

TUGAS AKHIR

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BAB 1
PENDAHULUAN**1.1. Latar Belakang**

Pesatnya perkembangan dunia teknik sipil menuntut bangsa Indonesia untuk dapat menghadapi segala kemajuan dan tantangan. Hal itu dapat terpenuhi apabila sumber daya yang dimiliki oleh bangsa Indonesia memiliki kualitas pendidikan yang tinggi, Karena pendidikan merupakan sarana utama untuk semakin siap menghadapi perkembangan ini.

Dalam hal ini bangsa Indonesia telah menyediakan berbagai sarana guna memenuhi sumber daya manusia yang berkualitas. Sehingga Universitas Sebelas Maret Surakarta sebagai salah satu lembaga pendidikan dalam merealisasikan hal tersebut memberikan Tugas Akhir sebuah perencanaan gedung bertingkat dengan maksud agar menghasilkan tenaga yang bersumber daya dan mampu bersaing dalam dunia kerja.

1.2. Maksud Dan Tujuan

Dalam menghadapi pesatnya perkembangan jaman yang semakin modern dan berteknologi, serta derasnya arus globalisasi saat ini, sangat diperlukan seorang teknisi yang berkualitas. Khususnya dalam bidang teknik sipil, sangat diperlukan teknisi-teknisi yang menguasai ilmu dan keterampilan dalam bidangnya. Fakultas Teknik Universitas Sebelas Maret Surakarta sebagai lembaga pendidikan bertujuan untuk menghasilkan ahli teknik yang berkualitas, bertanggungjawab, kreatif dalam menghadapi masa depan serta dapat mensukseskan pembangunan nasional di Indonesia.

TUGAS AKHIR

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Fakultas Teknik Universitas Sebelas Maret Program D III Jurusan Teknik Sipil memberikan Tugas Akhir dengan maksud dan tujuan :

1. Mahasiswa dapat merencanakan suatu konstruksi bangunan yang sederhana sampai bangunan bertingkat.
2. Mahasiswa diharapkan dapat memperoleh pengetahuan, pengertian dan pengalaman dalam merencanakan struktur gedung.
3. Mahasiswa dapat mengembangkan daya fikirnya dalam memecahkan suatu masalah yang dihadapi dalam perencanaan struktur gedung.

1.3. Kriteria Perencanaan

1. Spesifikasi Bangunan

- a. Fungsi Bangunan : Butik
- b. Luas Bangunan : 733,5 m²
- c. Jumlah Lantai : 2 lantai
- d. Tinggi Lantai : 4 m
- e. Konstruksi Atap : a. Plat beton bertulang
b. Rangka kuda-kuda baja
- f. Penutup Atap : Genteng
- g. Pondasi : *Foot Plat*

2. Spesifikasi Bahan

- a. Mutu Baja Profil : BJ 37
- b. Mutu Beton (f'c) : 30 MPa
- c. Mutu Baja Tulangan (fy) : Polos: 240 MPa. Ulir: 360 Mpa.

1.4. Peraturan-Peraturan Yang Digunakan

1. Standart tata cara perhitungan struktur beton untuk bangunan gedung (SKSNI T-15-1991-03)
2. Peraturan Pembebanan Indonesia Untuk Gedung 1983
3. Standart tata cara perencanaan struktur baja untuk bangunan gedung PPBBI 1984

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TUGAS AKHIR

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BAB 2**DASAR TEORI****2.1. Dasar Perencanaan****2.1.1. Jenis Pembebanan**

Dalam merencanakan struktur suatu bangunan bertingkat, digunakan struktur yang mampu mendukung berat sendiri, gaya angin, beban hidup maupun beban khusus yang bekerja pada struktur bangunan tersebut. Beban-beban yang bekerja pada struktur dihitung menurut **Peraturan Pembebanan Indonesia Untuk Gedung 1983**, beban-beban tersebut adalah :

1. Beban Mati (qd)

Beban mati adalah berat dari semua bagian suatu gedung yang bersifat tetap, termasuk segala unsur tambahan, penyelesaian–penyelesaian, mesin-mesin serta peralatan tetap yang merupakan bagian tak terpisahkan dari gedung. Untuk merencanakan gedung, beban mati yang terdiri dari berat sendiri bahan bangunan dan komponen gedung adalah :

a) Bahan Bangunan :

1. Beton Bertulang 2400 kg/m³

TUGAS AKHIR

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2. Pasir 1800 kg/m³
3. Beton biasa..... 2200 kg/m³

b) Komponen Gedung :

1. Langit – langit dan dinding (termasuk rusuk – rusuknya,
tanpa penggantung langit-langit atau pengaku),terdiri dari :
- semen asbes (eternit) dengan tebal maximum 4mm..... 11 kg/m²
 - kaca dengan tebal 3 – 4 mm..... 10 kg/m²
2. Penggantung langit- langit (dari kayu), dengan bentang
maksimum 5 m dan jarak s.k.s. minimum 0,80 m..... 7 kg/m²
3. Penutup lantai dari tegel, keramik dan beton (tanpa adukan)
3
per cm tebal..... 24 kg/m²
4. Adukan semen per cm tebal..... 21 kg/m²
5. Penutup atap genteng dengan reng dan usuk 50 kg/m²

2. Beban Hidup (ql)

Beban hidup adalah semua bahan yang terjadi akibat penghuni atau pengguna suatu gedung, termasuk beban-beban pada lantai yang berasal dari barang-barang yang dapat berpindah, mesin-mesin serta peralatan yang merupakan bagian yang tidak terpisahkan dari gedung dan dapat diganti selama masa hidup dari gedung

TUGAS AKHIR

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itu, sehingga mengakibatkan perubahan pembebanan lantai dan atap tersebut.

Khususnya pada atap, beban hidup dapat termasuk beban yang berasal dari air hujan (**PPIUG 1983**). Beban hidup yang bekerja pada bangunan ini disesuaikan dengan rencana fungsi bangunan tersebut. Beban hidup untuk bangunan ini terdiri dari :

Beban atap.....	100 kg/m ²
Beban tangga dan bordes	300 kg/m ²
Beban lantai	250 kg/m ²

Berhubung peluang untuk terjadi beban hidup penuh yang membebani semua bagian dan semua unsur struktur pemikul secara serempak selama unsur gedung tersebut adalah sangat kecil, maka pada perencanaan balok induk dan portal dari sistem pemikul beban dari suatu struktur gedung, beban hidupnya dikalikan dengan suatu koefisien reduksi yang nilainya tergantung pada penggunaan gedung yang ditinjau, seperti diperlihatkan pada tabel :

TUGAS AKHIR

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Tabel 2.1 Koefisien reduksi beban hidup

Penggunaan Gedung	Koefisien Beban Hidup untuk Perencanaan Balok Induk
<ul style="list-style-type: none"> • PERUMAHAN / HUNIAN: Rumah sakit / Poliklinik 	0,75
<ul style="list-style-type: none"> • PERTEMUAN UMUM : Ruang Rapat, R. Pagelaran, Musholla 	0,90
<ul style="list-style-type: none"> • PENYIMPANAN : Perpustakaan, Ruang Arsip 	0,80
<ul style="list-style-type: none"> • PEDAGANGAN : Toko, Toserba, pasar 	0,80

Sumber : PPIUG 1983

3. Beban Angin (W)

Beban Angin adalah semua beban yang bekerja pada gedung atau bagian gedung yang disebabkan oleh selisih dalam tekanan udara (**PPIUG 1983**).

Beban Angin ditentukan dengan menganggap adanya tekanan positif dan tekanan negatif (hisapan), yang bekerja tegak lurus pada bidang yang ditinjau. Besarnya tekanan positif dan negatif yang dinyatakan dalam kg/m^2 ini ditentukan dengan mengalikan tekanan tiup dengan koefisien – koefisien angin. Tekan tiup harus

TUGAS AKHIR

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diambil minimum 25 kg/m^2 , kecuali untuk daerah di laut dan di tepi laut sampai sejauh 5 km dari tepi pantai. Pada daerah tersebut tekanan hisap diambil minimum 40 kg/m^2 .

Sedangkan koefisien angin untuk gedung tertutup :

1. Dinding Vertikal

- a) Di pihak angin + 0,9
 b) Di belakang angin - 0,4

2. Atap segitiga dengan sudut kemiringan α

- a) Di pihak angin : $\alpha < 65^\circ$ $0,02 \alpha - 0,4$
 $65^\circ < \alpha < 90^\circ$ + 0,9
 b) Di belakang angin, untuk semua α - 0,4

2.1.2. Sistem Kerjanya Beban

Bekerjanya beban untuk bangunan bertingkat berlaku sistem gravitasi, yaitu elemen struktur yang berada di atas akan membebani elemen struktur di bawahnya, atau dengan kata lain elemen struktur yang mempunyai kekuatan lebih

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TUGAS AKHIR

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besar akan menahan atau memikul elemen struktur yang mempunyai kekuatan lebih kecil. Dengan demikian sistem kerjanya beban untuk elemen – elemen struktur gedung bertingkat secara umum dapat dinyatakan sebagai berikut; Beban pelat lantai didistribusikan terhadap balok anak dan balok portal, beban balok portal didistribusikan ke kolom dan beban kolom kemudian diteruskan ke tanah dasar melalui pondasi.

2.1.3. Provisi Keamanan

Dalam Peraturan Pembebanan Indonesia Untuk Gedung 1983, struktur harus direncanakan memiliki cadangan kekuatan untuk memikul beban yang lebih tinggi dari beban normal. Kapasitas cadangan ini mencakup faktor pembebanan (U), yaitu untuk memperhitungkan pelampauan beban dan faktor reduksi (ϕ), yaitu untuk memperhitungkan kurangnya mutu bahan di lapangan. Pelampauan beban dapat terjadi akibat perubahan dari penggunaan untuk apa struktur direncanakan dan penafsiran yang kurang tepat dalam memperhitungkan pembebanan. Sedang kekurangan kekuatan dapat diakibatkan oleh variasi yang merugikan dari kekuatan bahan, pengerjaan, dimensi, pengendalian dan tingkat pengawasan.

Tabel 2.2 Faktor Pembebanan U

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TUGAS AKHIR

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No.	KOMBINASI BEBAN	FAKTOR U
1.	D, L	$1,2 D + 1,6 L$
2.	D, L, W	$0,75 (1,2 D + 1,6 L + 1,6 W)$
3.	D, W	$0,9 D + 1,3 W$
4.	D, Lr, E	$1,05 (D + Lr \pm E)$
5.	D, E	$0,9 (D \pm E)$

Keterangan :

D = Beban mati

L = Beban hidup

Lr = Beban hidup tereduksi

W = Beban angin

E = Beban gempa

TUGAS AKHIR

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Tabel 2.3 Faktor Reduksi Kekuatan ϕ

No	GAYA	ϕ
1.	Lentur tanpa beban aksial	0,80
2.	Aksial tarik dan aksial tarik dengan lentur	0,80
3.	Aksial tekan dan aksial tekan dengan lentur	0,65 – 0,80
4.	Geser dan torsi	0,60
5.	Tumpuan Beton	0,70

Karena kandungan agregat kasar untuk beton struktural seringkali berisi agregat kasar berukuran diameter lebih dari 2 cm, maka diperlukan adanya jarak tulangan minimum agar campuran beton basah dapat melewati tulangan baja tanpa terjadi pemisahan material sehingga timbul rongga – rongga pada beton. Sedang untuk melindungi dari karat dan kehilangan kekuatannya dalam kasus kebakaran, maka diperlukan adanya tebal selimut beton minimum :

Beberapa persyaratan utama pada Peraturan Pembebanan Indonesia Untuk Gedung 1983 adalah sebagai berikut :

- a. Jarak bersih antara tulangan sejajar yang selapis tidak boleh kurang dari d_b atau 25 mm, dimana d_b adalah diameter tulangan
- b. Jika tulangan sejajar tersebut diletakkan dalam dua lapis atau lebih, tulangan pada lapisan atas harus diletakkan tepat diatas tulangan di bawahnya dengan jarak bersih tidak boleh kurang dari 25 mm

TUGAS AKHIR

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Tebal selimut beton minimum untuk beton yang dicor setempat adalah:

- | | |
|--|---------|
| a. Untuk pelat dan dinding | = 20 mm |
| b. Untuk balok dan kolom | = 40 mm |
| c. Beton yang berhubungan langsung dengan tanah atau cuaca | = 50 mm |

2.2. Perencanaan Atap

1. Pada perencanaan atap ini, beban yang bekerja adalah :

- Beban mati
- Beban hidup
- Beban angin

2. Asumsi Perletakan

- Tumpuan sebelah kiri adalah Sendi.
- Tumpuan sebelah kanan adalah Rol.

3. Analisa tampang menggunakan peraturan **PPBBI 1984**.

Dan untuk perhitungan dimensi profil rangka kuda kuda:

a. Batang tarik

$$Fn = \frac{P_{mak}}{\sigma_{ijin}}$$

$$\sigma_{ijin} = \frac{2}{3} \times (\sigma = 2400 \text{ kg/cm}^2) = 1600 \text{ kg/cm}^2$$

$$F_{bruto} = 1,15 \times Fn \dots\dots (< F \text{ Profil})$$

Dengan syarat $\sigma \text{ terjadi} \leq 0,75 \sigma \text{ ijin}$

$$\sigma \text{ terjadi} = \frac{P_{mak}}{0,85 \cdot F_{profil}}$$

TUGAS AKHIR

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b. Batang tekan

$$\lambda = \frac{lk}{i_x}$$

$$\lambda_g = \pi \sqrt{\frac{E}{0,7 \cdot \sigma_{leleh}}} \quad \text{..... dimana, } \sigma_{leleh} = 2400 \text{ kg/cm}^2$$

$$\lambda_s = \frac{\lambda}{\lambda_g}$$

Apabila = $\lambda_s \leq 1$ \longrightarrow $\omega = 1$

$0,813 < \lambda_s < 1$ \longrightarrow $\omega = \frac{1,41}{1,593 - \lambda_s}$

$\lambda_s \geq 1$ \longrightarrow $\omega = 2,381 \cdot \lambda_s^2$

kontrol tegangan :

$$\sigma = \frac{P_{maks.} \cdot \omega}{F_p} < \sigma_{ijin} = 0,75 \cdot 1600 \text{ kg/cm}^2$$

2.3. Perencanaan Tangga

Untuk perhitungan penulangan tangga dipakai kombinasi pembebanan akibat beban mati dan beban hidup yang disesuaikan dengan Peraturan Pembebanan

TUGAS AKHIR

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Indonesia Untuk Gedung (**PPIUG 1983**) dan **SK SNI T -15 -1991-03** dan analisa struktur menggunakan perhitungan **SAP 2000**.

sedangkan untuk tumpuan diasumsikan sebagai berikut :

- Tumpuan bawah adalah Jepit.
- Tumpuan tengah adalah Jepit.
- Tumpuan atas adalah Jepit.

Perhitungan untuk penulangan tangga

$$M_n = \frac{M_u}{\phi}$$

dimana, $\phi = 0,80$

$$m = \frac{f_y}{0,85x f'_c}$$

$$R_n = \frac{M_n}{bxd^2}$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{f_y}} \right)$$

$$\rho_b = \frac{0,85 \cdot f_c}{f_y} \cdot \beta_1 \cdot \left(\frac{600}{600 + f_y} \right)$$

$$\rho_{\max} = 0,75 \cdot \rho_b$$

$\rho_{\min} < \rho < \rho_{\max}$ → tulangan tunggal

$\rho < \rho_{\min}$ → dipakai $\rho_{\min} = 0,0025$

$$A_s = \rho_{ada} \cdot b \cdot d$$

Luas tampang tulangan

$$A_s = \rho b x d$$

2.4. Perencanaan Plat Lantai

1. Pembebanan :

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TUGAS AKHIR

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- Beban mati
 - Beban hidup : 400 kg/m²
2. Asumsi Perletakan : jepit penuh
 3. Analisa struktur menggunakan tabel 13.3.2 **PPIUG**.
 4. Analisa tampang menggunakan **SKSNI**

Pemasangan tulangan lentur disyaratkan sebagai berikut :

1. Jarak minimum tulangan sengkang 25 mm
2. Jarak maksimum tulangan sengkang 240 atau 2h

Penulangan lentur dihitung analisa tulangan tunggal dengan langkah-langkah sebagai berikut :

$$M_n = \frac{M_u}{\phi}$$

dimana, $\phi = 0,80$

$$m = \frac{f_y}{0,85x f'_c}$$

$$R_n = \frac{M_n}{bxd^2}$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{f_y}} \right)$$

$$\rho_b = \frac{0,85 \cdot f_c}{f_y} \cdot \beta \cdot \left(\frac{600}{600 + f_y} \right)$$

$$\rho_{\max} = 0,75 \cdot \rho_b$$

$\rho_{\min} < \rho < \rho_{\max}$ → tulangan tunggal

$\rho < \rho_{\min}$ → dipakai $\rho_{\min} = 0,0025$

$$A_s = \rho_{ada} \cdot b \cdot d$$

Luas tampang tulangan

$$A_s = \rho bxd$$

TUGAS AKHIR

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2.5. Perencanaan Balok Anak

1. Pembebanan
2. Asumsi Perletakan : jepit jepit
3. Analisa struktur pada perencanaan atap ini menggunakan program **SAP 2000**.
4. Analisa tampang menggunakan peraturan **SKSNI T -15-1991-03**.

Perhitungan tulangan lentur :

$$M_n = \frac{M_u}{\phi}$$

dimana, $\phi = 0,80$

$$m = \frac{f_y}{0,85x f'_c}$$

$$R_n = \frac{M_n}{bxd^2}$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2.m.R_n}{f_y}} \right)$$

$$\rho_b = \frac{0,85.f_c}{f_y} \cdot \beta_1 \cdot \left(\frac{600}{600 + f_y} \right)$$

$$\rho_{max} = 0,75 \cdot \rho_b$$

$\rho_{min} < \rho < \rho_{maks}$ → tulangan tunggal

$\rho < \rho_{min}$ → dipakai $\rho_{min} = \frac{1,4}{f'_y}$

Perhitungan tulangan geser :

$$\phi = 0,60$$

$$V_c = \frac{1}{6} x \sqrt{f'_c} x b x d$$

$$\phi V_c = 0,6 x V_c$$

$$\Phi.V_c \leq V_u \leq 3 \Phi V_c$$

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TUGAS AKHIR

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(perlu tulangan geser)

$$V_u < \emptyset V_c < 3 \emptyset V_c$$

(tidak perlu tulangan geser)

$$V_s \text{ perlu} = V_u - V_c$$

(pilih tulangan terpasang)

$$V_s \text{ ada} = \frac{(A_v \cdot f_y \cdot d)}{s}$$

(pakai V_s perlu)

TUGAS AKHIR

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2.6. Perencanaan Portal

1. Pembebanan
2. Asumsi Perletakan
 - Jepit pada kaki portal.
 - Bebas pada titik yang lain
3. Analisa struktur pada perencanaan atap ini menggunakan program **SAP 2000**.

Perhitungan tulangan lentur :

$$M_n = \frac{M_u}{\phi}$$

dimana, $\phi = 0,80$

$$m = \frac{f_y}{0,85x f'_c}$$

$$R_n = \frac{M_n}{bxd^2}$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{f_y}} \right)$$

$$\rho_b = \frac{0,85 \cdot f_c}{f_y} \cdot \beta \cdot \left(\frac{600}{600 + f_y} \right)$$

$$\rho_{\max} = 0,75 \cdot \rho_b$$

$\rho_{\min} < \rho < \rho_{\max}$ → tulangan tunggal

$\rho < \rho_{\min}$ → dipakai $\rho_{\min} = \frac{1,4}{f'_y}$

Perhitungan tulangan geser :

$$\phi = 0,60$$

$$V_c = \frac{1}{6} x \sqrt{f'_c} x b x d$$

$$\phi V_c = 0,6 x V_c$$

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$$\Phi \cdot V_c \leq V_u \leq 3 \Phi V_c$$

(perlu tulangan geser)

$$V_u < \emptyset V_c < 3 \emptyset V_c$$

(tidak perlu tulangan geser)

$$V_s \text{ perlu} = V_u - V_c$$

(pilih tulangan terpasang)

$$V_s \text{ ada} = \frac{(A_v \cdot f_y \cdot d)}{s}$$

(pakai V_s perlu)

2.7. Perencanaan Pondasi

1. Pembebanan : Beban aksial dan momen dari analisa struktur portal akibat beban mati dan beban hidup.
2. Analisa tampang menggunakan peraturan **SKSNI T -15-1991-03**.

Perhitungan kapasitas dukung pondasi :

$$\sigma_{\text{yang terjadi}} = \frac{V_{\text{tot}}}{A} + \frac{M_{\text{tot}}}{\frac{1}{6} \cdot b \cdot L^2}$$

$$= \sigma_{\text{tan ahterjadi}} < \sigma_{\text{ijin tanah}} \dots \dots \dots (\text{dianggap aman})$$

Sedangkan pada perhitungan tulangan lentur

$$M_u = \frac{1}{2} \cdot q_u \cdot t^2$$

$$m = \frac{f_y}{0,85 \cdot f'_c}$$

$$R_n = \frac{M_n}{b \cdot x d^2}$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{f_y}} \right)$$

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$$\rho_b = \frac{0,85 \cdot f_c}{f_y} \cdot \beta \cdot \left(\frac{600}{600 + f_y} \right)$$

$$\rho_{\max} = 0,75 \cdot \rho_b$$

$\rho_{\min} < \rho < \rho_{\max}$ → tulangan tunggal

$\rho < \rho_{\min}$ → dipakai $\rho_{\min} = 0,0036$

$$A_s = \rho_{\text{ada}} \cdot b \cdot d$$

Luas tampang tulangan

$$A_s = \rho b x d$$

Perhitungan tulangan geser :

$$V_u = \sigma \times A_{\text{efektif}}$$

$$\phi = 0,60$$

$$V_c = \frac{1}{6} \times \sqrt{f'_c} \times b \times d$$

$$\phi V_c = 0,6 \times V_c$$

$$\Phi \cdot V_c \leq V_u \leq 3 \Phi V_c$$

(perlu tulangan geser)

$$V_u < \Phi V_c < 3 \Phi V_c$$

(tidak perlu tulangan geser)

$$V_s \text{ perlu} = V_u - V_c$$

(pilih tulangan terpasang)

$$V_s \text{ ada} = \frac{(A_v \cdot f_y \cdot d)}{s}$$

(pakai V_s perlu)

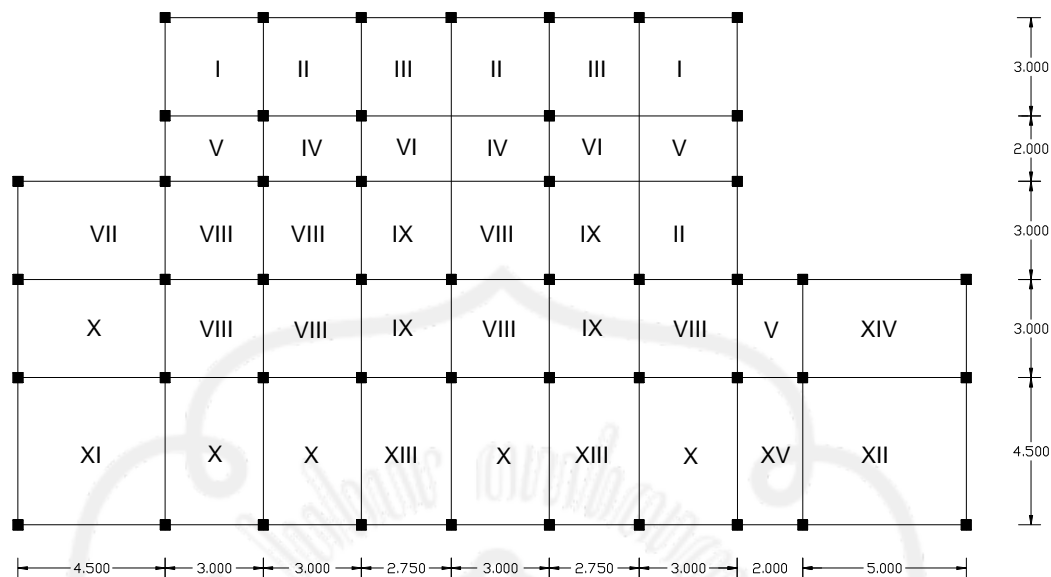
BAB 5

PLAT LANTAI

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5.1. Perencanaan Plat Lantai



Gambar 5.1. Denah Plat lantai

5.1.1. Perhitungan Pembebanan Plat Lantai

a. Beban Hidup (qL)

Berdasarkan PPIUG untuk gedung 1983 yaitu, beban hidup pada lantai gedung untuk R. Pagelaran adalah $= 400 \text{ kg/m}^2$
 $qL = 0,40 \text{ ton/m}^2$

b. Beban Mati (qD)

