which case the resistance factors may be modified. On the other hand, the uncertainty may relate to the loads and different overload factors may be used.

10. Future adjustments in the calibration of the method can be made without much complication. Calibration for LRFD was done for an *average* situation but might be adjusted in the future.

11. Economy is likely to result for low live load to dead load ratios. For high live load to dead load ratios there will be slightly greater costs.

12. Safer structures may result under LRFD because the method should lead to a better awareness of structural behavior.

13. Design practice is still at the beginning with regard to serviceability limit states; however, at least LRFD provides the approach.

1.11 Analisa Struktur

- Elastis (LRFD atau ASD)
- Plastic collapse mechanism
- First order analysis
- Second order effect