Berat plat sendiri	$= 0,12 \times 2,4 \times 1$	$= 0,288 \text{ ton/m}^2$
Berat keramik (1 cm)	$= 0,01 \times 2,4 \times 1$	$= 0,024 \text{ ton/m}^2$
Berat Spesi (2 cm)	$= 0,02 \times 2,1 \times 1$	$= 0,042 \text{ ton/m}^2$
Berat plafond + Penggantung	$= 0,011 + 0,007$	$= 0,018 \text{ ton/m}^2$
Berat Pasir (2 cm)	$= 0,02 \times 1,6 \times 1$	$= 0,032 \text{ ton/m}^2$
		$qD = 0,404 \text{ ton/m}^2$

➤ Beban Ultimate (qU)

$$qU = 1,2 qD + 1,6 qL$$

$$= 1,2 \cdot 0,404 + 1,6 \cdot 0,40 \quad 92$$

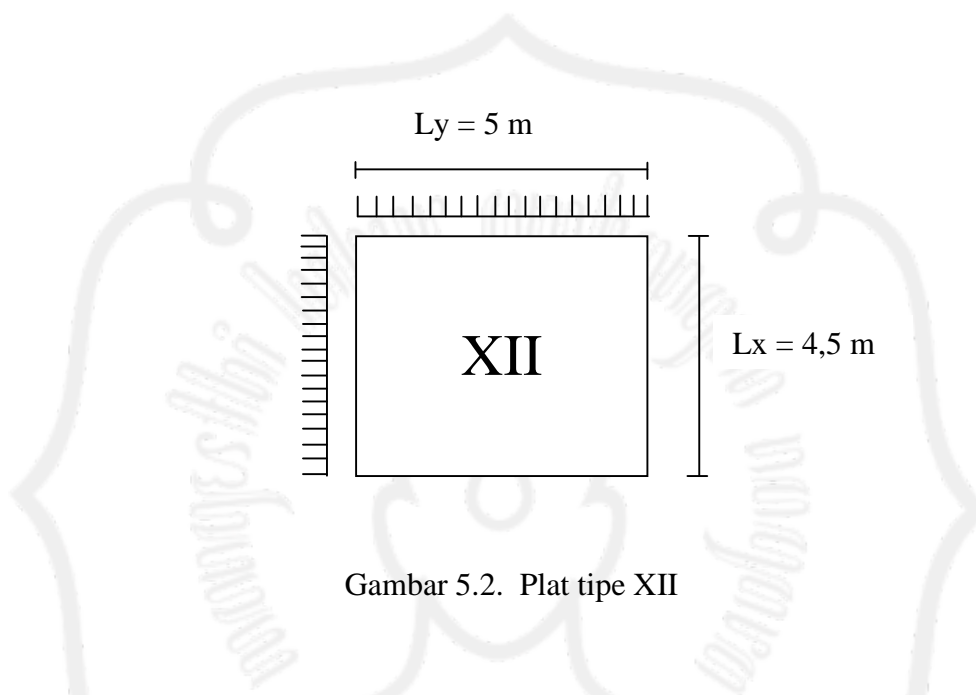
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$$= 1,125 \text{ ton/m}^2$$

5.1.2. Perhitungan Momen

Perhitungan momen untuk pelat dua arah yaitu dengan tabel momen per meter lebar dalam jalur tengah akibat beban terbagi rata



Gambar 5.2. Plat tipe XII

$$\frac{L_y}{L_x} = \frac{5,0}{4,5} = 1,11 = 1,2$$

$$M_{lx} = 0,001 \cdot q_u \cdot L_x^2 \cdot x = 0,001 \cdot 1,125 \cdot (4,5)^2 \cdot 38 = 0,866 \text{ ton m}$$

$$M_{ly} = 0,001 \cdot q_u \cdot L_x^2 \cdot x = 0,001 \cdot 1,125 \cdot (4,5)^2 \cdot 28 = 0,638 \text{ ton m}$$

$$M_{tx} = 0,001 \cdot q_u \cdot L_x^2 \cdot x = 0,001 \cdot 1,125 \cdot (4,5)^2 \cdot 85 = 1,936 \text{ ton m}$$

$$M_{ty} = 0,001 \cdot q_u \cdot L_x^2 \cdot x = 0,001 \cdot 1,125 \cdot (4,5)^2 \cdot 74 = 1,686 \text{ ton m}$$

Perhitungan selanjutnya disajikan dalam table dibawah ini,

Tabel 5.1. Perhitungan Momen Plat Lantai

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Tipe Pelat	Ly / Lx (m)	Mlx (ton m)	Mly (ton m)	Mtx (ton m)	Mty (ton m)
I	3/ 3	0,283	0,283	0,688	0,688
II	3/ 3	0,213	0,263	0,557	0,607
III	3/ 2,75	0,247	0,170	0,562	0,485
IV	3/ 2	0,162	0,077	0,342	0,257
V	3/ 2	0,171	0,067	0,355	0,257
VI	2,75/ 2	0,153	0,081	0,328	0,257
VII	4,5/ 3	0,486	0,253	1,043	0,779
VIII	3/ 3	0,213	0,213	0,526	0,526
IX	3/ 2,75	0,213	0,179	0,502	0,459
X	4,5/ 3	0,385	0,152	0,799	0,577
XI	4,5/ 4,5	0,478	0,592	1,253	1,367
XII	5/ 4,5	0,866	0,638	1,936	1,686
XIII	4,5/ 2,75	0,340	0,111	0,698	0,485
XIV	5/ 3	0,537	0,233	1,124	0,789
XV	4,5/ 2	0,189	0,045	0,374	0,257

5.1.3. Penulangan Plat Lantai

Dari perhitungan momen diambil momen terbesar yaitu:

$$M_{lx} = 0,866 \text{ ton m}$$

$$M_{ly} = 0,638 \text{ ton m}$$

$$M_{tx} = 1,936 \text{ ton m}$$

$$M_{ty} = 1,686 \text{ ton m}$$

$$\text{Data : Tebal plat (h)} = 12 \text{ cm} = 120 \text{ mm}$$

$$\text{Tebal penutup (p)} = 20 \text{ mm}$$

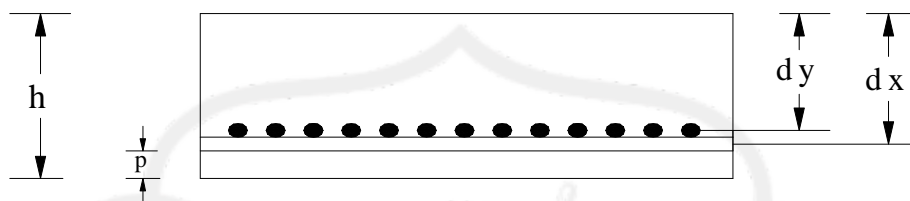
$$\text{Diameter tulangan (} \varnothing \text{)} = 12 \text{ mm}$$

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$$\begin{aligned} b &= 1000 \\ f_y &= 240 \text{ Mpa} \\ f'_c &= 30 \text{ Mpa} \end{aligned}$$



Gambar 5.3. Perencanaan Tinggi Efektif

$$\begin{aligned} dx &= h - p - \frac{1}{2} \text{Ø} \\ &= 120 - 20 - 6 = 94 \text{ mm} \\ dy &= h - p - \text{Ø} - \frac{1}{2} \text{Ø} \\ &= 120 - 20 - 12 - \frac{1}{2} \cdot 12 = 82 \text{ mm} \end{aligned}$$

untuk plat digunakan

$$\begin{aligned} \rho_b &= \frac{0,85 \cdot f_c}{f_y} \cdot \beta \cdot \left(\frac{600}{600 + f_y} \right) \\ &= \frac{0,85 \cdot 30}{240} \cdot 0,85 \cdot \left(\frac{600}{600 + 240} \right) \\ &= 0,0645 \\ \rho_{\max} &= 0,75 \cdot \rho_b \\ &= 0,0484 \\ \rho_{\min} &= 0,0025 \text{ (untuk pelat)} \end{aligned}$$

a) Penulangan lapangan arah x

$$M_u = 0,866 \text{ tm} = 0,866 \cdot 10^7 \text{ Nmm}$$

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$$M_n = \frac{M_u}{\phi} = \frac{0,866 \cdot 10^7}{0,8} = 1,0825 \cdot 10^7 \text{ Nmm}$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{1,0825 \cdot 10^7}{1000 \cdot (94)^2} = 1,225 \text{ N/mm}^2$$

$$m = \frac{f_y}{0,85 \cdot f'_c} = \frac{240}{0,85 \cdot 30} = 9,412$$

$$\rho_{\text{perlu}} = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2m \cdot R_n}{f_y}} \right)$$

$$= \frac{1}{9,412} \left(1 - \sqrt{1 - \frac{2 \cdot 9,412 \cdot 1,225}{240}} \right)$$

$$= 0,0052$$

$$\rho < \rho_{\text{max}}$$

$$\rho > \rho_{\text{min}}$$

di pakai $\rho_{\text{perlu}} = 0,0052$

$$\begin{aligned} A_s &= \rho_{\text{perlu}} \cdot b \cdot d \\ &= 0,0052 \cdot 1000 \cdot 94 \\ &= 491,948 \text{ mm}^2 \end{aligned}$$

$$\text{Digunakan tulangan } \varnothing 12 = \frac{1}{4} \cdot \pi \cdot (12)^2 = 113,04 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{491,948}{113,04} = 4,35 \sim 5 \text{ buah}$$

$$\text{Jarak tulangan dalam 1 m}^2 = \frac{1000}{5} = 200 \text{ mm}$$

$$\text{As terpasang} = \frac{1000}{180} \cdot 113,04 = 628 \text{ mm}^2 > A_s \dots\dots \text{ ok!}$$

Jadi, Dipakai tulangan $\varnothing 12 - 180 \text{ mm}$

b) Penulangan lapangan arah y

$$M_u = 0,638 \text{ tm} = 0,638 \cdot 10^7 \text{ Nmm}$$

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$$M_n = \frac{M_u}{\phi} = \frac{0,638 \cdot 10^7}{0,8} = 0,798 \cdot 10^7 \text{ Nmm}$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{0,798 \cdot 10^7}{1000 \cdot (94)^2} = 0,903 \text{ N/mm}^2$$

$$m = \frac{f_y}{0,85 \cdot f'_c} = \frac{240}{0,85 \cdot 30} = 9,412$$

$$\rho_{\text{perlu}} = \frac{1}{m} \cdot \left(1 - \sqrt{1 - \frac{2m \cdot R_n}{f_y}} \right)$$

$$= \frac{1}{9,412} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 9,412 \cdot 0,903}{240}} \right)$$

$$= 0,0038$$

$$\rho < \rho_{\text{max}}$$

$$\rho > \rho_{\text{min}}$$

di pakai $\rho_{\text{perlu}} = 0,0038$

$$A_s = \rho_{\text{perlu}} \cdot b \cdot d$$

$$= 0,0038 \cdot 1000 \cdot 94$$

$$= 360,22 \text{ mm}^2$$

$$\text{Digunakan tulangan } \varnothing 12 = \frac{1}{4} \cdot \pi \cdot (12)^2 = 113,04 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{360,22}{113,04} = 3,18 \sim 4 \text{ buah}$$

$$\text{Jarak tulangan dalam 1 m}^2 = \frac{1000}{4} = 250 \text{ mm}$$

$$A_s \text{ terpasang} = \frac{1000}{180} \cdot 113,04 = 628 \text{ mm}^2 > A_s \dots\dots \text{ ok!}$$

Jadi, Dipakai tulangan $\varnothing 12 - 180 \text{ mm}$

c) Penulangan tumpuan arah x

$$M_u = 1,936 \text{ tm} = 1,936 \cdot 10^7 \text{ Nmm}$$

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$$M_n = \frac{M_u}{\phi} = \frac{1,936 \cdot 10^7}{0,8} = 2,42 \cdot 10^7 \text{ Nmm}$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{2,42 \cdot 10^7}{1000 \cdot (94)^2} = 2,739 \text{ N/mm}^2$$

$$m = \frac{f_y}{0,85 \cdot f'_c} = \frac{240}{0,85 \cdot 30} = 9,412$$

$$\rho_{\text{perlu}} = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2m \cdot R_n}{f_y}} \right)$$

$$= \frac{1}{9,412} \left(1 - \sqrt{1 - \frac{2 \cdot 9,412 \cdot 2,739}{240}} \right)$$

$$= 0,0121$$

$$\rho < \rho_{\text{max}}$$

$$\rho > \rho_{\text{min}}$$

di pakai $\rho_{\text{perlu}} = 0,0121$

$$\begin{aligned} A_s &= \rho_{\text{perlu}} \cdot b \cdot d \\ &= 0,0121 \cdot 1000 \cdot 94 \\ &= 1137,56 \text{ mm}^2 \end{aligned}$$

$$\text{Digunakan tulangan } \varnothing 12 = \frac{1}{4} \cdot \pi \cdot (12)^2 = 113,04 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{1137,56}{113,04} = 10,06 \sim 11 \text{ buah.}$$

$$\text{Jarak tulangan dalam 1 m}^2 = \frac{1000}{11} = 90,9 \text{ mm}$$

$$\text{As terpasang} = \frac{1000}{90} \cdot 113,04 = 1256 \text{ mm}^2 > A_s \dots\dots \text{ ok!}$$

Jadi, Dipakai tulangan $\varnothing 12 - 90 \text{ mm}$

d) Penulangan tumpuan arah y

$$M_u = 1,686 \text{ tm} = 1,686 \cdot 10^7 \text{ Nmm}$$

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$$M_n = \frac{M_u}{\phi} = \frac{1,686 \cdot 10^7}{0,8} = 2,1075 \cdot 10^7 \text{ Nmm}$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{2,1075 \cdot 10^7}{1000 \cdot (94)^2} = 2,385 \text{ N/mm}^2$$

$$m = \frac{f_y}{0,85 \cdot f'_c} = \frac{240}{0,85 \cdot 30} = 9,412$$

$$\rho_{\text{perlu}} = \frac{1}{m} \cdot \left(1 - \sqrt{1 - \frac{2m \cdot R_n}{f_y}} \right)$$

$$= \frac{1}{9,412} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 9,412 \cdot 2,385}{240}} \right)$$

$$= 0,0104$$

$$\rho < \rho_{\text{max}}$$

$$\rho > \rho_{\text{min}}, \text{ di pakai } \rho_{\text{perlu}} = 0,0104$$

$$\begin{aligned} A_s &= \rho_{\text{perlu}} \cdot b \cdot d \\ &= 0,0104 \cdot 1000 \cdot 94 \\ &= 982,503 \text{ mm}^2 \end{aligned}$$

$$\text{Digunakan tulangan } \varnothing 12 = \frac{1}{4} \cdot \pi \cdot (12)^2 = 113,04 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{982,503}{113,04} = 8,69 \sim 9 \text{ buah.}$$

$$\text{Jarak tulangan dalam 1 m}^2 = \frac{1000}{9} = 111,11 \text{ mm}$$

$$\text{As terpasang} = \frac{1000}{90} \cdot 113,04 = 1256 \text{ mm}^2 > A_s \dots\dots \text{ ok!}$$

Jadi, Dipakai tulangan $\varnothing 12 - 90 \text{ mm}$

5.1.4. Rekapitulasi Tulangan

Dari perhitungan diatas diperoleh :

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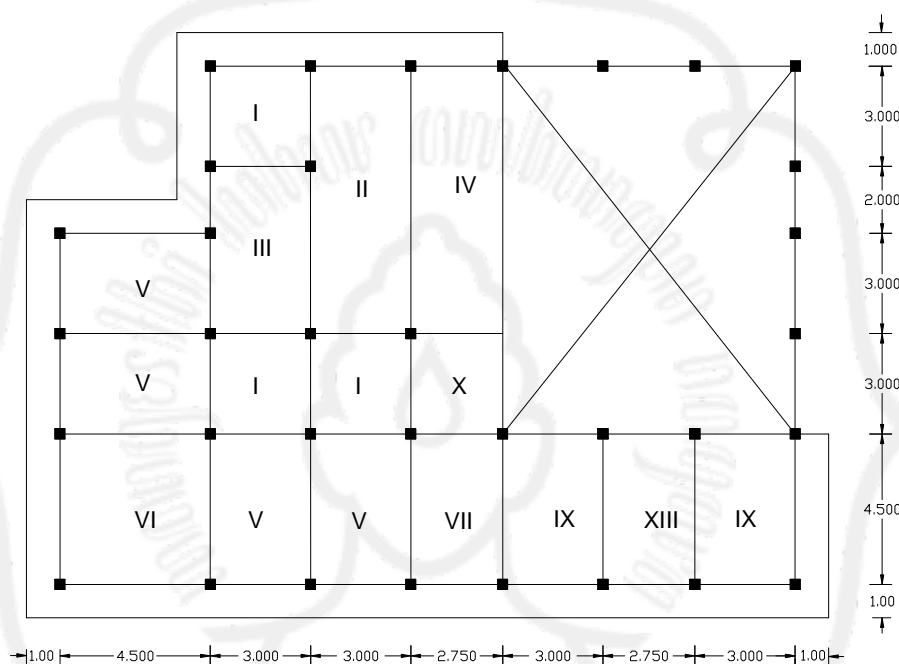
Tulangan lapangan arah x $\varnothing 12 - 180 \text{ mm}$

Tulangan lapangan arah y $\varnothing 12 - 180 \text{ mm}$

Tulangan tumpuan arah x $\varnothing 12 - 90 \text{ mm}$

Tulangan tumpuan arah y $\varnothing 12 - 90 \text{ mm}$

5.2. Perencanaan Plat Atap



Gambar 5.4. Denah Plat Atap

5.2.1. Perhitungan Pembebanan Plat Atap

a. Beban Hidup (qL)

Beban air hujan	$= 0,02 \text{ ton/m}^2$	
Beban Pekerja	$= 0,10 \text{ ton/m}^2$	+
	$qL = 0,12 \text{ ton/m}^2$	

b. Beban Mati (qD)

Berat plat sendiri (12 cm)	$= 0,12 \times 2,4 \times 1$	$= 0,288 \text{ ton/m}^2$
Berat plafond + penggantung		$= 0,018 \text{ ton/m}^2$
		+

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$$qD = 0,306 \text{ ton/m}^2$$

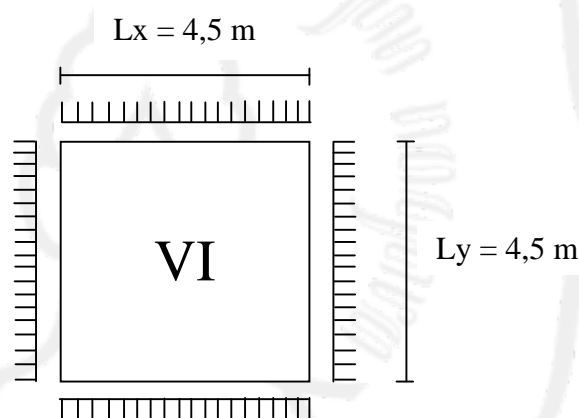
c. Beban Ultimate (qU)

Untuk tinjauan lebar 1 m pelat maka :

$$\begin{aligned} qU &= 1,2 qD + 1,6 qL \\ &= 1,2 \cdot 0,306 + 1,6 \cdot 0,12 \\ &= 0,560 \text{ ton/m}^2 \end{aligned}$$

5.2.2. Perhitungan Momen

Perhitungan momen untuk pelat dua arah yaitu dengan tabel momen per meter lebar dalam jalur tengah akibat beban terbagi rata



Gambar 5.5. Plat Tipe VI

$$\frac{L_y}{L_x} = \frac{4,5}{4,5} = 1$$

$$M_{lx} = 0,001 \cdot q_u \cdot L_x^2 \cdot x = 0,001 \cdot 0,56 \cdot (4,5)^2 \cdot 21 = 0,238 \text{ ton m}$$

$$M_{ly} = 0,001 \cdot q_u \cdot L_x^2 \cdot x = 0,001 \cdot 0,56 \cdot (4,5)^2 \cdot 21 = 0,238 \text{ ton m}$$

$$M_{tx} = 0,001 \cdot q_u \cdot L_x^2 \cdot x = 0,001 \cdot 0,56 \cdot (4,5)^2 \cdot 52 = 0,589 \text{ ton m}$$

$$M_{ty} = 0,001 \cdot q_u \cdot L_x^2 \cdot x = 0,001 \cdot 0,56 \cdot (4,5)^2 \cdot 52 = 0,589 \text{ ton m}$$

Perhitungan selanjutnya disajikan dalam tabel dibawah ini,

Tabel 5.2. Perhitungan Momen Plat Atap

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Type Pelat	Ly / Lx (m)	Mlx (ton m)	Mly (ton m)	Mtx (ton m)	Mty (ton m)
I	3/ 3	0,106	0,106	0,262	0,262
II	8/ 3	0,212	0,040	0,414	0,287
III	5/ 3	0,192	0,071	0,408	0,287
IV	8/ 2,75	0,267	0,055	0,529	0,335
V	4,5/ 3	0,181	0,086	0,383	0,287
VI	4,5/ 4,5	0,238	0,238	0,589	0,589
VII	4,5/ 2,75	0,157	0,068	0,335	0,241
VIII	4,5/ 2,75	0,165	0,059	0,339	0,241
IX	4,5/ 3	0,192	0,076	0,398	0,287
X	3/ 2,75	0,110	0,114	0,275	0,275

5.2.3. Penulangan Plat Atap

Dari perhitungan momen diambil momen terbesar yaitu :

$$M_{lx} = 0,267 \text{ ton m}$$

$$M_{ly} = 0,238 \text{ ton m}$$

$$M_{tx} = 0,589 \text{ ton m}$$

$$M_{ty} = 0,589 \text{ ton m}$$

Data : Tebal plat (h) = 12 cm = 120 mm

Tebal penutup (p) = 20 mm

Diameter tulangan (\varnothing) = 10 mm

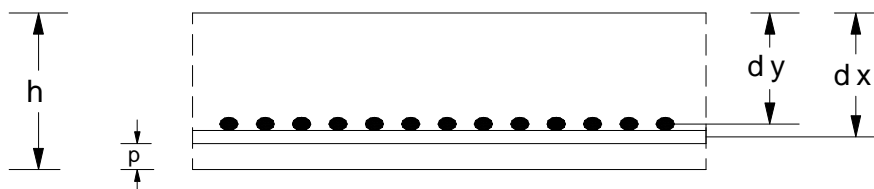
b = 1000

f_y = 240 Mpa

f'_c = 30 Mpa

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Gambar 5.6. Perencanaan Tinggi Efektif

$$\begin{aligned}
 dx &= h - p - \frac{1}{2} \emptyset \\
 &= 120 - 20 - 5 = 95 \text{ mm} \\
 dy &= h - p - \emptyset - \frac{1}{2} \emptyset \\
 &= 120 - 20 - 10 - \frac{1}{2} \cdot 10 = 85 \text{ mm}
 \end{aligned}$$

untuk plat digunakan :

$$\begin{aligned}
 \rho_b &= \frac{0,85 \cdot f_c}{f_y} \cdot \beta \cdot \left(\frac{600}{600 + f_y} \right) \\
 &= \frac{0,85 \cdot 30}{240} \cdot 0,85 \cdot \left(\frac{600}{600 + 240} \right) \\
 &= 0,0645 \\
 \rho_{\max} &= 0,75 \cdot \rho_b \\
 &= 0,0484 \\
 \rho_{\min} &= 0,0025 \text{ (untuk pelat)}
 \end{aligned}$$

a) Penulangan lapangan arah x

$$\begin{aligned}
 M_u &= 0,267 \text{ tm} = 0,267 \cdot 10^7 \text{ Nmm} \\
 M_n &= \frac{M_u}{\phi} = \frac{0,267 \cdot 10^7}{0,8} = 0,334 \cdot 10^7 \text{ Nmm} \\
 R_n &= \frac{M_n}{b \cdot d^2} = \frac{0,334 \cdot 10^7}{1000 \cdot (95)^2} = 0,37 \text{ N/mm}^2
 \end{aligned}$$

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$$m = \frac{f_y}{0,85 \cdot f'_c} = \frac{240}{0,85 \cdot 30} = 9,412$$

$$\begin{aligned} \rho_{\text{perlu}} &= \frac{1}{m} \left(1 - \sqrt{1 - \frac{2m \cdot R_n}{f_y}} \right) \\ &= \frac{1}{9,412} \left(1 - \sqrt{1 - \frac{2 \cdot 9,412 \cdot 0,37}{240}} \right) \\ &= 0,0015 \end{aligned}$$

$$\rho < \rho_{\text{max}}$$

$$\rho < \rho_{\text{min}}, \text{ di pakai } \rho_{\text{min}} = 0,0025$$

$$\begin{aligned} A_s &= \rho_{\text{min}} \cdot b \cdot d \\ &= 0,0025 \cdot 1000 \cdot 95 \\ &= 237,5 \text{ mm}^2 \end{aligned}$$

$$\text{Digunakan tulangan } \varnothing 10 = \frac{1}{4} \cdot \pi \cdot (10)^2 = 78,5 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{237,5}{78,5} = 3,025 \sim 4 \text{ buah.}$$

$$\text{Jarak tulangan dalam } 1 \text{ m}^2 = \frac{1000}{4} = 250 \text{ mm}$$

$$\text{Jarak maksimum} = 2 \times h = 2 \times 120 = 240 \text{ mm}$$

$$\text{As terpasang} = \frac{1000}{240} \cdot 78,5 = 327,083 \text{ mm}^2 > A_s \dots\dots \text{ ok!}$$

Jadi, Dipakai tulangan $\varnothing 10 - 240 \text{ mm}$

b) Penulangan lapangan arah y

$$M_u = 0,238 \text{ tm} = 0,238 \cdot 10^7 \text{ Nmm}$$

$$M_n = \frac{M_u}{\phi} = \frac{0,238 \cdot 10^7}{0,8} = 0,2975 \cdot 10^7 \text{ Nmm}$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{0,2975 \cdot 10^7}{1000 \cdot (95)^2} = 0,329 \text{ N/mm}^2$$

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$$m = \frac{f_y}{0,85 \cdot f'_c} = \frac{240}{0,85 \cdot 30} = 9,412$$

$$\begin{aligned} \rho_{\text{perlu}} &= \frac{1}{m} \left(1 - \sqrt{1 - \frac{2m \cdot R_n}{f_y}} \right) \\ &= \frac{1}{9,412} \left(1 - \sqrt{1 - \frac{2 \cdot 9,412 \cdot 0,329}{240}} \right) \\ &= 0,0014 \end{aligned}$$

$$\rho < \rho_{\text{max}}$$

$$\rho < \rho_{\text{min}}, \text{ di pakai } \rho_{\text{min}} = 0,0025$$

$$\begin{aligned} A_s &= \rho_{\text{min}} \cdot b \cdot d \\ &= 0,0025 \cdot 1000 \cdot 95 \\ &= 237,5 \text{ mm}^2 \end{aligned}$$

$$\text{Digunakan tulangan } \varnothing 10 = \frac{1}{4} \cdot \pi \cdot (10)^2 = 78,5 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{237,5}{78,5} = 3,025 \sim 4 \text{ buah.}$$

$$\text{Jarak tulangan dalam } 1 \text{ m}^2 = \frac{1000}{4} = 250 \text{ mm}$$

$$\text{Jarak maksimum} = 2 \times h = 2 \times 120 = 240 \text{ mm}$$

$$\text{As terpasang} = \frac{1000}{240} \cdot 78,5 = 327,083 \text{ mm}^2 > A_s \dots\dots \text{ ok!}$$

Jadi, Dipakai tulangan $\varnothing 10 - 240 \text{ mm}$

c) Penulangan tumpuan arah x dan y

$$M_u = 0,589 \text{ ton m} = 0,589 \times 10^7 \text{ Nmm}$$

$$M_n = \frac{M_u}{\phi} = \frac{0,589 \cdot 10^7}{0,8} = 0,736 \cdot 10^7 \text{ Nmm}$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{0,736 \cdot 10^7}{1000 \cdot (95)^2} = 0,816 \text{ N/mm}^2$$

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$$m = \frac{f_y}{0,85 \cdot f'_c} = \frac{240}{0,85 \cdot 30} = 9,412$$

$$\rho_{\text{perlu}} = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2m \cdot R_n}{f_y}} \right)$$

$$= \frac{1}{9,412} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 9,412 \cdot 0,816}{240}} \right)$$

$$= 0,0034$$

$$\rho < \rho_{\text{max}}$$

$$\rho > \rho_{\text{min}}$$

ρ di pakai $\rho_{\text{perlu}} = 0,0034$

$$A_s = \rho_{\text{perlu}} \cdot b \cdot d$$

$$= 0,0034 \cdot 1000 \cdot 95$$

$$= 328,254 \text{ mm}^2$$

$$\text{Digunakan tulangan } \varnothing 10 = \frac{1}{4} \cdot \pi \cdot (10)^2 = 78,5 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{328,254}{78,5} = 4,18 \sim 5 \text{ buah.}$$

$$\text{Jarak tulangan dalam } 1 \text{ m}^2 = \frac{1000}{5} = 200 \text{ mm}$$

$$\text{As terpasang} = \frac{1000}{120} \cdot 78,5 = 654,16 \text{ mm}^2 > A_s \dots\dots \text{ ok!}$$

Jadi, Dipakai tulangan $\varnothing 10 - 120 \text{ mm}$

5.2.4. Rekapitulasi Tulangan

Dari perhitungan diatas diperoleh :

Tulangan lapangan arah x $\varnothing 10 - 240 \text{ mm}$

Tulangan lapangan arah y $\varnothing 10 - 240 \text{ mm}$

Tulangan tumpuan arah x $\varnothing 10 - 120 \text{ mm}$

Tulangan tumpuan arah y $\varnothing 10 - 120 \text{ mm}$

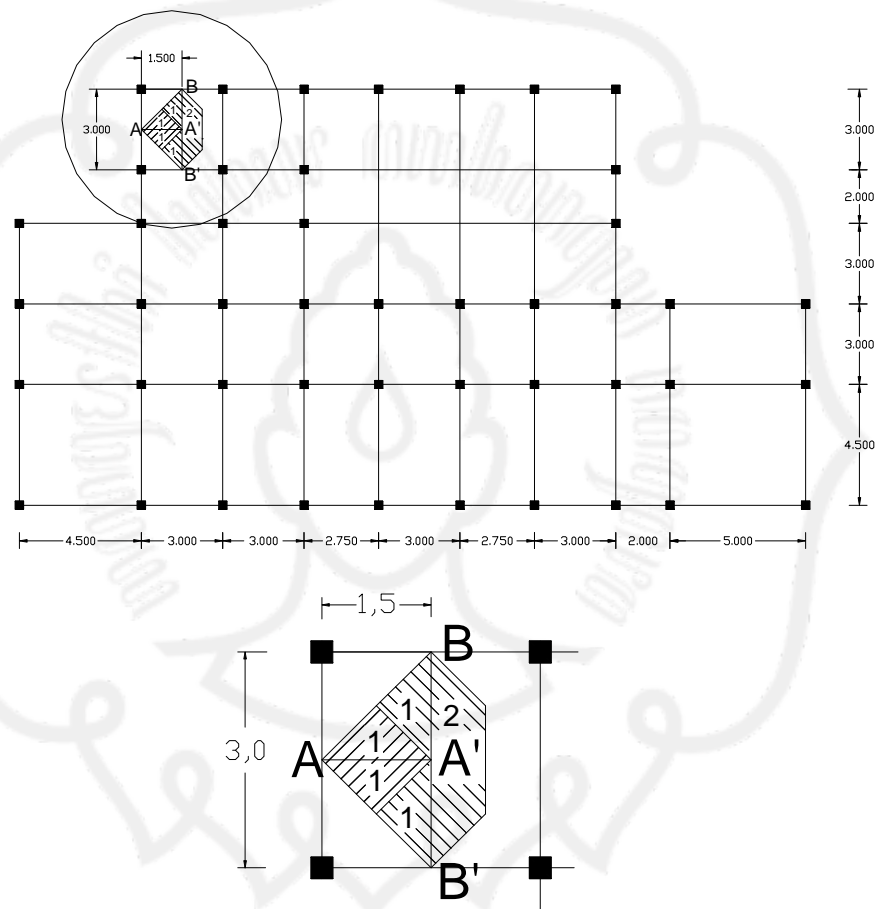
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BAB 6
PERENCANAAN BALOK ANAK

6.1. Perencanaan Balok Anak

Perencanaan balok anak antara plat atap dan plat lantai diambil satu perencanaan untuk hgtungan tulangan, yaitu balok anak pada plat lantai karena, mempunyai pembebanan yang lebih besar dibanding dengan balok anak pada plat atap



Gambar 6.1. Denah Rencana Balok Anak

6.2. Beban Plat Lantai

➤ **Beban Mati (qd)**

Beban plat sendiri = $0,12 \cdot 107 = 288 \text{ kg/m}^2$
 Beban spesi pasangan = $0,02 \cdot 2100 = 42 \text{ kg/m}^2$

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$$\begin{aligned}
 \text{Beban pasir} &= 0,02 \cdot 1600 = 32 \text{ kg/m}^2 \\
 \text{Beban keramik} &= 0,01 \cdot 2400 = 24 \text{ kg/m}^2 \\
 \text{Plafond + penggantung} &= 11 + 7 = 18 \text{ kg/m}^2 \\
 \text{qd} &= 404 \text{ kg/m}^2
 \end{aligned}$$

6.3. Analisa Pembebanan Balok Anak

$$\text{Dengan: Leq (segitiga)} = \frac{1}{3} \cdot Lx$$

$$\text{Leq (trapesium)} = \frac{1}{6} \cdot Lx \cdot \left[3 - 4 \left(\frac{Lx}{2 \cdot Ly} \right)^2 \right]$$

Tabel 6.1. Perhitungan Lebar Equivalent

No.	Ukuran Pelat	Lx	Ly	Leq (segitiga)	Leq (trapesium)
1.	1,5 x 1,5	1,5	1,5	0,5	--
2.	1,5 x 3,0	1,5	3,0	--	0,6875

6.3.1. Balok Anak As (A - A')**a. Dimensi Balok**

$$\begin{aligned}
 h &= 1/10 \cdot L \\
 &= 1/10 \cdot 1500 \\
 &= 150 \text{ mm} \sim 200 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 b &= 1/2 \cdot h \\
 &= 1/2 \cdot 200 \\
 &= 100 \text{ mm} \sim 150 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 \text{Leq} &= 2 \cdot \text{Leq}_1 \\
 &= 2 \cdot 0,5 \\
 &= 1
 \end{aligned}$$

b. Pembebanan Setiap Elemen➤ **Beban Mati (qd)**

$$\begin{aligned}
 \text{Berat sendiri balok} &= 0,15 \times (0,2 - 0,12) \times 2400 = 28,8 \text{ kg/m}^2 \\
 \text{Berat plat} &= 404 \times 1 = 404 \text{ kg/m}^2
 \end{aligned}$$

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$$\begin{aligned} \text{Berat dinding} &= 0,15 \times 3,4 \times 1700 &= 867 \text{ kg/m}^2 \\ & & \text{qd} = \frac{1299,8 \text{ kg/m}^2}{} \end{aligned}$$

$$\text{➤ Beban Hidup (ql)} = 400 \times 1 = 400 \text{ kg/m}^2$$

c. Hasil dari perhitungan SAP :

- $Mu_{\text{lap.}}$ = 549,94 kgm
- V_u = 1649,82 kg
- Beban reaksi = 1649,82 kg

6.3.2. Balok Anak As (B – B')

a. Dimensi Balok

$$\begin{aligned} h &= 1/10 \cdot L \\ &= 1/10 \cdot 3 \\ &= 300 \text{ mm} \end{aligned}$$

$$\begin{aligned} b &= 1/2 \cdot h \\ &= 1/2 \cdot 150 \\ &= 200 \text{ mm} \end{aligned}$$

$$\begin{aligned} Leq &= 2 \cdot Leq_1 + Leq_2 \\ &= 2 \cdot 0,5 + 0,6875 \\ &= 1,6875 \end{aligned}$$

b. Pembebanan Setiap Elemen

➤ Beban Mati (qd)

$$\begin{aligned} \text{Berat sendiri balok} &= 0,2 \times (0,3 - 0,12) \times 2400 = 86,4 \text{ kg/m}^2 \\ \text{Berat plat} &= 404 \times 1,6875 = 681,75 \text{ kg/m}^2 \\ \text{Berat dinding} &= 0,15 \times 3,4 \times 1700 = 867 \text{ kg/m}^2 \\ & \text{qd} = \frac{1635,15 \text{ kg/m}^2}{} \end{aligned}$$

$$\text{➤ Beban Hidup (ql)} = 400 \cdot 1,6875 = 675 \text{ kg/m}^2$$

c. Hasil dari perhitungan SAP :

- $Mu_{\text{lap.}}$ = 4907,29 kgm
- V_u = 5553,16 kg

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6.4. Hitungan Tulangan Lentur Dan Geser**6.4.1 Balok anak As (A – A')**

Hasil SAP 2000 :

- $Mu_{lap.} = 549,94 \text{ kgm}$

Data-Data: $V_u = 1649,82 \text{ kg}$

$b = 150 \text{ mm}$

$h = 200 \text{ mm}$

$f'c = 30 \text{ MPa}$

$f_y = 360 \text{ Mpa (ulir)}$

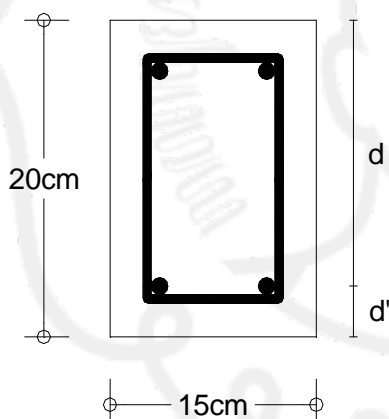
$f_{ys} = 240 \text{ Mpa (polos)}$

Dicoba :

ϕ tulangan = 13 mm

ϕ sengkang = 8 mm

Tebal selimut (s) = 40 mm



- $h = 200 \text{ mm}$
- $b = 150 \text{ mm}$
- $d' = 40 + 8 + \frac{1}{2} \cdot 13 = 54,5 \text{ mm}$
- $d = h - d' = 200 - 54 = 145,5 \text{ mm}$

$$m = \frac{f_y}{0,85 \cdot f_c} = \frac{360}{0,85 \cdot 30} = 14,118$$

$$\rho_b = \frac{0,85 \cdot f_c}{f_y} \cdot \beta \cdot \left(\frac{600}{600 + f_y} \right)$$

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$$= \frac{0,85 \cdot 30}{360} \cdot 0,85 \cdot \left(\frac{600}{600 + 360} \right)$$

$$= 0,0376$$

$$\rho_{\max} = 0,75 \cdot \rho_b$$

$$= 0,0282$$

$$\rho_{\min} = \frac{1,4}{f_y} = \frac{1,4}{360} = 0,0039$$

a) Penulangan Daerah Lapangan

$$M_u = 549,94 \text{ kgm} = 0,55 \cdot 10^7 \text{ Nmm}$$

$$M_n = \frac{M_u}{\phi} = \frac{0,55 \cdot 10^7}{0,8} = 0,516 \cdot 10^7 \text{ Nmm}$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{0,516 \cdot 10^7}{150 \cdot (145,5)^2} = 1,615 \text{ N/mm}^2$$

$$\rho_{\text{ada}} = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{f_y}} \right)$$

$$= \frac{1}{14,118} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14,118 \cdot 1,615}{360}} \right)$$

$$= 0,0046$$

$$\rho_{\text{ada}} > \rho_{\min}$$

$$< \rho_{\max}$$

$$A_s = \rho_{\text{ada}} \cdot b \cdot d$$

$$= 0,0046 \times 150 \times 145,5$$

$$= 101,57 \text{ mm}^2$$

$$\text{Dipakai tulangan D 13 mm} = \frac{1}{4} \cdot \pi \times 13^2 = 132,665 \text{ mm}^2$$

$$\text{As terpasang} = 2 \times 132,665$$

$$= 265,33 \text{ mm}^2 > A_s \dots\dots \text{ aman!}$$

Jadi, Dipakai tulangan 2 D 13

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b) Hitungan Tulangan Geser

$$V_u = 1649,82 \text{ kg} = 1,65 \cdot 10^4 \text{ N (Perhitungan SAP)}$$

$$\begin{aligned} V_c &= 1/6 \cdot b \cdot d \cdot \sqrt{f'_c} \\ &= 1/6 \cdot 150 \cdot 146 \cdot \sqrt{30} \\ &= 1,999 \cdot 10^4 \text{ N} \end{aligned}$$

$$\begin{aligned} \emptyset V_c &= 0,6 \cdot V_c \\ &= 1,199 \cdot 10^4 \text{ N} \end{aligned}$$

$$\begin{aligned} 3\emptyset V_c &= 3 \cdot \emptyset V_c \\ &= 3,598 \cdot 10^4 \text{ N} \end{aligned}$$

➤ $\emptyset V_c < V_u < 3\emptyset V_c \rightarrow$ perlu tulangan geser

$$\emptyset V_s = V_u - \emptyset V_c = 0,451 \cdot 10^4 \text{ N}$$

$$V_{s \text{ perlu}} = \frac{\phi v_s}{\phi} = \frac{0,451 \cdot 10^4}{0,6} = 0,752 \cdot 10^4 \text{ N}$$

Digunakan sengkang $\emptyset 8$,

$$A_v = 2 \cdot A = 100,48 \text{ mm}^2$$

$$S = \frac{A_v \cdot f'_y \cdot d}{V_{s \text{ perlu}}} = \frac{100,48 \cdot 240 \cdot 146}{0,752 \cdot 10^4} = 468,19 \text{ mm}$$

$$S_{\text{maks}} = \frac{d}{2} = \frac{146}{2} = 73 \text{ mm}$$

Jadi, dipakai sengkang $\emptyset 8 - 70 \text{ mm}$

6.4.2 Balok anak As (B – B')

Hasil SAP 2000 :

- $Mu_{\text{lap.}} = 4907,29 \text{ kgm}$

- $V_u = 5553,16 \text{ kg}$

Data-data:

b = 200 mm

h = 300 mm

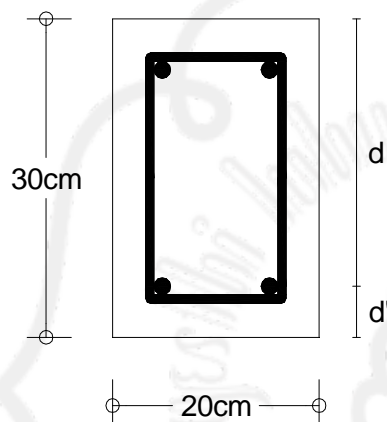
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$f'c = 30 \text{ MPa}$
 $f_y = 360 \text{ Mpa (ulir)}$
 $f_{ys} = 240 \text{ Mpa (polos)}$

Dicoba :

ϕ tulangan = 16 mm
 ϕ sengkang = 8 mm
 Tebal selimut (s) = 40 mm



- $h = 300 \text{ mm}$
- $b = 200 \text{ mm}$
- $d' = 40 + 8 + \frac{1}{2} \cdot 16 = 56 \text{ mm}$
- $d = h - d' = 300 - 56 = 244 \text{ mm}$

$$m = \frac{f_y}{0,85 \cdot f_c} = \frac{360}{0,85 \cdot 30} = 14,118$$

$$\begin{aligned}
 \rho_b &= \frac{0,85 \cdot f_c}{f_y} \cdot \beta \cdot \left(\frac{600}{600 + f_y} \right) \\
 &= \frac{0,85 \cdot 30}{360} \cdot 0,85 \cdot \left(\frac{600}{600 + 360} \right) \\
 &= 0,0376
 \end{aligned}$$

$$\begin{aligned}
 \rho_{\max} &= 0,75 \cdot \rho_b \\
 &= 0,0282
 \end{aligned}$$

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$$\rho_{\min} = \frac{1,4}{f_y} = \frac{1,4}{360} = 0,0039$$

a) Penulangan Daerah Lapangan

$$M_u = 4907,29 \text{ kgm} = 4,907 \cdot 10^7 \text{ Nmm}$$

$$M_n = \frac{M_u}{\phi} = \frac{4,907 \cdot 10^7}{0,8} = 6,134 \cdot 10^7 \text{ Nmm}$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{6,134 \cdot 10^7}{200 \cdot (244)^2} = 5,151 \text{ N/mm}^2$$

$$\rho_{\text{ada}} = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{f_y}} \right)$$

$$= \frac{1}{14,118} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14,118 \cdot 5,151}{360}} \right)$$

$$= 0,0162$$

$$\rho_{\text{ada}} > \rho_{\min}$$

$$< \rho_{\max}$$

$$A_s = \rho_{\text{ada}} \cdot b \cdot d$$

$$= 0,0162 \times 200 \times 244$$

$$= 788,139 \text{ mm}^2$$

$$\text{Dipakai tulangan } D 19 \text{ mm} = \frac{1}{4} \cdot \pi \times 19^2 = 283,385 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{788,139}{283,385} = 2,78 \approx 3 \text{ buah}$$

$$\text{As terpasang} = 3 \times 283,385$$

$$= 850,155 \text{ mm}^2 > A_s \dots\dots \text{ aman!}$$

Jadi, Dipakai tulangan 3 D 19

b) Hitungan Tulangan Geser

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$$V_u = 5553,16 \text{ kg} = 5,55 \cdot 10^4 \text{ N (Perhitungan SAP)}$$

$$\begin{aligned} V_c &= 1/6 \cdot b \cdot d \cdot \sqrt{f_c} \\ &= 1/6 \cdot 200 \cdot 244 \cdot \sqrt{30} \\ &= 4,455 \cdot 10^4 \text{ N} \end{aligned}$$

$$\begin{aligned} \phi V_c &= 0,6 \cdot V_c \\ &= 2,673 \cdot 10^4 \text{ N} \end{aligned}$$

$$\begin{aligned} 3\phi V_c &= 3 \cdot \phi V_c \\ &= 8,019 \cdot 10^4 \text{ N} \end{aligned}$$

➤ $\phi V_c < V_u < 3\phi V_c \rightarrow$ perlu tulangan geser

$$\phi V_s = V_u - \phi V_c = 2,877 \cdot 10^4 \text{ N}$$

$$V_{s \text{ perlu}} = \frac{\phi v_s}{\phi} = \frac{2,877 \cdot 10^4}{0,6} = 4,795 \cdot 10^4 \text{ N}$$

Digunakan sengkang $\phi 8$,

$$A_v = 2 \cdot A = 100,48 \text{ mm}^2$$

$$S = \frac{A_v \cdot f_y \cdot d}{V_{s \text{ perlu}}} = \frac{100,48 \cdot 360 \cdot 244}{4,795 \cdot 10^4} = 184,07 \text{ mm}$$

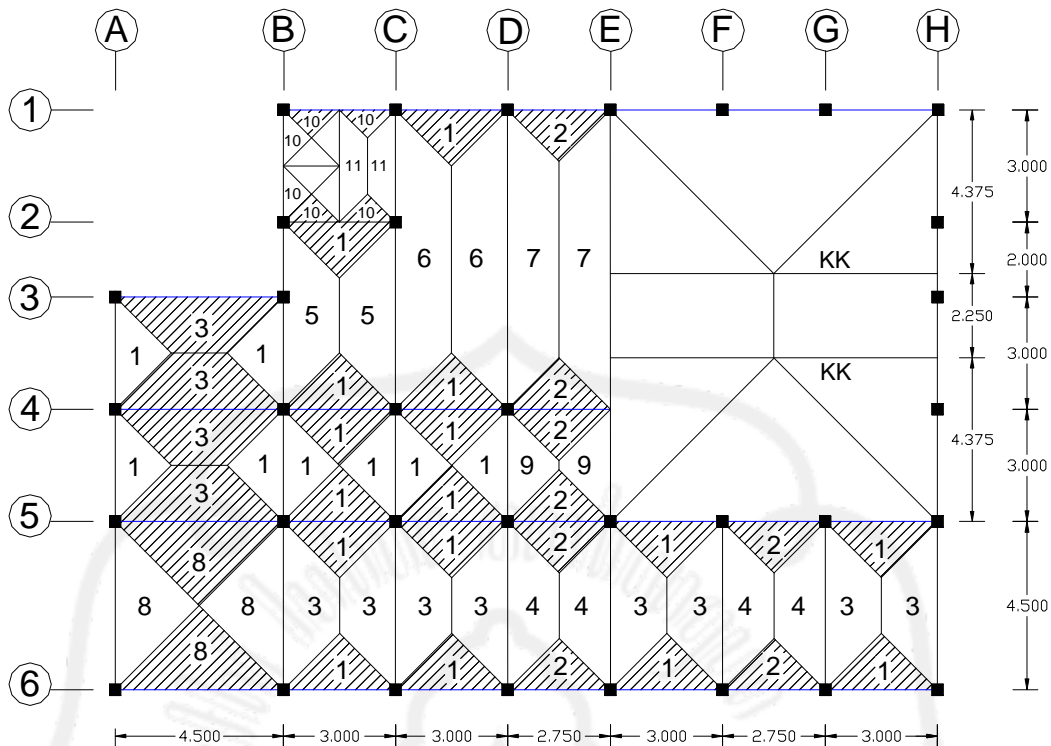
$$S_{\text{maks}} = \frac{d}{2} = \frac{244}{2} = 122 \text{ mm}$$

Jadi, dipakai sengkang $\phi 8 - 120 \text{ mm}$

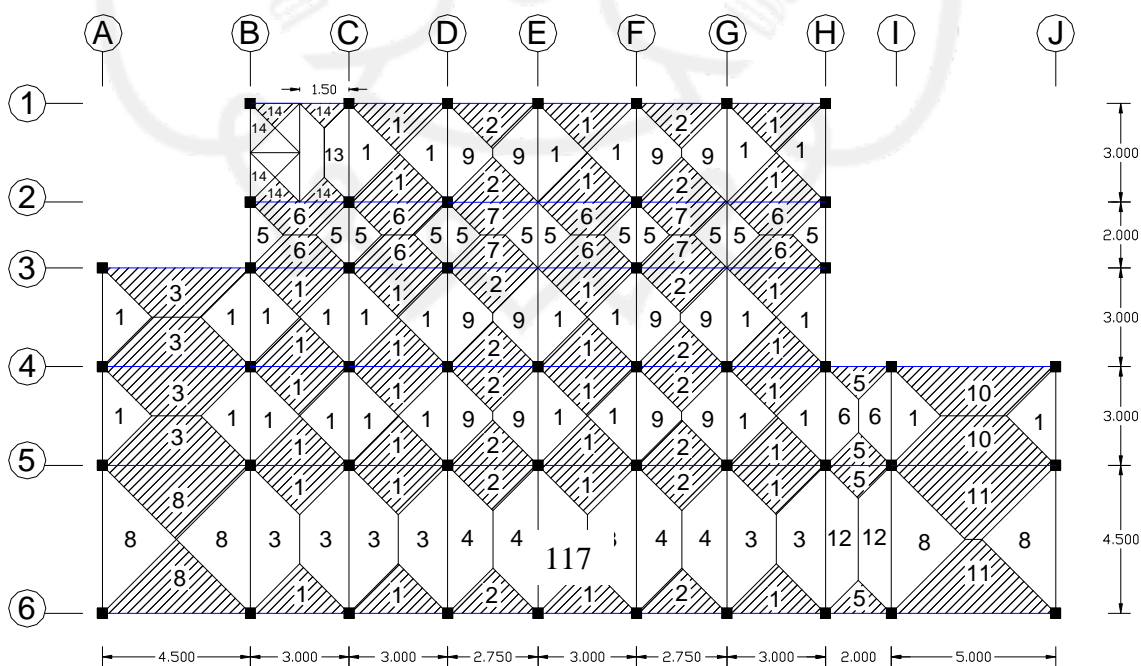
BAB 7**BALOK MEMANJANG****7.1. Perencanaan Balok Memanjang**

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Gambar 7.1. Denah Balok Memanjang (Atap)



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Gambar 7.2. Denah Balok Memanjang (Lantai)

7.1.1. Dasar Perencanaan

Secara umum data yang digunakan untuk hitungan rencana balok memanjang adalah sebagai berikut :

- a. Bentuk denah balok : Seperti tergambar
- b. Model perhitungan : SAP 2000 (3 D)
- c. Dimensi balok I : 200 (mm) x 300 (mm)
Dimensi balok II : 200 (mm) x 400 (mm)
Dimensi balok III : 350 (mm) x 600 (mm)
- d. Mutu beton : K300U36

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7.1.2. Perencanaan Pembebanan

Dalam hitungan balok memanjang, berat sendiri balok dimasukkan dalam perhitungan (input) SAP 2000, sedangkan beberapa pembebanan yang lain adalah sebagai berikut :

➤ Plat Lantai

Berat plat sendiri	= 0,12 x 2400 x 1	= 288	kg/m ²
Berat keramik (1 cm)	= 0,01 x 2400 x 1	= 24	kg/m ²
Berat Spesi (2 cm)	= 0,02 x 2100 x 1	= 42	kg/m ²
Berat plafond + instalasi listrik		= 25	kg/m ²
Berat Pasir (2 cm)	= 0,02 x 1600 x 1	= 32	kg/m ²
		<hr/>	
		qD = 411	kg/m ²

➤ Plat atap

Berat plat sendiri	= 0,12 x 2400 x 1	= 288	kg/m ²
Berat plafond + instalasi listrik		= 25	kg/m ²
		<hr/>	
		qD = 313	kg/m ²

➤ Dinding

$$\begin{aligned} \text{Berat sendiri dinding} &= 0,15 (4 - 0,6) \times 1700 \\ &= 867 \text{ kg/m}^2 \end{aligned}$$

7.1.3. Hitungan Luas Equivalen

$$\text{Luas equivalent segitiga} \quad : \frac{1}{3} \cdot Lx$$

$$\text{Luas equivalent trapezium} \quad : \frac{1}{6} \cdot Lx \cdot \left(3 - 4 \left(\frac{Lx}{2 \cdot Ly} \right)^2 \right)$$

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Table 7.1. Hitungan Luas Equivalen Pelat Atap

No.	Ukuran Plat (cm)	Lx (m)	Ly (m)	Leq (segitiga)	Leq (trapezium)
1	300 x 300	3	3	1,0	--
2	275 x 450	2,75	4	0,917	--
3	300 x 450	3	4,5	--	1,278
4	275 x 450	2,75	4,5	--	1,204
5	300 x 500	3	5	--	1,32
6	300 x 800	3	8	--	1,429
7	275 x 800	2,75	8	--	1,321
8	450 x 450	4,5	4,5	1,5	--
9	275 x 300	2,75	3	--	0,99
10	150 x 150	1,5	1,5	0,5	--

Table 7.2. Hitungan Luas Equivalen Pelat Lantai

No.	Ukuran Plat (cm)	Lx (m)	Ly (m)	Leq (segitiga)	Leq (trapezium)
1	300 x 300	3	3	1,0	--
2	275 x 300	2,75	3	0,917	--
3	300 x 450	3	4,5	--	1,278
4	275 x 450	2,75	4,5	--	1,204
5	200 x 300	2	3	0,67	--
6	200 x 300	2	3	--	0,852
7	200 x 275	2	2,75	--	0,824
8	450 x 450	4,5	4,5	1,5	--
9	275 x 300	2,75	3	--	0,99
10	300 x 500	3	5	--	1,32
11	450 x 500	4,5	5	--	1,6425
12	200 x 450	2	4,5	--	0,934
13	150 x 300	1,5	3	--	0,6875
14	150 x 150	1,5	1,5	0,5	--

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7.2. Hitungan Pembebanan Balok Memanjang**7.2.1. Pembebanan balok As 1 B – H****a. Pelat Atap**1. Pembebanan balok element **As 1 B – C**➤ **Beban Mati (qD)**

$$\begin{aligned} \text{Berat sendiri balok} &= 0,2 \cdot (0,3 - 0,12) \cdot 2400 &= 86,4 \text{ kg/m}^2 \\ \text{Berat pelat atap} &= (2 \times 0,5) \cdot 313 &= 313 \text{ kg/m}^2 \\ \hline \text{qD} &= 399,4 \text{ kg/m}^2 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\begin{aligned} \text{qL} &= (2 \times 0,5) \cdot 120 \\ &= 120 \text{ kg/m}^2 \end{aligned}$$

2. Pembebanan balok element **As 1 C – D**➤ **Beban Mati (qD)**

$$\begin{aligned} \text{Berat sendiri balok} &= 0,2 \cdot (0,3 - 0,12) \cdot 2400 &= 86,4 \text{ kg/m}^2 \\ \text{Berat pelat atap} &= (1 \times 1) \cdot 313 &= 313 \text{ kg/m}^2 \\ \hline \text{qD} &= 399,4 \text{ kg/m}^2 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\begin{aligned} \text{qL} &= (1 \times 1) \cdot 120 \\ &= 120 \text{ kg/m}^2 \end{aligned}$$

3. Pembebanan balok element **As 1 D – E**➤ **Beban Mati (qD)**

$$\begin{aligned} \text{Berat sendiri balok} &= 0,2 \cdot (0,3 - 0,12) \cdot 2400 &= 86,4 \text{ kg/m}^2 \\ \text{Berat pelat atap} &= (1 \times 0,917) \cdot 313 &= 287,021 \text{ kg/m}^2 \\ \hline \text{qD} &= 373,421 \text{ kg/m}^2 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\text{qL} = (1 \times 0,917) \cdot 120$$

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$$= 110,04 \text{ kg/m}^2$$

4. Pembebanan balok element **As 1 E – F = G – H**

➤ **Beban Mati (qD)**

$$\begin{aligned} \text{Berat sendiri balok} &= 0,2 \cdot (0,3 - 0,12) \cdot 2400 &&= 86,4 \text{ kg/m}^2 \\ \text{qD} &= 86,4 \text{ kg/m}^2 \end{aligned}$$

5. Pembebanan balok element **As 1 F – G**

➤ **Beban Mati (qD)**

$$\begin{aligned} \text{Berat sendiri balok} &= 0,2 \cdot (0,3 - 0,12) \cdot 2400 &&= 86,4 \text{ kg/m}^2 \\ \text{qD} &= 86,4 \text{ kg/m}^2 \end{aligned}$$

b. Pelat Lantai

1. Pembebanan balok element **As 1 B – C**

➤ **Beban Mati (qD)**

$$\begin{aligned} \text{Beban sendiri balok} &= 0,2 \cdot (0,3 - 0,12) \cdot 2400 &&= 86,4 \text{ kg/m}^2 \\ \text{Berat pelat lantai} &= (2 \times 0,5) \cdot 411 &&= 411 \text{ kg/m}^2 \\ \text{Berat dinding} & &&= 867 \text{ kg/m}^2 \\ \text{qD} & &&= 1364,4 \text{ kg/m}^2 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\begin{aligned} \text{qL} &= (2 \times 0,5) \cdot 400 \\ &= 400 \text{ kg/m}^2 \end{aligned}$$

2. Pembebanan balok element **As 1 C – D = E – F = G – H**

➤ **Beban Mati (qD)**

$$\begin{aligned} \text{Beban sendiri balok} &= 0,2 \cdot (0,3 - 0,12) \cdot 2400 &&= 86,4 \text{ kg/m}^2 \\ \text{Berat pelat lantai} &= (1 \times 1) \cdot 411 &&= 411 \text{ kg/m}^2 \\ \text{Berat dinding} & &&= 867 \text{ kg/m}^2 \\ \text{qD} & &&= 1364,4 \text{ kg/m}^2 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\text{qL} = (2 \times 0,5) \cdot 400$$

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$$= 400 \text{ kg/m}^2$$

3. Pembebanan balok element **As 1 D – E = F – G**➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat lantai} = (1 \times 0,917) \cdot 411 = 376,887 \text{ kg/m}^2$$

$$\text{Berat dinding} = 867 \text{ kg/m}^2$$

$$\underline{\text{qD}} = 1330,287 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = (1 \times 0,917) \cdot 400$$

$$= 366,8 \text{ kg/m}^2$$

7.2.2. Pembebanan balok As 2 B – H**a. Pelat Atap**1. Pembebanan balok element **As 2 B – C**➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat atap} = ((2 \times 0,5) + 1) \cdot 313 = 626 \text{ kg/m}^2$$

$$\underline{\text{qD}} = 712,4 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = ((2 \times 0,5) + 1) \cdot 120$$

$$= 240 \text{ kg/m}^2$$

b. Pelat Lantai1. Pembebanan balok element **As 2 B – C**➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat lantai} = ((2 \times 0,5) + 0,852) \cdot 411 = 761,172 \text{ kg/m}^2$$

$$\text{Berat dinding} = 867 \text{ kg/m}^2$$

$$\underline{\text{qD}} = 1714,572 \text{ kg/m}^2$$

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➤ **Beban hidup (qL)**

$$qL = ((2 \times 0,5) + 0,852) \cdot 400$$

$$= 740,8 \text{ kg/m}^2$$

2. Pembebanan balok element As 2 C – D➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat lantai} = (1 + 0,852) \cdot 411 = 761,172 \text{ kg/m}^2$$

$$qD = 847,572 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = (1 + 0,852) \cdot 400$$

$$= 704,8 \text{ kg/m}^2$$

3. Pembebanan balok element As 2 D – F = F – H➤ **Beban Mati (qD)**

$$\text{Berat sendiri balok} = 0,35 \cdot (0,6 - 0,12) \cdot 2400 = 403,2 \text{ kg/m}^2$$

$$\text{Berat pelat lantai} = (1 + 0,917 + 0,824 + 0,852) \cdot 411 = 1467,723 \text{ kg/m}^2$$

$$\text{Berat dinding catwalk} = 0,6 \times 0,15 \times 1700 = 153 \text{ kg/m}^2$$

$$qD = 2032,923 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = (1 + 0,917 + 0,824 + 0,852) \cdot 400$$

$$= 1437,2 \text{ kg/m}^2$$

7.2.3. Pembebanan balok As 3 A – H**a. Pelat Atap****1. Pembebanan balok element As 3 A – B**➤ **Beban Mati (qD)**

$$\text{Berat sendiri balok} = 0,2 \cdot (0,4 - 0,12) \cdot 2400 = 134,4 \text{ kg/m}^2$$

$$\text{Berat pelat atap} = (1 \times 1,278) \cdot 313 = 400,014 \text{ kg/m}^2$$

$$qD = 534,414 \text{ kg/m}^2$$

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- Beban hidup (qL)

$$qL = (1 \times 1,278) \cdot 120$$

$$= 153,36 \text{ kg/m}^2$$

b. Pelat Lantai

1. Pembebanan balok element **As 3 A – B**

- Beban Mati (qD)

$$\text{Berat sendiri balok} = 0,2 \cdot (0,4 - 0,12) \cdot 2400 = 134,4 \text{ kg/m}^2$$

$$\text{Berat pelat lantai} = (1 \times 1,278) \cdot 411 = 525,258 \text{ kg/m}^2$$

$$\text{Berat dinding} = 867 \text{ kg/m}^2$$

$$qD = 1526,658 \text{ kg/m}^2$$

- Beban hidup (qL)

$$qL = (1 \times 1,278) \cdot 400$$

$$= 511,2 \text{ kg/m}^2$$

2. Pembebanan balok element **As 3 B - C = 3 C - D**

- Beban Mati (qD)

$$\text{Beban sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat lantai} = (1 + 0,852) \cdot 411 = 761,172 \text{ kg/m}^2$$

$$qD = 847,572 \text{ kg/m}^2$$

- Beban hidup (qL)

$$qL = (1 + 0,852) \cdot 400$$

$$= 704,8 \text{ kg/m}^2$$

3. Pembebanan balok element **As 3 D – F = F – H**

- Beban Mati (qD)

$$\text{Berat sendiri balok} = 0,35 \cdot (0,6 - 0,12) \cdot 2400 = 403,2 \text{ kg/m}^2$$

$$\text{Berat pelat lantai} = (1 + 0,917 + 0,824 + 0,852) \cdot 411 = 1467,723 \text{ kg/m}^2$$

$$\text{Berat dinding catwalk} = 0,6 \times 0,15 \times 1700 = 153 \text{ kg/m}^2$$

$$qD = 2032,923 \text{ kg/m}^2$$

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➤ Beban hidup (qL)

$$qL = (1 + 0,917 + 0,824 + 0,852) \cdot 400$$

$$= 1437,2 \text{ kg/m}^2$$

7.2.4. Pembebanan balok As 4 A – J**a. Pelat Atap**

1. Pembebanan balok element **As 4 A – B**

➤ Beban Mati (qD)

Berat sendiri balok	= 0,2 .(0,4 – 0,12). 2400		= 134,4 kg/m ²
Berat pelat atap	= (2 x 1,278) . 313		= 869,514 kg/m ²
			qD = 1003,914 kg/m ²

➤ Beban hidup (qL)

$$qL = (2 \times 1,278) \cdot 120$$

$$= 306,72 \text{ kg/m}^2$$

2. Pembebanan balok element **As 4 B – C = C – D**

➤ Beban Mati (qD)

Beban sendiri balok	= 0,2 .(0,3 – 0,12) . 2400		= 86,4 kg/m ²
Berat pelat atap	= (2 x 1) . 313		= 626 kg/m ²
			qD = 712,4 kg/m ²

➤ Beban hidup (qL)

$$qL = (2 \times 1) \cdot 120$$

$$= 240 \text{ kg/m}^2$$

3. Pembebanan balok element **As 4 D - E**

➤ Beban Mati (qD)

Beban sendiri balok	= 0,2 .(0,3 – 0,12). 2400		= 86,4 kg/m ²
Berat pelat atap	= 2 (0,917) . 313		= 574,042 kg/m ²
			qD = 660,442 kg/m ²

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➤ **Beban hidup (qL)**

$$qL = 2 (0,917) \cdot 120$$

$$= 220,08 \text{ kg/m}^2$$

b. Pelat Lantai1. **Pembebanan balok element As 4 A – B**➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot (0,4 - 0,12) \cdot 2400 = 134,4 \text{ kg/m}^2$$

$$\text{Berat pelat lantai} = (2 \times 1,278) \cdot 411 = 1050,516 \text{ kg/m}^2$$

$$\text{Berat dinding} = 867 \text{ kg/m}^2$$

$$qD = 2051,916 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = (2 \times 1,278) \cdot 400$$

$$= 1022,4 \text{ kg/m}^2$$

2. **Pembebanan balok element As 4 B - C = C - D = E - F = G - H**➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat lantai} = (1 + 1) \cdot 411 = 822 \text{ kg/m}^2$$

$$qD = 908,4 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = (1 + 1) \cdot 400$$

$$= 800 \text{ kg/m}^2$$

3. **Pembebanan balok element As 4 D – E = F – G**➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat lantai} = 2 (0,917) \cdot 411 = 753,774 \text{ kg/m}^2$$

$$qD = 840,174 \text{ kg/m}^2$$

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➤ Beban hidup (qL)

$$qL = 2 (0,917) \cdot 400$$

$$= 733,6 \text{ kg/m}^2$$

4. Pembebanan balok element **As 4 H – I** (pelat atap)

➤ Beban Mati (qD)

$$\text{Beban sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat lantai} = (1 \times 0,67) \cdot 313 = 209,71 \text{ kg/m}^2$$

$$qD = 296,11 \text{ kg/m}^2$$

➤ Beban hidup (qL)

$$qL = (1 \times 0,67) \cdot 120$$

$$= 80,4 \text{ kg/m}^2$$

5. Pembebanan balok element **As 4 I – J** (pelat atap)

➤ Beban Mati (qD)

$$\text{Beban sendiri balok} = 0,2 \cdot (0,4 - 0,12) \cdot 2400 = 134,4 \text{ kg/m}^2$$

$$\text{Berat pelat lantai} = (1 \times 1,32) \cdot 313 = 413,16 \text{ kg/m}^2$$

$$qD = 547,56 \text{ kg/m}^2$$

➤ Beban hidup (qL)

$$qL = (1 \times 1,32) \cdot 120$$

$$= 158,4 \text{ kg/m}^2$$

7.2.5. Pembebanan balok As 5 A – J**a. Pelat Atap**1. Pembebanan balok element **As 5 A – B**

➤ Beban Mati (qD)

$$\text{Berat sendiri balok} = 0,2 \cdot (0,4 - 0,12) \cdot 2400 = 134,4 \text{ kg/m}^2$$

$$\text{Berat pelat atap} = (1,278 + 1,5) \cdot 313 = 869,514 \text{ kg/m}^2$$

$$qD = 1003,914 \text{ kg/m}^2$$

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➤ Beban hidup (qL)

$$\begin{aligned} qL &= (1,278 + 1,5) \cdot 120 \\ &= 333,36 \text{ kg/m}^2 \end{aligned}$$

2. Pembebanan balok element **As 5 B - C = C - D**

➤ Beban Mati (qD)

Beban sendiri balok	$= 0,2 \cdot (0,3 - 0,12) \cdot 2400$	$= 86,4 \text{ kg/m}^2$
Berat pelat atap	$= (1 + 1) \cdot 313$	$= 626 \text{ kg/m}^2$
		$qD = 712,4 \text{ kg/m}^2$

➤ Beban hidup (qL)

$$\begin{aligned} qL &= (1 + 1) \cdot 120 \\ &= 240 \text{ kg/m}^2 \end{aligned}$$

3. Pembebanan balok element **As 5 D - E**

➤ Beban Mati (qD)

Beban sendiri balok	$= 0,2 \cdot (0,3 - 0,12) \cdot 2400$	$= 86,4 \text{ kg/m}^2$
Berat pelat atap	$= 2 (0,917) \cdot 313$	$= 574,042 \text{ kg/m}^2$
		$qD = 660,442 \text{ kg/m}^2$

➤ Beban hidup (qL)

$$\begin{aligned} qL &= 2 (0,917) \cdot 120 \\ &= 220,08 \text{ kg/m}^2 \end{aligned}$$

4. Pembebanan balok element **As 5 E - F = G - H**

➤ Beban Mati (qD)

Beban sendiri balok	$= 0,2 \cdot (0,3 - 0,12) \cdot 2400$	$= 86,4 \text{ kg/m}^2$
Berat pelat atap	$= 1 \cdot 313$	$= 313 \text{ kg/m}^2$
		$qD = 399,4 \text{ kg/m}^2$

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➤ **Beban hidup (qL)**

$$\begin{aligned} qL &= 1 \cdot 120 \\ &= 120 \text{ kg/m}^2 \end{aligned}$$

5. **Pembebanan balok element As 5 F - G**➤ **Beban Mati (qD)**

$$\begin{aligned} \text{Beban sendiri balok} &= 0,2 \cdot (0,3 - 0,12) \cdot 2400 &= 86,4 \text{ kg/m}^2 \\ \text{Berat pelat atap} &= 0,917 \cdot 313 &= 287,021 \text{ kg/m}^2 \\ \hline qD &= 373,421 \text{ kg/m}^2 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\begin{aligned} qL &= 0,917 \cdot 120 \\ &= 110,04 \text{ kg/m}^2 \end{aligned}$$

b. Pelat Lantai1. **Pembebanan balok element As 5 A - B**➤ **Beban Mati (qD)**

$$\begin{aligned} \text{Beban sendiri balok} &= 0,2 \cdot (0,4 - 0,12) \cdot 2400 &= 134,4 \text{ kg/m}^2 \\ \text{Berat pelat lantai} &= (1,278 + 1,5) \cdot 411 &= 1141,76 \text{ kg/m}^2 \\ \hline qD &= 1276,16 \text{ kg/m}^2 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\begin{aligned} qL &= (1,278 + 1,5) \cdot 400 \\ &= 1111,2 \text{ kg/m}^2 \end{aligned}$$

2. **Pembebanan balok element As 5 B - C = C - D = E - F = G - H**➤ **Beban Mati (qD)**

$$\begin{aligned} \text{Beban sendiri balok} &= 0,2 \cdot (0,3 - 0,12) \cdot 2400 &= 86,4 \text{ kg/m}^2 \\ \text{Berat pelat lantai} &= (1 + 1) \cdot 411 &= 822 \text{ kg/m}^2 \\ \text{Berat dinding} & &= 867 \text{ kg/m}^2 \\ \hline qD &= 1775,4 \text{ kg/m}^2 \end{aligned}$$

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➤ Beban hidup (qL)

$$qL = (1 + 1) \cdot 400$$

$$= 800 \text{ kg/m}^2$$

3. Pembebanan balok element **As 5 D - E = F - G**

➤ Beban Mati (qD)

$$\text{Beban sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat lantai} = 2 (0,917) \cdot 411 = 753,774 \text{ kg/m}^2$$

$$\text{Berat dinding} = 867 \text{ kg/m}^2$$

$$qD = 1707,174 \text{ kg/m}^2$$

➤ Beban hidup (qL)

$$qL = 2 (0,917) \cdot 400$$

$$= 733,6 \text{ kg/m}^2$$

4. Pembebanan balok element **As 5 H - I (pelat atap)**

➤ Beban Mati (qD)

$$\text{Beban sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat atap} = 2 (0,67) \cdot 313 = 419,42 \text{ kg/m}^2$$

$$qD = 505,82 \text{ kg/m}^2$$

➤ Beban hidup (qL)

$$qL = 2 (0,67) \cdot 120$$

$$= 160,8 \text{ kg/m}^2$$

5. Pembebanan balok element **As 5 I - J (pelat atap)**

➤ Beban Mati (qD)

$$\text{Beban sendiri balok} = 0,2 \cdot (0,4 - 0,12) \cdot 2400 = 134,4 \text{ kg/m}^2$$

$$\text{Berat pelat atap} = (1,32 + 1,6425) \cdot 313 = 927,262 \text{ kg/m}^2$$

$$qD = 1155,262 \text{ kg/m}^2$$

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- Beban hidup (qL)

$$qL = (1,32 + 1,6425) \cdot 120$$

$$= 355,5 \text{ kg/m}^2$$

7.2.6. Pembebanan balok As 6 A – J**a. Pelat Atap**

1. Pembebanan balok element **As 6 A – B**

- Beban Mati (qD)

$$\text{Berat sendiri balok} = 0,2 \cdot (0,4 - 0,12) \cdot 2400 = 134,4 \text{ kg/m}^2$$

$$\text{Berat pelat atap} = (1 \times 1,5) \cdot 313 = 469,5 \text{ kg/m}^2$$

$$qD = 603,9 \text{ kg/m}^2$$

- Beban hidup (qL)

$$qL = (1 \times 1,5) \cdot 120$$

$$= 180 \text{ kg/m}^2$$

2. Pembebanan balok element **As 6 B – C = C – D = E – F = G – H**

- Beban Mati (qD)

$$\text{Beban sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat atap} = 1 \times 313 = 313 \text{ kg/m}^2$$

$$qD = 399,4 \text{ kg/m}^2$$

- Beban hidup (qL)

$$qL = 1 \times 120$$

$$= 120 \text{ kg/m}^2$$

3. Pembebanan balok element **As 6 D – E = F – G**

- Beban Mati (qD)

$$\text{Beban sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat atap} = 2 (0,917) \cdot 313 = 574,042 \text{ kg/m}^2$$

$$qD = 660,442 \text{ kg/m}^2$$

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- Beban hidup (qL)

$$\begin{aligned} qL &= 2 (0,917) \cdot 120 \\ &= 220,08 \text{ kg/m}^2 \end{aligned}$$

b. Pelat Lantai

1. Pembebanan balok element **As 6 A – B**

- Beban Mati (qD)

$$\begin{aligned} \text{Beban sendiri balok} &= 0,2 \cdot (0,4 - 0,12) \cdot 2400 &= 134,4 \text{ kg/m}^2 \\ \text{Berat pelat lantai} &= (1 \times 1,5) \cdot 411 &= 616,5 \text{ kg/m}^2 \\ \text{Berat dinding} & &= 867 \text{ kg/m}^2 \\ \hline qD &= 1617,9 \text{ kg/m}^2 \end{aligned}$$

- Beban hidup (qL)

$$\begin{aligned} qL &= (1 \times 1,5) \cdot 400 \\ &= 600 \text{ kg/m}^2 \end{aligned}$$

2. Pembebanan balok element **As 6 B - C = C - D = E - F = G - H**

- Beban Mati (qD)

$$\begin{aligned} \text{Beban sendiri balok} &= 0,2 \cdot (0,3 - 0,12) \cdot 2400 &= 86,4 \text{ kg/m}^2 \\ \text{Berat pelat lantai} &= 1 \times 411 &= 411 \text{ kg/m}^2 \\ \text{Berat dinding} & &= 867 \text{ kg/m}^2 \\ \hline qD &= 1364,4 \text{ kg/m}^2 \end{aligned}$$

- Beban hidup (qL)

$$\begin{aligned} qL &= 1 \times 400 \\ &= 400 \text{ kg/m}^2 \end{aligned}$$

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3. Pembebanan balok element **As 6 D - E = F - G**➤ **Beban Mati (qD)**

$$\begin{aligned}
 \text{Beban sendiri balok} &= 0,2 \cdot (0,3 - 0,12) \cdot 2400 &= 86,4 \text{ kg/m}^2 \\
 \text{Berat pelat lantai} &= 0,917 \times 411 &= 376,887 \text{ kg/m}^2 \\
 \text{Berat dinding} & &= 867 \text{ kg/m}^2 \\
 \hline
 \text{qD} &= 1330,287 \text{ kg/m}^2
 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\begin{aligned}
 \text{qL} &= 0,917 \times 400 \\
 &= 366,8 \text{ kg/m}^2
 \end{aligned}$$

4. Pembebanan balok element **As 6 H - I (pelat atap)**➤ **Beban Mati (qD)**

$$\begin{aligned}
 \text{Beban sendiri balok} &= 0,2 \cdot (0,3 - 0,12) \cdot 2400 &= 86,4 \text{ kg/m}^2 \\
 \text{Berat pelat atap} &= 0,67 \times 313 &= 209,71 \text{ kg/m}^2 \\
 \hline
 \text{qD} &= 296,11 \text{ kg/m}^2
 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\begin{aligned}
 \text{qL} &= 0,67 \times 120 \\
 &= 80,4 \text{ kg/m}^2
 \end{aligned}$$

5. Pembebanan balok element **As 6 I - J (pelat atap)**➤ **Beban Mati (qD)**

$$\begin{aligned}
 \text{Beban sendiri balok} &= 0,2 \cdot (0,4 - 0,12) \cdot 2400 &= 134,4 \text{ kg/m}^2 \\
 \text{Berat pelat atap} &= 1,6425 \times 313 &= 514,103 \text{ kg/m}^2 \\
 \hline
 \text{qD} &= 648,503 \text{ kg/m}^2
 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\begin{aligned}
 \text{qL} &= 1,6425 \times 120 \\
 &= 197,1 \text{ kg/m}^2
 \end{aligned}$$

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7.3. Pembebanan sloof

➤ Beban Mati (qD)

$$\text{Beban sendiri balok} = 0,2 \cdot 0,3 \cdot 2400 = 144 \text{ kg/m}^2$$

$$\text{Berat dinding} = 867 \text{ kg/m}^2$$

$$qD = 1011 \text{ kg/m}^2$$

7.4. Penulangan Balok**7.4.1. Balok dimensi 20/30****a) Perhitungan tulangan lentur**

Data perencanaan :

$$h = 300 \text{ mm}$$

$$f'c = 30 \text{ MPa}$$

$$b = 200 \text{ mm}$$

$$\varnothing_s = 8 \text{ mm}$$

$$p = 40 \text{ mm}$$

$$\varnothing_t = 22 \text{ mm}$$

$$f_y = 360 \text{ Mpa}$$

$$m = \frac{f_y}{0,85 \cdot f_c} = \frac{360}{0,85 \cdot 30} = 14,118$$

$$\begin{aligned} \rho_b &= \frac{0,85 \cdot f_c}{f_y} \cdot \beta \cdot \left(\frac{600}{600 + f_y} \right) \\ &= \frac{0,85 \cdot 30}{360} \cdot 0,85 \cdot \left(\frac{600}{600 + 360} \right) \\ &= 0,0376 \end{aligned}$$

$$\begin{aligned} \rho_{\max} &= 0,75 \cdot \rho_b \\ &= 0,0282 \end{aligned}$$

$$\rho_{\min} = \frac{1,4}{f_y} = \frac{1,4}{360} = 0,0039$$

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➤ **Daerah Tumpuan (Frame 232/ As 3 C – D)**

Dari Perhitungan SAP 2000 diperoleh :

$$M_u = 6272,41 \text{ kgm} = 6,273 \cdot 10^7 \text{ Nmm}$$

$$M_n = \frac{M_u}{\phi} = \frac{6,273 \cdot 10^7}{0,8} = 7,841 \cdot 10^7 \text{ Nmm}$$

$$\begin{aligned} d &= h - p - \phi_t - \phi_s - \frac{1}{2} \text{ spasi tul} \\ &= 300 - 40 - 22 - 8 - \frac{1}{2} \cdot 30 \\ &= 215 \text{ mm} \end{aligned}$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{7,841 \cdot 10^7}{200 \cdot 215^2} = 8,481$$

$$\begin{aligned} \rho_{\text{ada}} &= \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{f_y}} \right) \\ &= \frac{1}{14,118} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14,118 \cdot 8,481}{360}} \right) \\ &= 0,0298 \end{aligned}$$

$$\rho > \rho_{\text{max}}$$

$$\text{Digunakan } \rho_{\text{max}} = 0,0282$$

$$\begin{aligned} \text{As perlu} &= \rho_{\text{max}} \cdot b \cdot d \\ &= 0,0282 \cdot 200 \cdot 215 \\ &= 1212,6 \text{ mm}^2 \end{aligned}$$

$$\text{Dipakai tulangan D 22 mm} = \frac{1}{4} \cdot \pi \cdot 22^2 = 379,94 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{1212,6}{379,94} = 3,19 \approx 4 \text{ buah}$$

$$\begin{aligned} \text{As terpasang} &= 4 \times 379,94 \\ &= 1519,76 \text{ mm}^2 > \text{As aman!} \end{aligned}$$

Jadi, Dipakai tulangan 4 D22

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➤ **Daerah Lapangan (Frame 251/ As 1 B – C)**

Dari Perhitungan SAP 2000 diperoleh :

$$M_u = 3958,19 \text{ kgm} = 3,958 \cdot 10^7 \text{ Nmm}$$

$$M_n = \frac{M_u}{\phi} = \frac{3,958 \cdot 10^7}{0,8} = 4,947 \cdot 10^7 \text{ Nmm}$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{4,947 \cdot 10^7}{200 \cdot 215^2} = 5,351$$

$$\rho_{\text{ada}} = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{f_y}} \right)$$

$$= \frac{1}{14,118} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14,118 \cdot 5,351}{360}} \right)$$

$$= 0,0169$$

$$\rho > \rho_{\text{min}}$$

$$\rho < \rho_{\text{max}}$$

Digunakan $\rho_{\text{ada}} = 0,0169$

$$\begin{aligned} \text{As perlu} &= \rho_{\text{ada}} \cdot b \cdot d \\ &= 0,0169 \cdot 200 \cdot 215 \\ &= 726,70 \text{ mm}^2 \end{aligned}$$

$$\text{Dipakai tulangan D 22 mm} = \frac{1}{4} \cdot \pi \cdot 22^2 = 379,94 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{726,7}{379,94} = 1,91 \approx 2 \text{ buah}$$

$$\begin{aligned} \text{As terpasang} &= 2 \times 379,94 \\ &= 759,88 \text{ mm}^2 > \text{As aman!} \end{aligned}$$

Jadi, Dipakai tulangan 2 D22

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b) Perhitungan Tulangan Geser (Frame 197/ As 5 B – C)Dari perhitungan **SAP 2000** Diperoleh :

$$V_u = 5584,97 \text{ kg} = 5,585 \cdot 10^4 \text{ N (Perhitungan SAP)}$$

$$V_c = 1/6 \cdot b \cdot d \cdot \sqrt{f'_c}$$

$$= 1/6 \cdot 200 \cdot 215 \cdot \sqrt{30}$$

$$= 3,925 \cdot 10^4 \text{ N}$$

$$\phi V_c = 0,6 \cdot V_c$$

$$= 2,355 \cdot 10^4 \text{ N}$$

$$3\phi V_c = 3 \cdot \phi V_c$$

$$= 7,066 \cdot 10^4 \text{ N}$$

$$\phi V_c < V_u < 3\phi V_c \longrightarrow \text{perlu tulangan geser}$$

$$\phi V_s = V_u - \phi V_c = 3,23 \cdot 10^4 \text{ N}$$

$$V_{s \text{ perlu}} = \frac{\phi V_s}{\phi} = \frac{3,23 \cdot 10^4}{0,6} = 5,383 \cdot 10^4 \text{ N}$$

Digunakan sengkang $\phi 8$,

$$A_v = 2 \cdot A = 100,48 \text{ mm}^2$$

$$S = \frac{A_v \cdot f'_y \cdot d}{V_{s \text{ perlu}}} = \frac{100,48 \cdot 240 \cdot 215}{5,383 \cdot 10^4} = 96,3 \text{ mm}$$

$$S_{\text{maks}} = \frac{d}{2} = \frac{215}{2} = 107,5 \text{ mm}$$

Jadi, dipakai sengkang $\phi 8 - 75 \text{ mm}$

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7.4.2. Balok dimensi 20/40**a) Perhitungan tulangan lentur**

Data perencanaan :

$$\begin{aligned}
 h &= 400 \text{ mm} & \emptyset_t &= 22 \text{ mm} \\
 b &= 200 \text{ mm} & \emptyset_s &= 8 \text{ mm} \\
 p &= 40 \text{ mm} & d &= h - p - \frac{1}{2} \emptyset_t - \emptyset_s \\
 f_y &= 360 \text{ Mpa} & &= 400 - 40 - \frac{1}{2} \cdot 22 - 8 \\
 f'_c &= 30 \text{ MPa} & &= 341 \text{ mm}
 \end{aligned}$$

$$m = \frac{f_y}{0,85 \cdot f_c} = \frac{360}{0,85 \cdot 30} = 14,118$$

$$\begin{aligned}
 \rho_b &= \frac{0,85 \cdot f_c}{f_y} \cdot \beta \cdot \left(\frac{600}{600 + f_y} \right) \\
 &= \frac{0,85 \cdot 30}{360} \cdot 0,85 \cdot \left(\frac{600}{600 + 360} \right) \\
 &= 0,0376
 \end{aligned}$$

$$\rho_{\max} = 0,75 \cdot \rho_b = 0,0282$$

$$\rho_{\min} = \frac{1,4}{f_y} = \frac{1,4}{360} = 0,0039$$

➤ Daerah Tumpuan (Frame 215/ As 4 A – B)

Dari Perhitungan **SAP 2000** diperoleh :

$$M_u = 6818,12 \text{ kgm} = 6,818 \cdot 10^7 \text{ Nmm}$$

$$M_n = \frac{M_u}{\phi} = \frac{6,818 \cdot 10^7}{0,8} = 8,523 \cdot 10^7 \text{ Nmm}$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{8,523 \cdot 10^7}{200 \cdot 341^2} = 3,665$$

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$$\begin{aligned}\rho_{\text{ada}} &= \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{f_y}} \right) \\ &= \frac{1}{14,118} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14,118 \cdot 3,665}{360}} \right) \\ &= 0,0110\end{aligned}$$

$$\rho > \rho_{\text{min}}$$

$$\rho < \rho_{\text{max}}$$

$$\begin{aligned}\text{As perlu} &= \rho_{\text{ada}} \cdot b \cdot d \\ &= 0,011 \cdot 200 \cdot 341 \\ &= 752,916 \text{ mm}^2\end{aligned}$$

$$\text{Dipakai tulangan D 22 mm} = \frac{1}{4} \cdot \pi \cdot 22^2 = 379,94 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{752,916}{379,94} = 1,98 \approx 2 \text{ buah}$$

$$\begin{aligned}\text{As terpasang} &= 2 \times 379,94 \\ &= 759,88 \text{ mm}^2 > \text{As aman!}\end{aligned}$$

Jadi, Dipakai tulangan 2 D22

➤ **Daerah Lapangan (Frame 242/ As 2 B – C)**

Dari Perhitungan SAP 2000 diperoleh :

$$M_u = 4669,35 \text{ kgm} = 4,67 \cdot 10^7 \text{ Nmm}$$

$$M_n = \frac{M_u}{\phi} = \frac{4,67 \cdot 10^7}{0,8} = 5,8375 \cdot 10^7 \text{ Nmm}$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{5,8375 \cdot 10^7}{200 \cdot 341^2} = 2,51$$

$$\begin{aligned}\rho_{\text{ada}} &= \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{f_y}} \right) \\ &= \frac{1}{14,118} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14,118 \cdot 2,51}{360}} \right) \\ &= 0,0073\end{aligned}$$

$$\rho > \rho_{\text{min}}$$

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$$\rho < \rho_{\max}$$

Digunakan $\rho_{\text{ada}} = 0,0073$

$$\begin{aligned} \text{As perlu} &= \rho_{\text{ada}} \cdot b \cdot d \\ &= 0,0073 \cdot 200 \cdot 341 \\ &= 501,559 \text{ mm}^2 \end{aligned}$$

$$\text{Dipakai tulangan D 22 mm} = \frac{1}{4} \cdot \pi \times 22^2 = 379,94 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{501,559}{379,94} = 1,32 \approx 2 \text{ buah}$$

$$\begin{aligned} \text{As terpasang} &= 2 \times 379,94 \\ &= 759,88 \text{ mm}^2 > \text{As aman!} \end{aligned}$$

Jadi, Dipakai tulangan 2 D22

b) Perhitungan Tulangan Geser (Frame 215/ As 4 A – B)

Dari perhitungan **SAP 2000** Diperoleh :

$$V_u = 9568,54 \text{ kg} = 9,569 \cdot 10^4 \text{ N (Perhitungan SAP)}$$

$$\begin{aligned} V_c &= 1/6 \cdot b \cdot d \cdot \sqrt{f'c} \\ &= 1/6 \cdot 200 \cdot 341 \cdot \sqrt{30} \\ &= 6,225 \cdot 10^4 \text{ N} \end{aligned}$$

$$\begin{aligned} \emptyset V_c &= 0,6 \cdot V_c \\ &= 3,735 \cdot 10^4 \text{ N} \end{aligned}$$

$$\begin{aligned} 3\emptyset V_c &= 3 \cdot \emptyset V_c \\ &= 11,206 \cdot 10^4 \text{ N} \end{aligned}$$

$\emptyset V_c < V_u < 3\emptyset V_c$ —————▶ **perlu tulangan geser**

$$\emptyset V_s = V_u - \emptyset V_c = 5,834 \cdot 10^4 \text{ N}$$

$$V_{s \text{ perlu}} = \frac{\phi v_s}{\phi} = \frac{5,834 \cdot 10^4}{0,6} = 9,723 \cdot 10^4 \text{ N}$$

Digunakan sengkang $\emptyset 8$,

$$A_v = 2 \cdot A = 100,48 \text{ mm}^2$$

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$$S = \frac{Av \cdot f'_y \cdot d}{V_{s_{perlu}}} = \frac{100,48 \cdot 240 \cdot 341}{9,723 \cdot 10^4} = 84,5 \text{ mm}$$

$$S_{maks} = \frac{d}{2} = \frac{341}{2} = 170,5 \text{ mm}$$

Jadi, dipakai sengkang $\varnothing 8 - 75 \text{ mm}$

7.4.3. Balok dimensi 35/60**a) Perhitungan tulangan lentur**

Data perencanaan :

$h = 600 \text{ mm}$	$\varnothing_t = 22 \text{ mm}$
$b = 350 \text{ mm}$	$\varnothing_s = 8 \text{ mm}$
$p = 40 \text{ mm}$	$d = h - p - \frac{1}{2} \varnothing_t - \varnothing_s$
$f_y = 360 \text{ Mpa}$	$= 600 - 40 - \frac{1}{2} \cdot 22 - 8$
$f'_c = 30 \text{ MPa}$	$= 541 \text{ mm}$

$$m = \frac{f_y}{0,85 \cdot f'_c} = \frac{360}{0,85 \cdot 30} = 14,118$$

$$\begin{aligned} \rho_b &= \frac{0,85 \cdot f'_c}{f_y} \cdot \beta \cdot \left(\frac{600}{600 + f_y} \right) \\ &= \frac{0,85 \cdot 30}{360} \cdot 0,85 \cdot \left(\frac{600}{600 + 360} \right) \\ &= 0,0376 \end{aligned}$$

$$\rho_{max} = 0,75 \cdot \rho_b = 0,0282$$

$$\rho_{min} = \frac{1,4}{f_y} = \frac{1,4}{360} = 0,0039$$

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➤ **Daerah Tumpuan (Frame 234/ As 3 F – H)**

Dari Perhitungan **SAP 2000** diperoleh :

$$M_u = 15014,34 \text{ kgm} = 15,015 \cdot 10^7 \text{ Nmm}$$

$$M_n = \frac{M_u}{\Phi} = \frac{15,015 \cdot 10^7}{0,8} = 18,769 \cdot 10^7 \text{ Nmm}$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{18,769 \cdot 10^7}{350 \cdot 541^2} = 1,832$$

$$\rho_{\text{ada}} = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{f_y}} \right)$$

$$= \frac{1}{14,118} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14,118 \cdot 1,832}{360}} \right)$$

$$= 0,0053$$

$$\rho > \rho_{\text{min}}$$

$$\rho < \rho_{\text{max}}$$

$$\begin{aligned} \text{As perlu} &= \rho_{\text{ada}} \cdot b \cdot d \\ &= 0,0053 \cdot 350 \cdot 541 \\ &= 1001,044 \text{ mm}^2 \end{aligned}$$

$$\text{Dipakai tulangan D 22 mm} = \frac{1}{4} \cdot \pi \cdot 22^2 = 379,94 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{1001,044}{379,94} = 2,63 \approx 3 \text{ buah}$$

$$\begin{aligned} \text{As terpasang} &= 3 \times 379,94 \\ &= 1139,82 \text{ mm}^2 > \text{Asaman!} \end{aligned}$$

Jadi, Dipakai tulangan 3 D22

➤ **Daerah Lapangan (Frame 234/ As 3 F – H)**

Dari Perhitungan **SAP 2000** diperoleh :

$$M_u = 7717,54 \text{ kgm} = 7,718 \cdot 10^7 \text{ Nmm}$$

$$M_n = \frac{M_u}{\phi} = \frac{7,718 \cdot 10^7}{0,8} = 9,648 \cdot 10^7 \text{ Nmm}$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{9,648 \cdot 10^7}{350 \cdot 541^2} = 0,942$$

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$$\begin{aligned}\rho_{\text{ada}} &= \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{f_y}} \right) \\ &= \frac{1}{14,118} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14,118 \cdot 0,942}{360}} \right) \\ &= 0,0027\end{aligned}$$

$$\rho < \rho_{\text{min}}$$

Digunakan $\rho_{\text{min}} = 0,0039$

$$\begin{aligned}\text{As perlu} &= \rho_{\text{min}} \cdot b \cdot d \\ &= 0,0039 \cdot 350 \cdot 541 \\ &= 738,465 \text{ mm}^2\end{aligned}$$

$$\text{Dipakai tulangan D 22 mm} = \frac{1}{4} \cdot \pi \cdot 22^2 = 379,94 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{738,465}{379,94} = 1,94 \approx 2 \text{ buah}$$

$$\begin{aligned}\text{As terpasang} &= 2 \times 379,94 \\ &= 759,88 \text{ mm}^2 > \text{As} \dots\dots \text{ aman!}\end{aligned}$$

Jadi, Dipakai tulangan 2 D22

b) Perhitungan Tulangan Geser (Frame 234/ As 3 F – H)

Dari perhitungan SAP 2000 Diperoleh :

$$V_u = 14719,09 \text{ kg} = 14,72 \cdot 10^4 \text{ N (Perhitungan SAP)}$$

$$\begin{aligned}V_c &= 1/6 \cdot b \cdot d \cdot \sqrt{f'c} \\ &= 1/6 \cdot 350 \cdot 541 \cdot \sqrt{30} \\ &= 17,285 \cdot 10^4 \text{ N}\end{aligned}$$

$$\begin{aligned}\emptyset V_c &= 0,6 \cdot V_c \\ &= 10,371 \cdot 10^4 \text{ N}\end{aligned}$$

$$\begin{aligned}3\emptyset V_c &= 3 \cdot \emptyset V_c \\ &= 31,113 \cdot 10^4 \text{ N}\end{aligned}$$

$\emptyset V_c < V_u < 3\emptyset V_c$ —————▶ **perlu tulangan geser**

$$\emptyset V_s = V_u - \emptyset V_c = 4,349 \cdot 10^4 \text{ N}$$

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$$V_{s \text{ perlu}} = \frac{\phi v_s}{\phi} = \frac{4,349 \cdot 10^4}{0,6} = 7,248 \cdot 10^4 \text{ N}$$

Digunakan sengkang Ø8,

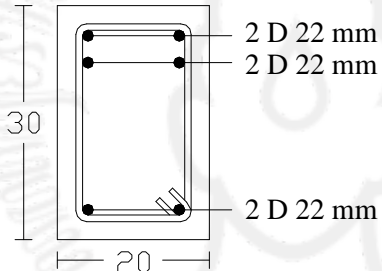
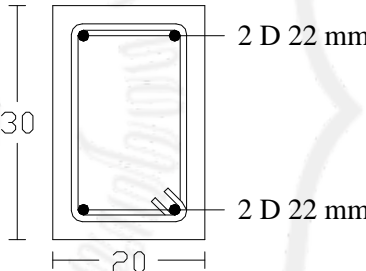
$$A_v = 2 \cdot A = 100,48 \text{ mm}^2$$

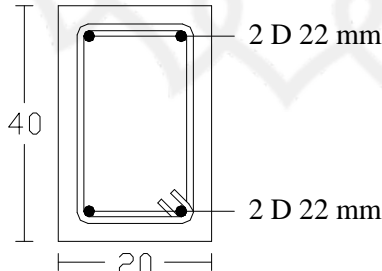
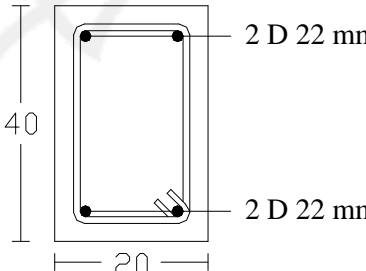
$$S = \frac{A_v \cdot f'_y \cdot d}{V_{s \text{ perlu}}} = \frac{100,48 \cdot 240 \cdot 541}{7,248 \cdot 10^4} = 179,9 \text{ mm}$$

$$S_{\text{maks}} = \frac{d}{2} = \frac{541}{2} = 270,5 \text{ mm}$$

Jadi, dipakai sengkang Ø 8 – 150 mm

Tabel 7.3. Tulangan Balok

Potongan	Tumpuan	Lapangan
Balok 20 x 30		
Tulangan	4 D 22 mm	2 D 22 mm
Sengkang	Ø 8 - 75 mm	Ø 8 - 100 mm

Potongan	Tumpuan	Lapangan
Balok 20 x 40		
Tulangan	2 D 22 mm	2 D 22 mm
Sengkang	Ø 8 - 75 mm	Ø 8 - 170 mm

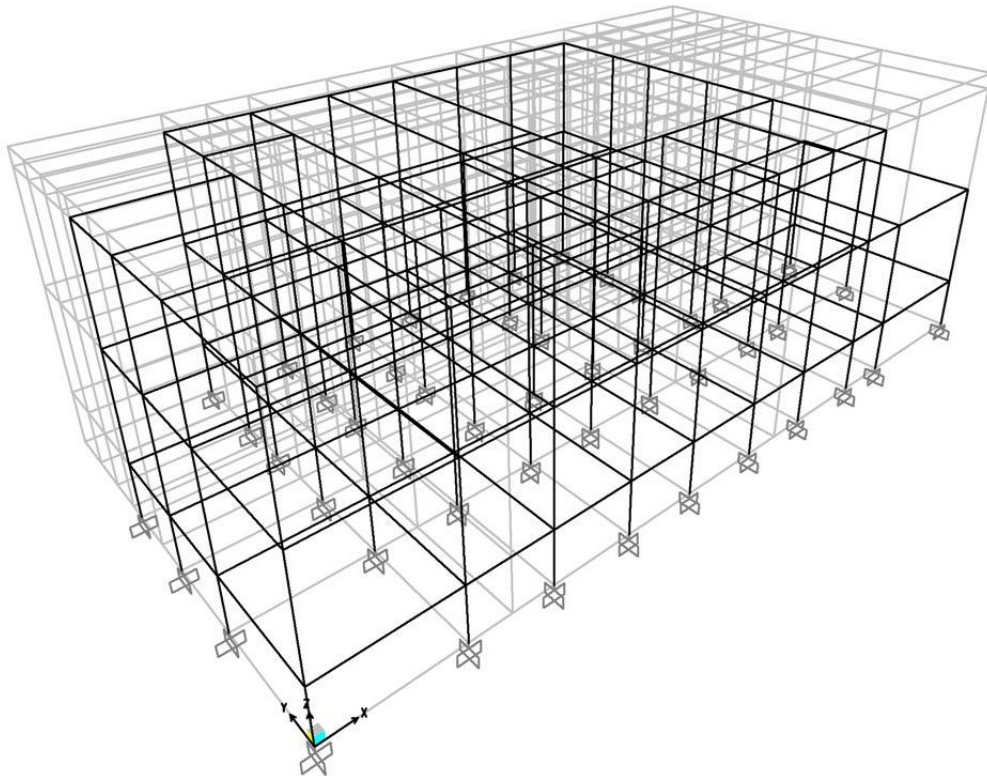
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Potongan	Tumpuan	Lapangan
Balok 35 x 60		
Tulangan	3 D 22 mm	2 D 22 mm
Sengkang	∅ 8 - 150 mm	∅ 8 - 250 mm

**BAB 8
PORTAL**

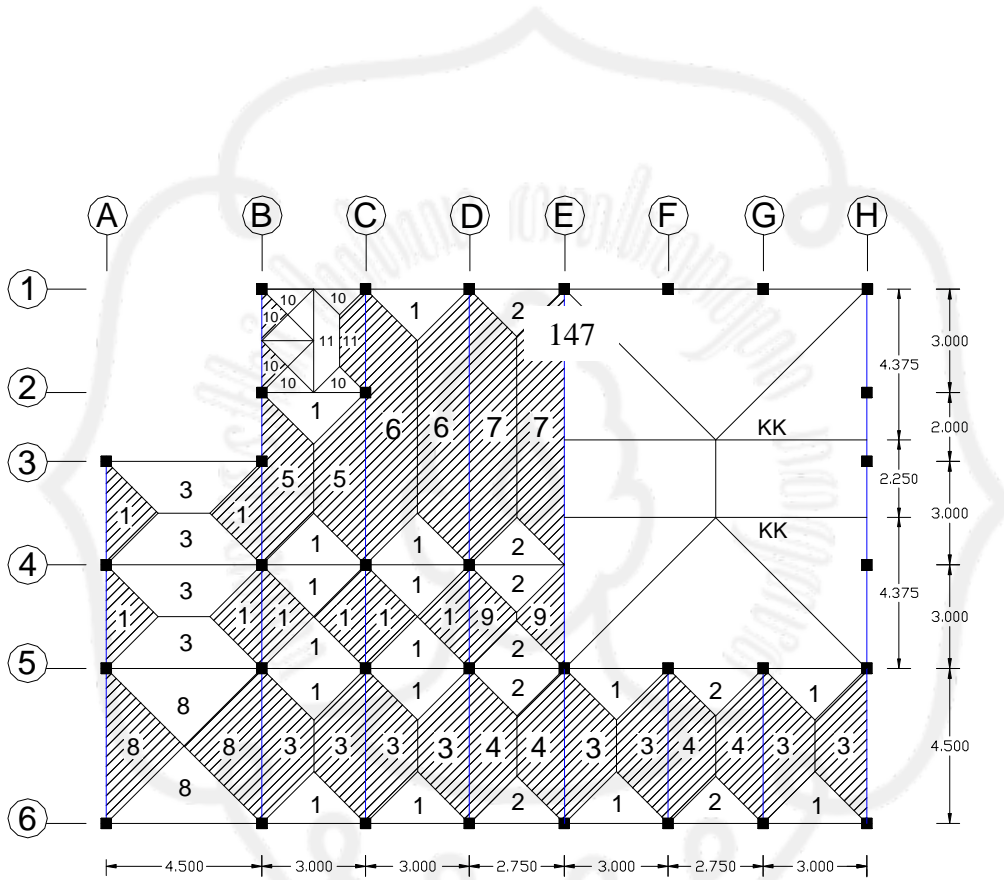
7.5. Perencanaan Portal



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Gambar 8.1. Gambar Portal 3 Dimensi

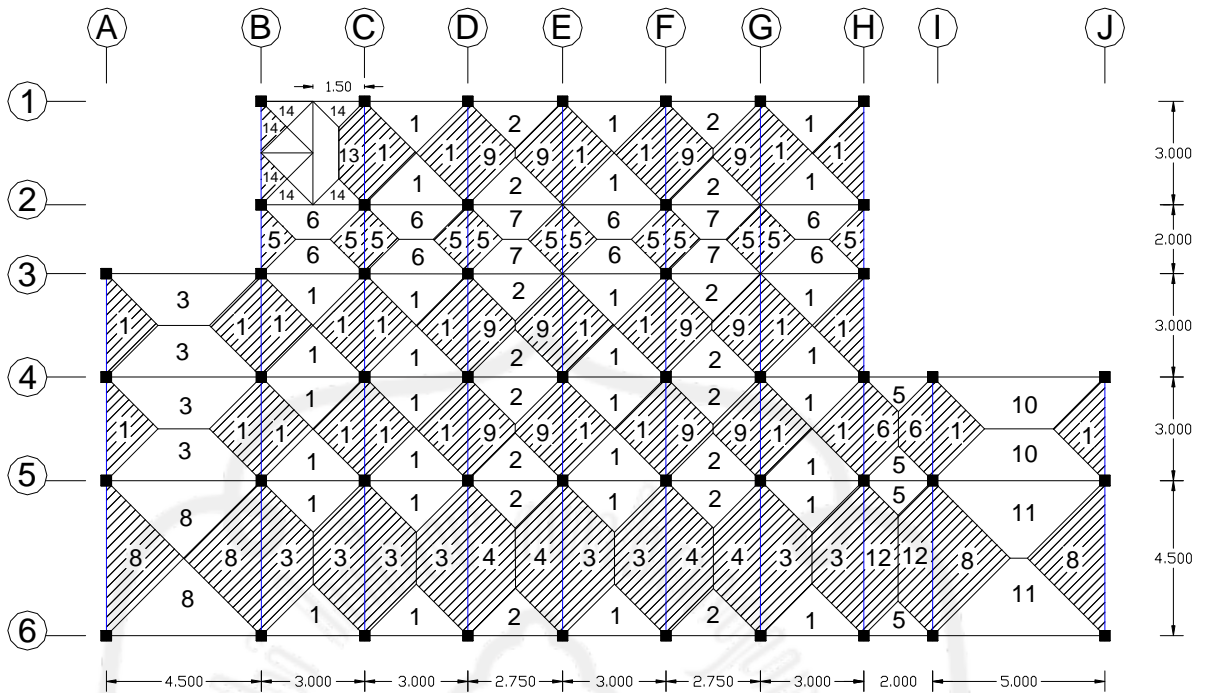


Gambar 8.2. Denah Balok Portal (Atap)

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Gambar 8.3. Denah Balok Portal (Lantai)

7.1.4. Dasar Perencanaan

Secara umum data yang digunakan untuk hitungan rencana portal adalah sebagai berikut :

- a. Bentuk denah balok : Seperti tergambar
- b. Model perhitungan : SAP 2000 (3 D)
- c. Dimensi balok I : 200 (mm) x 300 (mm)
 Dimensi balok II : 200 (mm) x 400 (mm)
 Dimensi balok III : 350 (mm) x 600 (mm)
- d. Mutu beton : K300U36
- e. Dimensi kolom : 350 (mm) x 350 (mm)

7.1.5. Perencanaan Pembebanan

Dalam hitungan portal, berat sendiri balok dimasukkan dalam perhitungan (input) SAP 2000, sedangkan beberapa pembebanan yang lain adalah sebagai berikut :

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➤ Plat Lantai

Berat plat sendiri	= 0,12 x 2400 x1	= 288	kg/m ²
Berat keramik (1 cm)	= 0,01 x 2400 x1	= 24	kg/m ²
Berat Spesi (2 cm)	= 0,02 x 2100 x1	= 42	kg/m ²
Berat plafond + instalasi listrik		= 25	kg/m ²
Berat Pasir (2 cm)	= 0,02 x 1600 x1	= 32	kg/m ²
		<u>qD = 411</u>	<u>kg/m²</u>

➤ Plat atap

Berat plat sendiri	= 0,12 x 2400 x 1	= 288	kg/m ²
Berat plafond + instalasi listrik		= 25	kg/m ²
		<u>qD = 313</u>	<u>kg/m²</u>

➤ Dinding

$$\begin{aligned} \text{Berat sendiri dinding} &= 0,15 (4 - 0,6) \times 1700 \\ &= 867 \text{ kg/m}^2 \end{aligned}$$

➤ Atap

Reaksi Kuda kuda	(P1) = 4952,50 kg (SAP 2000)
Reaksi Jurai	(P2) = 1203,79 kg (SAP 2000)
Reaksi Setengah Kuda-kuda	(P3) = 1165,92 kg (SAP 2000)

➤ Kolom tumpuan rangka atap

$$P = 0,2 \times 0,2 \times 0,6 \times 2400 = 57,6 \text{ kg}$$

7.1.6. Hitungan Luas Equivalen

$$\text{Luas equivalent segitiga} \quad : \frac{1}{3} \cdot Lx$$

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$$\text{Luas equivalent trapezium} : \frac{1}{6} \cdot Lx \cdot \left(3 - 4 \left(\frac{Lx}{2 \cdot Ly} \right)^2 \right)$$

Table 8.1. Hitungan Luas Equivalen Pelat Atap

No.	Ukuran Plat (cm)	Lx (m)	Ly (m)	Leq (segitiga)	Leq (trapezium)
1	300 x 300	3	3	1,0	--
2	275 x 450	2,75	4	0,917	--
3	300 x 450	3	4,5	--	1,278
4	275 x 450	2,75	4,5	--	1,204
5	300 x 500	3	5	--	1,32
6	300 x 800	3	8	--	1,429
7	275 x 800	2,75	8	--	1,321
8	450 x 450	4,5	4,5	1,5	--
9	275 x 300	2,75	3	--	0,99
10	150 x 150	1,5	1,5	0,5	--
11	150 x 300	1,5	3	--	0,6875

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Table 8.2. Hitungan Luas Equivalen Pelat Lantai

No.	Ukuran Plat (cm)	Lx (m)	Ly (m)	Leq (segitiga)	Leq (trapezium)
1	300 x 300	3	3	1,0	--
2	275 x 300	2,75	3	0,917	--
3	300 x 450	3	4,5	--	1,278
4	275 x 450	2,75	4,5	--	1,204
5	200 x 300	2	3	0,67	--
6	200 x 300	2	3	--	0,852
7	200 x 275	2	2,75	--	0,824
8	450 x 450	4,5	4,5	1,5	--
9	275 x 300	2,75	3	--	0,99
10	300 x 500	3	5	--	1,32
11	450 x 500	4,5	5	--	1,6425
12	200 x 450	2	4,5	--	0,934
13	150 x 300	1,5	3	--	0,6875
14	150 x 150	1,5	1,5	0,5	--

7.6. Hitungan Pembebanan Portal**7.3.1. Pembebanan balok induk As A 3 – 6****a. Pelat Atap**

1. Pembebanan balok induk element **As A 3 – 4 = 4 – 5**

➤ **Beban Mati (qD)**

$$\text{Berat sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat atap} = 1 \times 313 = 313 \text{ kg/m}^2$$

$$qD = 399,4 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = 1 \times 120$$

$$= 120 \text{ kg/m}^2$$

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2. Pembebanan balok induk element **As A 5 – 6**➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot (0,4 - 0,12) \cdot 2400 = 134,4 \text{ kg/m}^2$$

$$\text{Beban pelat atap} = 1,5 \times 313 = 469,5 \text{ kg/m}^2$$

$$\underline{\text{qD} = 603,9 \text{ kg/m}^2}$$

➤ **Beban hidup (qL)**

$$qL = 1,5 \times 120$$

$$= 180 \text{ kg/m}^2$$

b. Pelat Lantai1. Pembebanan balok induk element **As A 3 – 4 = 4 – 5**➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Beban pelat lantai} = 1 \times 411 = 411 \text{ kg/m}^2$$

$$\text{Beban dinding} = 867 \text{ kg/m}^2$$

$$\underline{\text{qD} = 1364,4 \text{ kg/m}^2}$$

➤ **Beban hidup (qL)**

$$qL = 1 \times 400$$

$$= 400 \text{ kg/m}^2$$

2. Pembebanan balok induk element **As A 5 – 6**➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot (0,4 - 0,12) \cdot 2400 = 134,4 \text{ kg/m}^2$$

$$\text{Beban pelat lantai} = 1,5 \times 411 = 616,5 \text{ kg/m}^2$$

$$\text{Beban dinding} = 867 \text{ kg/m}^2$$

$$\underline{\text{qD} = 1617,9 \text{ kg/m}^2}$$

➤ **Beban hidup (qL)**

$$qL = 1,5 \times 400$$

$$= 600 \text{ kg/m}^2$$

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7.3.2. Pembebanan balok induk As B 1 – 6**a. Pelat Atap**1. Pembebanan balok induk element **As B 1 – 2**➤ **Beban Mati (qD)**

$$\text{Berat sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat atap} = (2 \times 0,5) \times 313 = 313 \text{ kg/m}^2$$

$$qD = 399,4 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = (2 \times 0,5) \times 120 \\ = 120 \text{ kg/m}^2$$

2. Pembebanan balok induk element **As B 2 – 4**➤ **Beban Mati (qD) Trapesium Leq 5**

$$\text{Berat sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat atap} = (1 \times 1,32) \cdot 313 = 413,16 \text{ kg/m}^2$$

$$qD = 499,56 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = (1 \times 1,32) \cdot 120 \\ = 158,4 \text{ kg/m}^2$$

➤ **Beban Mati (qD) Segitiga Leq 1**

$$\text{Berat pelat atap} = 1 \cdot 313 = 313 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = 1 \cdot 120$$

$$= 120 \text{ kg/m}^2$$

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3. Pembebanan balok induk element **As B 4 – 5**➤ **Beban Mati (qD)**

$$\text{Berat sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat atap} = (1 \times 2) \cdot 313 = 626 \text{ kg/m}^2$$

$$qD = 712,4 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = (1 \times 2) \cdot 120$$

$$= 240 \text{ kg/m}^2$$

4. Pembebanan balok induk element **As B 5 – 6**➤ **Beban Mati (qD)**

$$\text{Berat sendiri balok} = 0,2 \cdot (0,4 - 0,12) \cdot 2400 = 134,4 \text{ kg/m}^2$$

$$\text{Berat pelat atap} = (1,278 + 1,5) \cdot 313 = 869,514 \text{ kg/m}^2$$

$$qD = 1003,914 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = (1,278 + 1,5) \cdot 120$$

$$= 333,36 \text{ kg/m}^2$$

b. Pelat Lantai1. Pembebanan balok induk element **As B 1 – 2**➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat lantai} = (0,5 \cdot 2) \times 411 = 411 \text{ kg/m}^2$$

$$\text{Berat dinding} = 867 \text{ kg/m}^2$$

$$qD = 1364,4 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = (0,5 \cdot 2) \times 400$$

$$= 400 \text{ kg/m}^2$$

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2. Pembebanan balok induk element **As B 2 – 3**➤ **Beban Mati (qD)**

$$\begin{aligned} \text{Beban sendiri balok} &= 0,2 \cdot (0,3 - 0,12) \cdot 2400 &= 86,4 \text{ kg/m}^2 \\ \text{Berat pelat lantai} &= 0,67 \times 411 &= 275,37 \text{ kg/m}^2 \\ \text{Berat dinding} & &= 867 \text{ kg/m}^2 \\ \hline \text{qD} &= 1228,77 \text{ kg/m}^2 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\begin{aligned} \text{qL} &= 0,67 \times 400 \\ &= 268 \text{ kg/m}^2 \end{aligned}$$

3. Pembebanan balok induk element **As B 3 – 4 = 4 – 5**➤ **Beban Mati (qD)**

$$\begin{aligned} \text{Beban sendiri balok} &= 0,2 \cdot (0,3 - 0,12) \cdot 2400 &= 86,4 \text{ kg/m}^2 \\ \text{Berat pelat lantai} &= (2 \times 1) \cdot 411 &= 822 \text{ kg/m}^2 \\ \text{Berat dinding} & &= 867 \text{ kg/m}^2 \\ \hline \text{qD} &= 1775,4 \text{ kg/m}^2 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\begin{aligned} \text{qL} &= (2 \times 1) \times 400 \\ &= 800 \text{ kg/m}^2 \end{aligned}$$

4. Pembebanan balok induk element **As B 5 – 6**➤ **Beban Mati (qD)**

$$\begin{aligned} \text{Beban sendiri balok} &= 0,2 \cdot (0,4 - 0,12) \cdot 2400 &= 134,4 \text{ kg/m}^2 \\ \text{Berat pelat lantai} &= (1,278 + 1,5) \cdot 411 &= 1141,758 \text{ kg/m}^2 \\ \hline \text{qD} &= 1276,158 \text{ kg/m}^2 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\begin{aligned} \text{qL} &= (1,278 + 1,5) \cdot 400 \\ &= 1111,2 \text{ kg/m}^2 \end{aligned}$$

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7.3.3. Pembebanan balok induk As C 1 – 6**a. Pelat Atap**1. Pembebanan balok induk element **As C 1 - 4**➤ **Beban Mati (qD) Trapesium Lq 6**

$$\text{Berat sendiri balok} = 0,2 \cdot (0,4 - 0,12) \cdot 2400 = 134,4 \text{ kg/m}^2$$

$$\text{Berat pelat atap} = 1,429 \times 313 = 447,277 \text{ kg/m}^2$$

$$qD = 518,677 \text{ kg/m}^2$$

➤ **Beban hidup (qL) Trapesium Lq 6**

$$qL = 1,429 \times 120$$

$$= 171,48 \text{ kg/m}^2$$

➤ **Beban Mati (qD) Trapesium Lq 5**

$$\text{Berat pelat atap} = 1,32 \times 313 = 413,16 \text{ kg/m}^2$$

➤ **Beban hidup (qL) Trapesium Lq 5**

$$qL = 1,32 \times 120$$

$$= 158,4 \text{ kg/m}^2$$

➤ **Beban Mati (qD) Trapesium Lq 11**

$$\text{Berat pelat atap} = 0,6875 \times 313 = 215,188 \text{ kg/m}^2$$

➤ **Beban hidup (qL) Trapesium Lq 11**

$$qL = 0,6875 \times 120$$

$$= 82,5 \text{ kg/m}^2$$

2. Pembebanan balok induk element **As C 4 – 5**➤ **Beban Mati (qD)**

$$\text{Berat sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat atap} = (1 \times 2) \cdot 313 = 626 \text{ kg/m}^2$$

$$qD = 712,4 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

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$$qL = (1 \times 2) \cdot 120 = 240 \text{ kg/m}^2$$

3. Pembebanan balok induk element **As C 5 – 6**➤ **Beban Mati (qD)**

$$\text{Berat sendiri balok} = 0,2 \cdot (0,4 - 0,12) \cdot 2400 = 134,4 \text{ kg/m}^2$$

$$\text{Berat pelat atap} = (1,278 \times 2) \cdot 313 = 800,03 \text{ kg/m}^2$$

$$qD = 934,43 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = (1,278 \times 2) \cdot 120$$

$$= 306,72 \text{ kg/m}^2$$

b. Pelat Lantai1. Pembebanan balok induk element **As C 1 – 2**➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat lantai} = (0,6875 + 1) \times 411 = 693,563 \text{ kg/m}^2$$

$$qD = 779,963 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = (0,6875 + 1) \cdot 400$$

$$= 675 \text{ kg/m}^2$$

2. Pembebanan balok induk element **As C 2 – 3**➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat lantai} = (2 \cdot 0,67) \times 411 = 550,74 \text{ kg/m}^2$$

$$qD = 637,14 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = (2 \cdot 0,67) \cdot 400$$

$$= 536 \text{ kg/m}^2$$

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3. Pembebanan balok induk element **As C 3 – 4 = 4 – 5**➤ **Beban Mati (qD)**

$$\begin{aligned}
 \text{Beban sendiri balok} &= 0,2 \cdot (0,3 - 0,12) \cdot 2400 &= 86,4 \text{ kg/m}^2 \\
 \text{Berat pelat lantai} &= (2 \times 1) \cdot 411 &= 822 \text{ kg/m}^2 \\
 \text{Berat dinding} & &= 867 \text{ kg/m}^2 \\
 \hline
 \text{qD} &= 1775,4 \text{ kg/m}^2
 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\begin{aligned}
 \text{qL} &= (2 \times 1) \times 400 \\
 &= 800 \text{ kg/m}^2
 \end{aligned}$$

4. Pembebanan balok induk element **As C 5 – 6**➤ **Beban Mati (qD)**

$$\begin{aligned}
 \text{Beban sendiri balok} &= 0,2 \cdot (0,4 - 0,12) \cdot 2400 &= 134,4 \text{ kg/m}^2 \\
 \text{Berat pelat lantai} &= (1,278 \cdot 2) \cdot 411 &= 1050,516 \text{ kg/m}^2 \\
 \text{Berat dinding} & &= 867 \text{ kg/m}^2 \\
 \hline
 \text{qD} &= 2051,916 \text{ kg/m}^2
 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\begin{aligned}
 \text{qL} &= (1,278 \cdot 2) \cdot 400 \\
 &= 1022,4 \text{ kg/m}^2
 \end{aligned}$$

7.3.4. Pembebanan balok induk As D 1 – 6**a. Pelat Atap**1. Pembebanan balok induk element **As D 1 – 4**➤ **Beban Mati (qD)**

$$\begin{aligned}
 \text{Berat sendiri balok} &= 0,35 \cdot (0,6 - 0,12) \cdot 2400 &= 403,2 \text{ kg/m}^2 \\
 \text{Berat pelat atap} &= (1,429 + 1,321) \cdot 313 &= 860,75 \text{ kg/m}^2 \\
 \hline
 \text{qD} &= 1263,95 \text{ kg/m}^2
 \end{aligned}$$

➤ **Beban hidup (qL)**

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$$qL = (1,429 + 1,321) \cdot 120$$

$$= 330 \text{ kg/m}^2$$

2. Pembebanan balok induk element **As D 4 – 5**➤ **Beban Mati (qD)**

Beban sendiri balok	= 0,2 .(0,3 – 0,12). 2400	= 86,4 kg/m ²
Berat pelat atap	= (1 + 0,99) . 313	<u>= 622,87 kg/m²</u>
		qD = 709,27 kg/m ²

➤ **Beban hidup (qL)**

$$qL = (1 + 0,99) \cdot 120$$

$$= 238 \text{ kg/m}^2$$

3. Pembebanan balok induk element **As D 5 – 6**➤ **Beban Mati (qD)**

Beban sendiri balok	= 0,2 .(0,4 – 0,12). 2400	= 134,4 kg/m ²
Berat pelat atap	= (1,278 + 1,204) . 313	<u>= 776,866 kg/m²</u>
		qD = 911,266 kg/m ²

➤ **Beban hidup (qL)**

$$qL = (1,278 + 1,204) \cdot 120$$

$$= 297,84 \text{ kg/m}^2$$

b. Pelat Lantai1. Pembebanan balok induk element **As D 1 – 2 = 3 – 4 = 4 – 5**➤ **Beban Mati (qD)**

Beban sendiri balok	= 0,2 .(0,3 – 0,12). 2400	= 86,4 kg/m ²
Berat pelat lantai	= (1 + 0,99) . 411	<u>= 817,89 kg/m²</u>
		qD = 904,29 kg/m ²

➤ **Beban hidup (qL)**

$$qL = (1 + 0,99) \cdot 400$$

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$$= 796 \text{ kg/m}^2$$

2. Pembebanan balok induk element **As D 2 – 3**➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat lantai} = (0,67 + 0,67) \cdot 411 = 550,74 \text{ kg/m}^2$$

$$qD = 637,14 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = (0,67 + 0,67) \cdot 400$$

$$= 536 \text{ kg/m}^2$$

3. Pembebanan balok induk element **As D 5 – 6**➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot (0,4 - 0,12) \cdot 2400 = 134,4 \text{ kg/m}^2$$

$$\text{Berat pelat lantai} = (1,278 + 1,204) \cdot 411 = 1020,102 \text{ kg/m}^2$$

$$\text{Berat dinding} = 867 \text{ kg/m}^2$$

$$qD = 2021,502 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = (1,278 + 1,204) \cdot 400$$

$$= 992,8 \text{ kg/m}^2$$

7.3.5. Pembebanan balok induk As E 1 – 6**a. Pelat Atap**1. Pembebanan balok induk element **As E 1 - 5**➤ **Beban Mati (qD)**

$$\text{Berat sendiri balok} = 0,35 \cdot (0,6 - 0,12) \cdot 2400 = 403,2 \text{ kg/m}^2$$

$$\text{Berat pelat atap} = (1,321 + 0,99) \cdot 313 = 723,343 \text{ kg/m}^2$$

$$qD = 1126,543 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

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$$qL = (1,321 + 0,99) \cdot 120$$

$$= 277,32 \text{ kg/m}^2$$

➤ **Beban Titik**

$$P1 \text{ (kuda – kuda utama)} = 4952,50 \text{ kg}$$

$$P \text{ (kolom tumpuan)} = \frac{57,60 \text{ kg}}{P = 5010,10 \text{ kg}}$$

2. **Pembebanan balok induk element As E 5 – 6**➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot (0,4 - 0,12) \cdot 2400 = 134,4 \text{ kg/m}^2$$

$$\text{Berat pelat atap} = (1,278 + 1,204) \cdot 313 = 776,866 \text{ kg/m}^2$$

$$qD = 911,266 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = (1,278 + 1,204) \cdot 120$$

$$= 297,84 \text{ kg/m}^2$$

b. Pelat Lantai1. **Pembebanan balok induk element As E 1 – 4**➤ **Beban Mati (qD)**

$$\text{Berat sendiri balok} = 0,45 \cdot (0,9 - 0,12) \cdot 2400 = 842,4 \text{ kg/m}^2$$

$$\text{Berat pelat lantai} = (2 \cdot (0,99 + 1)) + (2 \cdot 0,67) \cdot 411 = 2186,52 \text{ kg/m}^2$$

$$\text{Berat dinding catwalk} = 0,6 \times 0,15 \times 1700 = 153 \text{ kg/m}^2$$

$$qD = 3181,92 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = (2 \cdot (0,99 + 1)) + (2 \cdot 0,67) \cdot 400$$

$$= 2128 \text{ kg/m}^2$$

2. **Pembebanan balok induk element As E 4 – 5**➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

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$$\begin{aligned} \text{Berat pelat lantai} &= (1 + 0,99) \cdot 411 && \underline{= 817,89 \text{ kg/m}^2} \\ qD &= 904,29 \text{ kg/m}^2 \end{aligned}$$

➤ Beban hidup (qL)

$$\begin{aligned} qL &= (1 + 0,99) \cdot 400 \\ &= 796 \text{ kg/m}^2 \end{aligned}$$

3. Pembebanan balok induk element As E 5 – 6

➤ Beban Mati (qD)

$$\begin{aligned} \text{Beban sendiri balok} &= 0,2 \cdot (0,4 - 0,12) \cdot 2400 && = 134,4 \text{ kg/m}^2 \\ \text{Berat pelat lantai} &= (1,278 + 1,204) \cdot 411 && = 1020,102 \text{ kg/m}^2 \\ \text{Berat dinding} & && \underline{= 867 \text{ kg/m}^2} \\ qD &= 2021,502 \text{ kg/m}^2 \end{aligned}$$

➤ Beban hidup (qL)

$$\begin{aligned} qL &= (1,278 + 1,204) \cdot 400 \\ &= 992,8 \text{ kg/m}^2 \end{aligned}$$

7.3.6. Pembebanan balok induk As F 1 – 6**a. Pelat Atap****1. Pembebanan balok induk element As F 5 – 6**

➤ Beban Mati (qD)

$$\begin{aligned} \text{Beban sendiri balok} &= 0,2 \cdot (0,4 - 0,12) \cdot 2400 && = 134,4 \text{ kg/m}^2 \\ \text{Berat pelat atap} &= (1,278 + 1,204) \cdot 313 && \underline{= 776,866 \text{ kg/m}^2} \\ qD &= 911,266 \text{ kg/m}^2 \end{aligned}$$

➤ Beban hidup (qL)

$$\begin{aligned} qL &= (1,278 + 1,204) \cdot 120 \\ &= 297,84 \text{ kg/m}^2 \end{aligned}$$

b. Pelat Lantai**1. Pembebanan balok induk element As F 1 – 2 = 3 – 4 = 4 – 5**

➤ Beban Mati (qD)

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$$\text{Beban sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat lantai} = (1 + 0,99) \cdot 411 = 817,89 \text{ kg/m}^2$$

$$qD = 904,29 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = (1 + 0,99) \cdot 400$$

$$= 796 \text{ kg/m}^2$$

2. Pembebanan balok induk element **As F 2 – 3**

➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat lantai} = (0,67 + 0,67) \cdot 411 = 550,74 \text{ kg/m}^2$$

$$qD = 637,14 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = (0,67 + 0,67) \cdot 400$$

$$= 536 \text{ kg/m}^2$$

3. Pembebanan balok induk element **As F 5 – 6**

➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot (0,4 - 0,12) \cdot 2400 = 134,4 \text{ kg/m}^2$$

$$\text{Berat pelat lantai} = (1,278 + 1,204) \cdot 411 = 1020,102 \text{ kg/m}^2$$

$$\text{Berat dinding} = 867 \text{ kg/m}^2$$

$$qD = 2021,502 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = (1,278 + 1,204) \cdot 400$$

$$= 992,8 \text{ kg/m}^2$$

7.3.7. Pembebanan balok induk **As G 1 – 6**

a. Pelat Atap

1. Pembebanan balok induk element **As G 5 – 6**

➤ **Beban Mati (qD)**

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$$\begin{aligned} \text{Beban sendiri balok} &= 0,2 \cdot (0,4 - 0,12) \cdot 2400 &= 134,4 \text{ kg/m}^2 \\ \text{Berat pelat atap} &= (1,278 + 1,204) \cdot 313 &= 776,866 \text{ kg/m}^2 \\ \hline \text{qD} &= 911,266 \text{ kg/m}^2 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\begin{aligned} \text{qL} &= (1,278 + 1,204) \cdot 120 \\ &= 297,84 \text{ kg/m}^2 \end{aligned}$$

b. Pelat Lantai1. **Pembebanan balok induk element As F 1 – 4**➤ **Beban Mati (qD)**

$$\begin{aligned} \text{Beban sendiri balok} &= 0,45 \cdot (0,9 - 0,12) \cdot 2400 &= 842,4 \text{ kg/m}^2 \\ \text{Berat pelat lantai} &= (2 \cdot (0,99 + 1)) + (2 \cdot 0,67) \cdot 411 &= 2186,52 \text{ kg/m}^2 \\ \text{Berat dinding catwalk} &= 0,6 \times 0,15 \times 1700 &= 153 \text{ kg/m}^2 \\ \hline \text{qD} &= 3181,92 \text{ kg/m}^2 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\begin{aligned} \text{qL} &= (2 \cdot (0,99 + 1)) + (2 \cdot 0,67) \cdot 400 \\ &= 2128 \text{ kg/m}^2 \end{aligned}$$

2. **Pembebanan balok induk element As F 4 – 5**➤ **Beban Mati (qD)**

$$\begin{aligned} \text{Beban sendiri balok} &= 0,2 \cdot (0,3 - 0,12) \cdot 2400 &= 86,4 \text{ kg/m}^2 \\ \text{Berat pelat lantai} &= (1 + 0,99) \cdot 411 &= 817,89 \text{ kg/m}^2 \\ \hline \text{qD} &= 904,29 \text{ kg/m}^2 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\begin{aligned} \text{qL} &= (1 + 0,99) \cdot 400 \\ &= 796 \text{ kg/m}^2 \end{aligned}$$

3. **Pembebanan balok induk element As F 5 – 6**➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot (0,4 - 0,12) \cdot 2400 = 134,4 \text{ kg/m}^2$$

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$$\text{Berat pelat lantai} = (1,278 + 1,204) \cdot 411 = 1020,102 \text{ kg/m}^2$$

$$\text{Berat dinding} = 867 \text{ kg/m}^2$$

$$qD = 2021,502 \text{ kg/m}^2$$

➤ Beban hidup (qL)

$$qL = (1,278 + 1,204) \cdot 400$$

$$= 992,8 \text{ kg/m}^2$$

7.3.8. Pembebanan balok induk As H 1 – 6**a. Pelat Atap**

1. Pembebanan balok induk element **As H 1 – 2 = 2 – 3 = 3 – 4 = 4 – 5**

➤ Beban Mati (qD)

$$\text{Berat sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$qD = 86,4 \text{ kg/m}^2$$

➤ Beban Titik

$$P1 \text{ (kuda – kuda utama)} = 4952,50 \text{ kg}$$

$$P \text{ (kolom tumpuan)} = 57,60 \text{ kg}$$

$$P = 5010,10 \text{ kg}$$

2. Pembebanan balok induk element **As E 5 – 6**

➤ Beban Mati (qD)

$$\text{Beban sendiri balok} = 0,2 \cdot (0,4 - 0,12) \cdot 2400 = 134,4 \text{ kg/m}^2$$

$$\text{Berat pelat atap} = 1,278 \cdot 313 = 400,02 \text{ kg/m}^2$$

$$qD = 534,42 \text{ kg/m}^2$$

➤ Beban hidup (qL)

$$qL = 1,278 \cdot 120$$

$$= 153,36 \text{ kg/m}^2$$

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b. Pelat Lantai

1. Pembebanan balok induk element **As H 1 – 2 = 3 – 4**

➤ **Beban Mati (qD)**

$$\begin{aligned} \text{Berat sendiri balok} &= 0,2 \cdot (0,3 - 0,12) \cdot 2400 &= 86,4 \text{ kg/m}^2 \\ \text{Berat pelat lantai} &= 1 \cdot 411 &= 411 \text{ kg/m}^2 \\ \text{Berat dinding} & &= 867 \text{ kg/m}^2 \\ \hline \text{qD} & &= 1364,4 \text{ kg/m}^2 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\begin{aligned} \text{qL} &= 1 \cdot 400 \\ &= 400 \text{ kg/m}^2 \end{aligned}$$

2. Pembebanan balok induk element **As H 2 – 3**

➤ **Beban Mati (qD)**

$$\begin{aligned} \text{Beban sendiri balok} &= 0,2 \cdot (0,3 - 0,12) \cdot 2400 &= 86,4 \text{ kg/m}^2 \\ \text{Berat pelat lantai} &= 0,67 \cdot 411 &= 275,37 \text{ kg/m}^2 \\ \text{Berat dinding} & &= 867 \text{ kg/m}^2 \\ \hline \text{qD} & &= 1228,77 \text{ kg/m}^2 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\begin{aligned} \text{qL} &= 0,67 \cdot 400 \\ &= 268 \text{ kg/m}^2 \end{aligned}$$

3. Pembebanan balok induk element **As H 4 – 5**

➤ **Beban Mati (qD)**

$$\begin{aligned} \text{Beban sendiri balok} &= 0,2 \cdot (0,3 - 0,12) \cdot 2400 &= 86,4 \text{ kg/m}^2 \\ \text{Berat pelat lantai} &= (1 + 0,852) \cdot 411 &= 761,172 \text{ kg/m}^2 \\ \text{Berat dinding} & &= 867 \text{ kg/m}^2 \\ \hline \text{qD} & &= 1714,572 \text{ kg/m}^2 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\text{qL} = (1 + 0,852) \cdot 400 = 740,8 \text{ kg/m}^2$$

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4. Pembebanan balok induk element **As H 5 – 6**➤ **Beban Mati (qD)**

$$\begin{aligned} \text{Beban sendiri balok} &= 0,2 \cdot (0,4 - 0,12) \cdot 2400 &= 134,4 \text{ kg/m}^2 \\ \text{Berat pelat lantai} &= (1,278 + 0,934) \cdot 411 &= 909,132 \text{ kg/m}^2 \\ \text{Berat dinding} & &= 867 \text{ kg/m}^2 \\ \hline \text{qD} &= 1910,532 \text{ kg/m}^2 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\begin{aligned} \text{qL} &= (1,278 + 0,934) \cdot 400 \\ &= 884,8 \text{ kg/m}^2 \end{aligned}$$

7.3.9. Pembebanan balok induk As I 4 – 6**Pelat Atap**1. Pembebanan balok induk element **As I 4 – 5**➤ **Beban Mati (qD)**

$$\begin{aligned} \text{Beban sendiri balok} &= 0,2 \cdot (0,3 - 0,12) \cdot 2400 &= 86,4 \text{ kg/m}^2 \\ \text{Berat pelat atap} &= (1 + 0,852) \cdot 313 &= 579,676 \text{ kg/m}^2 \\ \hline \text{qD} &= 666,076 \text{ kg/m}^2 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\begin{aligned} \text{qL} &= (1 + 0,852) \cdot 120 \\ &= 222,24 \text{ kg/m}^2 \end{aligned}$$

2. Pembebanan balok induk element **As I 5 – 6**➤ **Beban Mati (qD)**

$$\begin{aligned} \text{Beban sendiri balok} &= 0,2 \cdot (0,4 - 0,12) \cdot 2400 &= 134,4 \text{ kg/m}^2 \\ \text{Berat pelat atap} &= (1,5 + 0,934) \cdot 313 &= 761,842 \text{ kg/m}^2 \\ \hline \text{qD} &= 896,242 \text{ kg/m}^2 \end{aligned}$$

➤ **Beban hidup (qL)**

$$\begin{aligned} \text{qL} &= (1,5 + 0,934) \cdot 120 \\ &= 292,08 \text{ kg/m}^2 \end{aligned}$$

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7.3.10. Pembebanan balok induk As J 4 – 6**Pelat Atap**1. Pembebanan balok induk element **As I 4 – 5**➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot (0,3 - 0,12) \cdot 2400 = 86,4 \text{ kg/m}^2$$

$$\text{Berat pelat atap} = 1 \cdot 313 = 313 \text{ kg/m}^2$$

$$qD = 399,4 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = 1 \cdot 120$$

$$= 120 \text{ kg/m}^2$$

2. Pembebanan balok induk element **As J 5 – 6**➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot (0,4 - 0,12) \cdot 2400 = 134,4 \text{ kg/m}^2$$

$$\text{Berat pelat atap} = 1,5 \cdot 313 = 469,5 \text{ kg/m}^2$$

$$qD = 603,9 \text{ kg/m}^2$$

➤ **Beban hidup (qL)**

$$qL = 1,5 \cdot 120$$

$$= 180 \text{ kg/m}^2$$

7.7. Pembebanan sloof➤ **Beban Mati (qD)**

$$\text{Beban sendiri balok} = 0,2 \cdot 0,3 \cdot 2400 = 144 \text{ kg/m}^2$$

$$\text{Berat dinding} = 867 \text{ kg/m}^2$$

$$qD = 1011 \text{ kg/m}^2$$

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7.8. Penulangan Balok**8.4.1. Balok Dimensi 20/30****c) Perhitungan tulangan lentur**

Data perencanaan :

$$\begin{aligned} h &= 300 \text{ mm} & f'c &= 30 \text{ MPa} \\ b &= 200 \text{ mm} & \emptyset_s &= 8 \text{ mm} \\ p &= 40 \text{ mm} & \emptyset_t &= 22 \text{ mm} \\ f_y &= 360 \text{ Mpa} \end{aligned}$$

$$m = \frac{f_y}{0,85 \cdot f_c} = \frac{360}{0,85 \cdot 30} = 14,118$$

$$\begin{aligned} \rho_b &= \frac{0,85 \cdot f_c}{f_y} \cdot \beta \cdot \left(\frac{600}{600 + f_y} \right) \\ &= \frac{0,85 \cdot 30}{360} \cdot 0,85 \cdot \left(\frac{600}{600 + 360} \right) = 0,0376 \end{aligned}$$

$$\rho_{\max} = 0,75 \cdot \rho_b = 0,0282$$

$$\rho_{\min} = \frac{1,4}{f_y} = \frac{1,4}{360} = 0,0039$$

➤ **Daerah Tumpuan (Frame 207/ As C 4 – 5)**

Dari Perhitungan **SAP 2000** diperoleh :

$$M_u = 5326,29 \text{ kgm} = 5,327 \cdot 10^7 \text{ Nmm}$$

$$M_n = \frac{M_u}{\phi} = \frac{5,327 \cdot 10^7}{0,8} = 6,658 \cdot 10^7 \text{ Nmm}$$

$$\begin{aligned} d &= h - p - \emptyset_t - \emptyset_s - \frac{1}{2} \text{ spasi tul} \\ &= 300 - 40 - 22 - 8 - \frac{1}{2} \cdot 30 \\ &= 215 \text{ mm} \end{aligned}$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{6,658 \cdot 10^7}{200 \cdot 215^2} = 7,202$$

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$$\begin{aligned}\rho_{\text{ada}} &= \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{f_y}} \right) \\ &= \frac{1}{14,118} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14,118 \cdot 7,202}{360}} \right) \\ &= 0,0241\end{aligned}$$

$$\rho > \rho_{\text{min}}$$

$$\rho < \rho_{\text{max}}$$

Digunakan $\rho_{\text{ada}} = 0,0241$

$$\begin{aligned}\text{As perlu} &= \rho_{\text{ada}} \cdot b \cdot d \\ &= 0,0241 \cdot 200 \cdot 215 \\ &= 1036,756 \text{ mm}^2\end{aligned}$$

$$\text{Dipakai tulangan D 22 mm} = \frac{1}{4} \cdot \pi \cdot 22^2 = 379,94 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{1036,756}{379,94} = 2,73 \approx 3 \text{ buah}$$

$$\begin{aligned}\text{As terpasang} &= 4 \times 379,94 \\ &= 1519,76 \text{ mm}^2 > \text{Asaman!}\end{aligned}$$

Jadi, Dipakai tulangan 4 D22

➤ **Daerah Lapangan (Frame 324/ As H 2 – 3)**

Dari Perhitungan **SAP 2000** diperoleh :

$$M_u = 2717,32 \text{ kgm} = 2,718 \cdot 10^7 \text{ Nmm}$$

$$M_n = \frac{M_u}{\phi} = \frac{2,718 \cdot 10^7}{0,8} = 3,3975 \cdot 10^7 \text{ Nmm}$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{3,3975 \cdot 10^7}{200 \cdot 215^2} = 3,675$$

$$\begin{aligned}\rho_{\text{ada}} &= \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{f_y}} \right) \\ &= \frac{1}{14,118} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14,118 \cdot 3,675}{360}} \right) \\ &= 0,0111\end{aligned}$$

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$$\rho > \rho_{\min}$$

$$\rho < \rho_{\max}$$

Digunakan $\rho_{\text{ada}} = 0,0111$

$$\begin{aligned} \text{As perlu} &= \rho_{\text{ada}} \cdot b \cdot d \\ &= 0,0111 \cdot 200 \cdot 215 \\ &= 477,30 \text{ mm}^2 \end{aligned}$$

$$\text{Dipakai tulangan D 22 mm} = \frac{1}{4} \cdot \pi \times 22^2 = 379,94 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{477,3}{379,94} = 1,25 \approx 2 \text{ buah}$$

$$\begin{aligned} \text{As terpasang} &= 2 \times 379,94 \\ &= 759,88 \text{ mm}^2 > \text{As aman!} \end{aligned}$$

Jadi, Dipakai tulangan 2 D22

d) Perhitungan Tulangan Geser (Frame 207/ As C 4 – 5)

Dari perhitungan SAP 2000 Diperoleh :

$$V_u = 6363,29 \text{ kg} = 6,364 \cdot 10^4 \text{ N (Perhitungan SAP)}$$

$$\begin{aligned} V_c &= 1/6 \cdot b \cdot d \cdot \sqrt{f'c} \\ &= 1/6 \cdot 200 \cdot 215 \cdot \sqrt{30} \\ &= 3,925 \cdot 10^4 \text{ N} \end{aligned}$$

$$\begin{aligned} \emptyset V_c &= 0,6 \cdot V_c \\ &= 2,355 \cdot 10^4 \text{ N} \end{aligned}$$

$$\begin{aligned} 3\emptyset V_c &= 3 \cdot \emptyset V_c \\ &= 7,066 \cdot 10^4 \text{ N} \end{aligned}$$

$\emptyset V_c < V_u < 3\emptyset V_c \longrightarrow$ perlu tulangan geser

$$\emptyset V_s = V_u - \emptyset V_c = 4,009 \cdot 10^4 \text{ N}$$

$$V_{s \text{ perlu}} = \frac{\phi v_s}{\phi} = \frac{4,009 \cdot 10^4}{0,6} = 6,682 \cdot 10^4 \text{ N}$$

Digunakan sengkang $\emptyset 8$,

$$A_v = 2 \cdot A = 100,48 \text{ mm}^2$$

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$$S = \frac{Av \cdot f'_y \cdot d}{V_{s_{perlu}}} = \frac{100,48 \cdot 240 \cdot 215}{6,682 \cdot 10^4} = 77,5 \text{ mm}$$

$$S_{maks} = \frac{d}{2} = \frac{215}{2} = 107,5 \text{ mm}$$

Jadi, dipakai sengkang $\varnothing 8 - 75 \text{ mm}$

8.4.2. Balok Dimensi 20/40**c) Perhitungan tulangan lentur**

Data perencanaan :

$$\begin{aligned} h &= 400 \text{ mm} & \varnothing_t &= 22 \text{ mm} \\ b &= 200 \text{ mm} & \varnothing_s &= 8 \text{ mm} \\ p &= 40 \text{ mm} & d &= h - p - \frac{1}{2} \varnothing_t - \varnothing_s \\ f_y &= 360 \text{ Mpa} & &= 400 - 40 - \frac{1}{2} \cdot 22 - 8 \\ f'_c &= 30 \text{ MPa} & &= 341 \text{ mm} \end{aligned}$$

$$m = \frac{f_y}{0,85 \cdot f'_c} = \frac{360}{0,85 \cdot 30} = 14,118$$

$$\begin{aligned} \rho_b &= \frac{0,85 \cdot f'_c}{f_y} \cdot \beta \cdot \left(\frac{600}{600 + f_y} \right) \\ &= \frac{0,85 \cdot 30}{360} \cdot 0,85 \cdot \left(\frac{600}{600 + 360} \right) \\ &= 0,0376 \end{aligned}$$

$$\rho_{max} = 0,75 \cdot \rho_b = 0,0282$$

$$\rho_{min} = \frac{1,4}{f_y} = \frac{1,4}{360} = 0,0039$$

➤ **Daerah Tumpuan (Frame 188/ As C 5 – 6)**

Dari Perhitungan **SAP 2000** diperoleh :

$$M_u = 6790,9 \text{ kgm} = 6,791 \cdot 10^7 \text{ Nmm}$$

$$M_n = \frac{M_u}{\phi} = \frac{6,791 \cdot 10^7}{0,8} = 8,489 \cdot 10^7 \text{ Nmm}$$

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$$R_n = \frac{M_n}{b \cdot d^2} = \frac{8,489 \cdot 10^7}{200 \cdot 341^2} = 3,650$$

$$\begin{aligned} \rho_{ada} &= \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{f_y}} \right) \\ &= \frac{1}{14,118} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14,118 \cdot 3,65}{360}} \right) \\ &= 0,0109 \end{aligned}$$

$$\rho > \rho_{min}$$

$$\rho < \rho_{max}$$

$$\begin{aligned} \text{As perlu} &= \rho_{ada} \cdot b \cdot d \\ &= 0,0109 \cdot 200 \cdot 341 \\ &= 749,659 \text{ mm}^2 \end{aligned}$$

$$\text{Dipakai tulangan D 22 mm} = \frac{1}{4} \cdot \pi \cdot 22^2 = 379,94 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{749,659}{379,94} = 1,97 \approx 2 \text{ buah}$$

$$\begin{aligned} \text{As terpasang} &= 2 \times 379,94 \\ &= 759,88 \text{ mm}^2 > \text{Asaman!} \end{aligned}$$

Jadi, Dipakai tulangan 2 D22

➤ **Daerah Lapangan (Frame 190/ As E 5 – 6)**

Dari Perhitungan **SAP 2000** diperoleh :

$$M_u = 7447,32 \text{ kgm} = 7,448 \cdot 10^7 \text{ Nmm}$$

$$M_n = \frac{M_u}{\phi} = \frac{7,448 \cdot 10^7}{0,8} = 9,31 \cdot 10^7 \text{ Nmm}$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{9,31 \cdot 10^7}{200 \cdot 341^2} = 4,003$$

$$\begin{aligned} \rho_{ada} &= \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{f_y}} \right) \\ &= \frac{1}{14,118} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14,118 \cdot 4,003}{360}} \right) \\ &= 0,0111 \end{aligned}$$

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$$\rho > \rho_{\min}$$

$$\rho < \rho_{\max}$$

$$\begin{aligned} \text{As perlu} &= \rho_{\text{ada}} \cdot b \cdot d \\ &= 0,0111 \cdot 200 \cdot 341 \\ &= 757,02 \text{ mm}^2 \end{aligned}$$

$$\text{Dipakai tulangan D 22 mm} = \frac{1}{4} \cdot \pi \times 22^2 = 379,94 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{757,02}{379,94} = 1,9 \approx 2 \text{ buah}$$

$$\begin{aligned} \text{As terpasang} &= 2 \times 379,94 \\ &= 759,88 \text{ mm}^2 > \text{As aman!} \end{aligned}$$

Jadi, Dipakai tulangan 2 D22

d) Perhitungan Tulangan Geser (Frame 190/ As E 5 – 6)

Dari perhitungan SAP 2000 Diperoleh :

$$V_u = 10297, \text{ kg} = 10,297 \cdot 10^4 \text{ N (Perhitungan SAP)}$$

$$\begin{aligned} V_c &= 1/6 \cdot b \cdot d \cdot \sqrt{f'c} \\ &= 1/6 \cdot 200 \cdot 341 \cdot \sqrt{30} \\ &= 6,225 \cdot 10^4 \text{ N} \end{aligned}$$

$$\begin{aligned} \emptyset V_c &= 0,6 \cdot V_c \\ &= 3,735 \cdot 10^4 \text{ N} \end{aligned}$$

$$\begin{aligned} 3\emptyset V_c &= 3 \cdot \emptyset V_c \\ &= 11,206 \cdot 10^4 \text{ N} \end{aligned}$$

$\emptyset V_c < V_u < 3 \emptyset V_c \longrightarrow$ **perlu tulangan geser**

$$\emptyset V_s = V_u - \emptyset V_c = 6,562 \cdot 10^4 \text{ N}$$

$$V_{s \text{ perlu}} = \frac{\phi v_s}{\phi} = \frac{6,562 \cdot 10^4}{0,6} = 10,936 \cdot 10^4 \text{ N}$$

Digunakan sengkang $\emptyset 8$,

$$A_v = 2 \cdot A = 100,48 \text{ mm}^2$$

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$$S = \frac{Av \cdot f'_y \cdot d}{V_{s_{perlu}}} = \frac{100,48 \cdot 240 \cdot 341}{10,936 \cdot 10^4} = 75,19 \text{ mm}$$

$$S_{maks} = \frac{d}{2} = \frac{341}{2} = 170,5 \text{ mm}$$

Jadi, dipakai sengkang $\varnothing 8 - 75 \text{ mm}$

8.4.3. Balok Dimensi 35/60**c) Perhitungan tulangan lentur**

Data perencanaan :

$h = 600 \text{ mm}$	$\varnothing_t = 22 \text{ mm}$
$b = 350 \text{ mm}$	$\varnothing_s = 12 \text{ mm}$
$p = 40 \text{ mm}$	$d = h - p - \varnothing_t - \varnothing_s - \frac{1}{2} \text{ spasi tul}$
$f_y = 360 \text{ Mpa}$	$= 600 - 40 - 22 - 12 - \frac{1}{2} \cdot 30$
$f'_c = 30 \text{ MPa}$	$= 511 \text{ mm}$

$$m = \frac{f_y}{0,85 \cdot f'_c} = \frac{360}{0,85 \cdot 30} = 14,118$$

$$\begin{aligned} \rho_b &= \frac{0,85 \cdot f'_c}{f_y} \cdot \beta \cdot \left(\frac{600}{600 + f_y} \right) \\ &= \frac{0,85 \cdot 30}{360} \cdot 0,85 \cdot \left(\frac{600}{600 + 360} \right) \\ &= 0,0376 \end{aligned}$$

$$\rho_{max} = 0,75 \cdot \rho_b = 0,0282$$

$$\rho_{min} = \frac{1,4}{f_y} = \frac{1,4}{360} = 0,0039$$

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➤ **Daerah Tumpuan (Frame 240/ As G 1 – 4)**Dari Perhitungan **SAP 2000** diperoleh :

$$M_u = 37064,98 \text{ kgm} = 37,065 \cdot 10^7 \text{ Nmm}$$

$$M_n = \frac{M_u}{\phi} = \frac{37,065 \cdot 10^7}{0,8} = 46,331 \cdot 10^7 \text{ Nmm}$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{46,331 \cdot 10^7}{350 \cdot 511^2} = 5,069$$

$$\rho_{\text{ada}} = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{f_y}} \right)$$

$$= \frac{1}{14,118} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14,118 \cdot 5,069}{360}} \right)$$

$$= 0,0158$$

$$\rho > \rho_{\text{min}}$$

$$\rho < \rho_{\text{max}}$$

Digunakan $\rho_{\text{ada}} = 0,0158$

$$\begin{aligned} \text{As perlu} &= \rho_{\text{ada}} \cdot b \cdot d \\ &= 0,0158 \cdot 350 \cdot 511 \\ &= 2835,9 \text{ mm}^2 \end{aligned}$$

$$\text{Dipakai tulangan D 22 mm} = \frac{1}{4} \cdot \pi \cdot 22^2 = 379,94 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{2835,9}{379,94} = 7,46 \approx 8 \text{ buah}$$

$$\begin{aligned} \text{As terpasang} &= 8 \times 379,94 \\ &= 3039,52 \text{ mm}^2 > \text{Asaman!} \end{aligned}$$

Jadi, Dipakai tulangan 8 D22➤ **Daerah Lapangan (Frame 240/ As G 1 – 4)**Dari Perhitungan **SAP 2000** diperoleh :

$$M_u = 27656,15 \text{ kgm} = 27,656 \cdot 10^7 \text{ Nmm}$$

$$M_n = \frac{M_u}{\phi} = \frac{27,656 \cdot 10^7}{0,8} = 34,57 \cdot 10^7 \text{ Nmm}$$

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$$R_n = \frac{M_n}{b \cdot d^2} = \frac{34,57 \cdot 10^7}{350 \cdot 511^2} = 3,782$$

$$\begin{aligned} \rho_{ada} &= \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{f_y}} \right) \\ &= \frac{1}{14,118} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14,118 \cdot 3,782}{360}} \right) \\ &= 0,0114 \end{aligned}$$

$$\rho > \rho_{min}$$

$$\rho < \rho_{max}$$

$$\begin{aligned} \text{As perlu} &= \rho_{ada} \cdot b \cdot d \\ &= 0,0114 \cdot 350 \cdot 511 \\ &= 2044,132 \text{ mm}^2 \end{aligned}$$

$$\text{Dipakai tulangan } D \ 22 \text{ mm} = \frac{1}{4} \cdot \pi \cdot 22^2 = 379,94 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{2044,132}{379,94} = 5,38 \approx 6 \text{ buah}$$

$$\begin{aligned} \text{As terpasang} &= 6 \times 379,94 \\ &= 2279,64 \text{ mm}^2 > \text{Asaman!} \end{aligned}$$

Jadi, Dipakai tulangan 6 D22

d) Perhitungan Tulangan Geser (Frame 240/ As G 1 – 4)

Dari perhitungan **SAP 2000** Diperoleh :

$$V_u = 30626,49 \text{ kg} = 30,627 \cdot 10^4 \text{ N (Perhitungan SAP)}$$

$$\begin{aligned} V_c &= 1/6 \cdot b \cdot d \cdot \sqrt{f'c} \\ &= 1/6 \cdot 350 \cdot 511 \cdot \sqrt{30} \\ &= 17,173 \cdot 10^4 \text{ N} \end{aligned}$$

$$\begin{aligned} \emptyset V_c &= 0,6 \cdot V_c \\ &= 10,304 \cdot 10^4 \text{ N} \end{aligned}$$

$$\begin{aligned} 3\emptyset V_c &= 3 \cdot \emptyset V_c \\ &= 30,912 \cdot 10^4 \text{ N} \end{aligned}$$

$\emptyset V_c < V_u < 3\emptyset V_c \longrightarrow$ perlu tulangan geser

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$$\phi V_s = V_u - \phi V_c = 20,323 \cdot 10^4 \text{ N}$$

$$V_{s \text{ perlu}} = \frac{\phi v_s}{\phi} = \frac{20,323 \cdot 10^4}{0,6} = 33,872 \cdot 10^4 \text{ N}$$

Digunakan sengkang $\phi 12$,

$$A_v = 2 \cdot A = 226,08 \text{ mm}^2$$

$$S = \frac{A_v \cdot f'_y \cdot d}{V_{s \text{ perlu}}} = \frac{226,08 \cdot 240 \cdot 511}{33,872 \cdot 10^4} = 81,8 \text{ mm}$$

$$S_{\text{maks}} = \frac{d}{2} = \frac{511}{2} = 255,5 \text{ mm}$$

Jadi, dipakai sengkang $\phi 12 - 80 \text{ mm}$

Tabel 8.3. Tulangan Balok

Potongan	Tumpuan	Lapangan
Balok 20 x 30		
Tulangan	4 D 22 mm	2 D 22 mm
Sengkang	$\phi 8 - 75 \text{ mm}$	$\phi 8 - 100 \text{ mm}$

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$$\begin{aligned}\rho_b &= \frac{0,85 \cdot f_c}{f_y} \cdot \beta \cdot \left(\frac{600}{600 + f_y} \right) \\ &= \frac{0,85 \cdot 30}{360} \cdot 0,85 \cdot \left(\frac{600}{600 + 360} \right) \\ &= 0,0376\end{aligned}$$

$$\rho_{\max} = 0,75 \cdot \rho_b = 0,0282$$

$$\rho_{\min} = \frac{1,4}{f_y} = \frac{1,4}{360} = 0,0039$$

➤ **Daerah Tumpuan (Frame 112/ As G 1 – 4)**

Dari Perhitungan **SAP 2000** diperoleh :

$$M_u = 6834,9 \text{ kgm} = 6,835 \cdot 10^7 \text{ Nmm}$$

$$M_n = \frac{M_u}{\phi} = \frac{6,835 \cdot 10^7}{0,8} = 8,544 \cdot 10^7 \text{ Nmm}$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{8,544 \cdot 10^7}{200 \cdot 215^2} = 9,241$$

$$\begin{aligned}\rho_{\text{ada}} &= \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{f_y}} \right) \\ &= \frac{1}{14,118} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14,118 \cdot 9,241}{360}} \right) \\ &= 0,0336\end{aligned}$$

$$\rho > \rho_{\max}$$

$$\begin{aligned}\text{As perlu} &= \rho_{\max} \cdot b \cdot d \\ &= 0,0282 \cdot 200 \cdot 215 \\ &= 1212,6 \text{ mm}^2\end{aligned}$$

$$\text{Dipakai tulangan D 22 mm} = \frac{1}{4} \cdot \pi \cdot 22^2 = 379,94 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{1212,6}{379,94} = 3,19 \approx 4 \text{ buah}$$

$$\begin{aligned}\text{As terpasang} &= 4 \times 379,94 \\ &= 1519,76 \text{ mm}^2 > \text{As aman!}\end{aligned}$$

Jadi, Dipakai tulangan 4 D22

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➤ **Daerah Lapangan (Frame 110/ As E 1 – 4)**Dari Perhitungan **SAP 2000** diperoleh :

$$M_u = 3367,79 \text{ kgm} = 3,368 \cdot 10^7 \text{ Nmm}$$

$$M_n = \frac{M_u}{\phi} = \frac{3,368 \cdot 10^7}{0,8} = 4,21 \cdot 10^7 \text{ Nmm}$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{4,21 \cdot 10^7}{200 \cdot 215^2} = 4,554$$

$$\rho_{\text{ada}} = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{f_y}} \right)$$

$$= \frac{1}{14,118} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14,118 \cdot 4,554}{360}} \right)$$

$$= 0,0140$$

$$\rho > \rho_{\text{min}}$$

$$\rho < \rho_{\text{max}}$$

$$\text{As perlu} = \rho_{\text{ada}} \cdot b \cdot d$$

$$= 0,014 \cdot 200 \cdot 215 = 603,77 \text{ mm}^2$$

$$\text{Dipakai tulangan } D 22 \text{ mm} = \frac{1}{4} \cdot \pi \cdot 22^2 = 379,94 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{603,77}{379,94} = 1,58 \approx 2 \text{ buah}$$

$$\text{As terpasang} = 2 \times 379,94$$

$$= 759,88 \text{ mm}^2 > \text{As} \dots\dots \text{ aman!}$$

Jadi, Dipakai tulangan 2 D22**b) Perhitungan Tulangan Geser (Frame 112/ As G 1 – 4)**Dari perhitungan **SAP 2000** Diperoleh :

$$V_u = 4945,26 \text{ kg} = 4,946 \cdot 10^4 \text{ N (Perhitungan SAP)}$$

$$V_c = 1/6 \cdot b \cdot d \cdot \sqrt{f'c}$$

$$= 1/6 \cdot 200 \cdot 215 \cdot \sqrt{30}$$

$$= 3,925 \cdot 10^4 \text{ N}$$

$$\phi V_c = 0,6 \cdot V_c$$

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$$= 2,355 \cdot 10^4 \text{ N}$$

$$3 \phi V_c = 3 \cdot \phi V_c$$

$$= 7,066 \cdot 10^4 \text{ N}$$

$\phi V_c < V_u < 3 \phi V_c \longrightarrow$ perlu tulangan geser

$$\phi V_s = V_u - \phi V_c = 2,591 \cdot 10^4 \text{ N}$$

$$V_{s \text{ perlu}} = \frac{\phi V_s}{\phi} = \frac{2,591 \cdot 10^4}{0,6} = 4,318 \cdot 10^4 \text{ N}$$

Digunakan sengkang $\phi 8$,

$$A_v = 2 \cdot A = 100,48 \text{ mm}^2$$

$$S = \frac{A_v \cdot f'_y \cdot d}{V_{s \text{ perlu}}} = \frac{100,48 \cdot 240 \cdot 215}{4,318 \cdot 10^4} = 120,07 \text{ mm}$$

$$S_{\text{maks}} = \frac{d}{2} = \frac{215}{2} = 107,5 \text{ mm}$$

Jadi, dipakai sengkang $\phi 8 - 100 \text{ mm}$

Tabel 8.4. Tulangan Sloof

Potongan	Tumpuan	Lapangan
Balok Sloof		
Tulangan	4 D 22 mm	2 D 22 mm
Sengkang	$\phi 8 - 100 \text{ mm}$	$\phi 8 - 100 \text{ mm}$

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7.10. Penulangan Kolom**7.6.1. Kolom dimensi 350 x 350****a) Perhitungan tulangan lentur**

Untuk contoh perhitungan tulangan lentur kolom diambil momen terbesar dari perhitungan dengan SAP 2000, yaitu **frame 164** arah M_3

Data perencanaan :

$$\begin{aligned} b &= 350 \text{ mm} & \phi \text{ tulangan} &= 16 \text{ mm} \\ h &= 350 \text{ mm} & \phi \text{ sengkang} &= 8 \text{ mm} \\ f'c &= 30 \text{ Mpa} & p \text{ (tebal selimut)} &= 40 \text{ mm} \\ f_y &= 360 \text{ MPa} \end{aligned}$$

Dari perhitungan SAP didapat :

$$P_u = 26179,54 \text{ kg} = 261795,4 \text{ N}$$

$$M_u = 6378,38 \text{ kgm} = 6,379 \cdot 10^7 \text{ Nmm}$$

$$\begin{aligned} d &= h - p - \phi \text{ sengkang} - \frac{1}{2} \phi \text{ tulangan} \\ &= 350 - 40 - 8 - \frac{1}{2} \cdot 16 = 294 \text{ mm} \end{aligned}$$

$$d' = h - d = 350 - 294 = 56 \text{ mm}$$

$$e = \frac{M_u}{P_u} = \frac{6,379 \cdot 10^7}{261795,4} = 243,66 \text{ mm}$$

$$e_{\min} = 0,1 \cdot h = 0,1 \cdot 350 = 35 \text{ mm}$$

$$c_b = \frac{600}{600 + f_y} \cdot d = \frac{600}{600 + 360} \cdot 294 = 183,75$$

$$a_b = \beta_1 \cdot c_b = 0,85 \cdot 183,75 = 156,1875$$

$$P_{n_b} = 0,85 \cdot f'c \cdot a_b \cdot b = 0,85 \cdot 30 \cdot 156,1875 \cdot 350 = 1.393.973,438 \text{ N}$$

$$P_{n_{\text{perlu}}} = \frac{P_u}{\phi} ; 0,1 \cdot f'c \cdot A_g = 0,1 \cdot 30 \cdot 350 \cdot 350 = 3,675 \cdot 10^5 \text{ N}$$

$$\rightarrow \text{karena } P_u = 261795,4 \text{ N} < 0,1 \cdot f'c \cdot A_g, \text{ maka } \phi = 0,8 - \frac{1,5 \cdot P_u}{f'c \cdot A_g}$$

$$\phi = 0,8 - \frac{1,5 \cdot 261795,4}{30 \cdot (350 \cdot 350)} = 0,69$$

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$$Pn_{\text{perlu}} = \frac{Pu}{\phi} = \frac{261795,4}{0,69} = 379.413,62 \text{ N}$$

$Pn_{\text{perlu}} < Pn_b \rightarrow$ analisis keruntuhan tarik

$$a = \frac{Pn_{\text{perlu}}}{0,85 \cdot f'c \cdot b} = \frac{3,795 \cdot 10^5}{0,85 \cdot 30 \cdot 350} = 42,511$$

$$As = \frac{Pn_{\text{perlu}} \left(e - \frac{h}{2} + \frac{a}{2} \right)}{fy(d - d')} = \frac{3,795 \cdot 10^5 \left(243,66 - \frac{350}{2} + \frac{42,511}{2} \right)}{360(294 - 56)} = 209,967 \text{ mm}^2$$

$$As_t = 1 \% Ag = 0,01 \cdot 350 \cdot 350 = 1225 \text{ mm}^2$$

$$\text{Sehingga, } As = As' = \frac{As_t}{2} = \frac{1225}{2} = 612,5 \text{ mm}^2$$

Menghitung jumlah tulangan

$$n = \frac{612,5}{\frac{1}{4} \cdot \pi \cdot (16)^2} = 3,05 \approx 4 \text{ tulangan}$$

$$\begin{aligned} As \text{ ada} &= 4 \cdot \frac{1}{4} \cdot \pi \cdot 16^2 \\ &= 803,84 \text{ mm}^2 > 612,5 \text{ mm}^2 \dots\dots\text{aman!} \end{aligned}$$

$$\begin{aligned} \text{➤ Spasi} &= \frac{h - 2 \cdot p - 2 \cdot \Phi_s - n \cdot \Phi_{tul}}{n - 1} \\ &= \frac{350 - (2 \cdot 40) - (2 \cdot 8) - (4 \cdot 16)}{4 - 1} \\ &= 63,33 \text{ mm} \\ &\geq 25 \text{ mm} \dots\dots\text{ok!} \end{aligned}$$

Jadi, dipakai tulangan 4 D16

Untuk **frame 164** arah M_2

Data perencanaan :

$$b = 350 \text{ mm} \quad \phi \text{ tulangan} = 16 \text{ mm}$$

$$h = 350 \text{ mm} \quad \phi \text{ sengkang} = 8 \text{ mm}$$

$$f'c = 30 \text{ Mpa} \quad p \text{ (tebal selimut)} = 40 \text{ mm}$$

$$fy = 360 \text{ MPa}$$

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Dari perhitungan SAP arah M_2 didapat :

$$P_u = 26179,54 \text{ kg} = 261795,4 \text{ N}$$

$$M_u = 138,14 \text{ kgm} = 0,139 \cdot 10^7 \text{ Nmm}$$

$$d = h - p - \emptyset \text{ sengkang} - \frac{1}{2} \emptyset \text{ tulangan}$$

$$= 350 - 40 - 8 - \frac{1}{2} \cdot 16 = 294 \text{ mm}$$

$$d' = h - d = 350 - 294 = 56 \text{ mm}$$

$$e = \frac{M_u}{P_u} = \frac{0,139 \cdot 10^7}{261795,4} = 5,31 \text{ mm}$$

$$e_{\text{min}} = 0,1 \cdot h = 0,1 \cdot 350 = 35 \text{ mm}$$

$$c_b = \frac{600}{600 + f_y} \cdot d = \frac{600}{600 + 360} \cdot 294 = 183,75$$

$$a_b = \beta_1 \cdot c_b = 0,85 \cdot 183,75 = 156,1875$$

$$P_{n_b} = 0,85 \cdot f'_c \cdot a_b \cdot b = 0,85 \cdot 30 \cdot 156,1875 \cdot 350 = 1.393.973,438 \text{ N}$$

$$P_{n_{\text{perlu}}} = \frac{P_u}{\phi} ; 0,1 \cdot f'_c \cdot A_g = 0,1 \cdot 30 \cdot 350 \cdot 350 = 3,675 \cdot 10^5 \text{ N}$$

$$\rightarrow \text{karena } P_u = 261795,4 \text{ N} < 0,1 \cdot f'_c \cdot A_g, \text{ maka } \emptyset = 0,8 - \frac{1,5 \cdot P_u}{f'_c \cdot A_g}$$

$$\phi = 0,8 - \frac{1,5 \cdot 261795,4}{30 \cdot (350 \cdot 350)} = 0,69$$

$$P_{n_{\text{perlu}}} = \frac{P_u}{\phi} = \frac{261795,4}{0,69} = 379.413,62 \text{ N}$$

$P_{n_{\text{perlu}}} < P_{n_b} \rightarrow$ **analisis keruntuhan tarik**

$$a = \frac{P_{n_{\text{perlu}}}}{0,85 \cdot f'_c \cdot b} = \frac{3,795 \cdot 10^5}{0,85 \cdot 30 \cdot 350} = 42,511$$

$$A_s = \frac{P_{n_{\text{perlu}}} \left(\frac{h}{2} - e - \frac{a}{2} \right)}{f_y (d - d')} = \frac{3,795 \cdot 10^5 \left(\frac{350}{2} - 35 - \frac{42,511}{2} \right)}{360 (294 - 56)} = 525,95 \text{ mm}^2$$

$$A_{s_t} = 1 \% A_g = 0,01 \cdot 350 \cdot 350 = 1225 \text{ mm}^2$$

$$\text{Sehingga, } A_s = A_{s'} = \frac{A_{s_t}}{2} = \frac{1225}{2} = 612,5 \text{ mm}^2$$

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Menghitung jumlah tulangan

$$n = \frac{612,5}{\frac{1}{4} \cdot \pi \cdot (16)^2} = 3,05 \approx 4 \text{ tulangan}$$

$$\begin{aligned} \text{As ada} &= 4 \cdot \frac{1}{4} \cdot \pi \cdot 16^2 \\ &= 803,84 \text{ mm}^2 > 612,5 \text{ mm}^2 \dots\dots\dots \text{aman!} \end{aligned}$$

Jadi, dipakai tulangan 4 D16

b) Perhitungan tulangan geser

$$V_u = 2380,15 \text{ kg} = 2,38 \cdot 10^4 \text{ N}$$

$$\begin{aligned} V_c &= \frac{1}{6} \cdot \sqrt{f'c} \cdot b \cdot d \\ &= \frac{1}{6} \cdot \sqrt{30} \cdot 350 \cdot 294 \\ &= 9,393 \cdot 10^4 \text{ N} \end{aligned}$$

$$\phi V_c = 0,6 \cdot V_c = 5,636 \cdot 10^4 \text{ N}$$

$$3 \phi V_c = 16,908 \cdot 10^4 \text{ N}$$

$V_u < \phi V_c < 3 \phi V_c \rightarrow$ **tidak perlu tulangan geser**

Jadi dipakai sengkang dengan tulangan $\phi 8 - 200 \text{ mm}$

Tabel 8.5. Tulangan Kolom

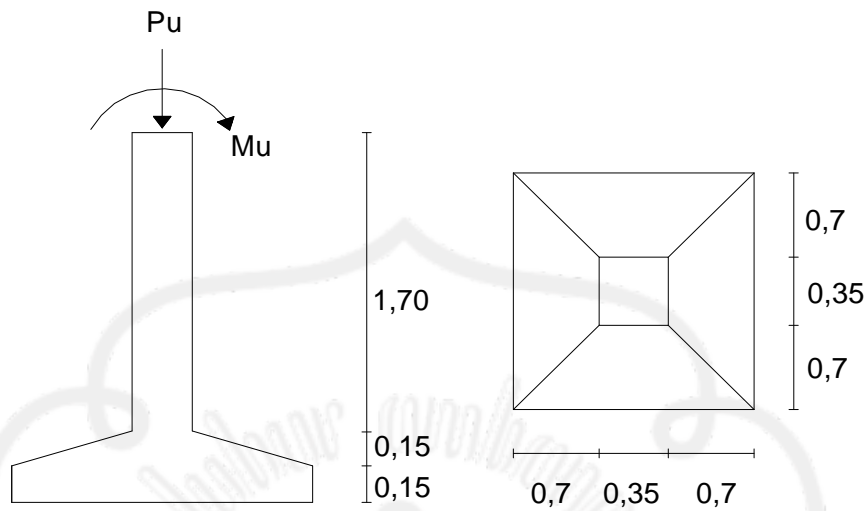
Potongan	
Kolom 350 x 350	
Tulangan	4 D 16 mm
Sengkang	$\phi 8 - 200 \text{ mm}$

BAB 9

PERENCANAAN PONDASI

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9.1. Data Perencanaan Pondasi

Gambar 9.1 Perencanaan Pondasi

Direncanakan pondasi telapak dengan kedalaman 2 m, panjang 1,75 m dan 1,75 m

- $f'c$ = 30 Mpa
- f_y = 360 Mpa
- σ tanah = $2 \text{ kg/cm}^2 = 20.000 \text{ kg/m}^2$
- γ tanah = $1,7 \text{ t/m}^3 = 1700 \text{ kg/m}^3$
- γ beton = $2,4 \text{ t/m}^3$

Dari perhitungan **SAP 2000** pada Frame 164 diperoleh :

- P_u = 26179,54 kg
- M_u = 6378,38 kgm

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Dimensi Pondasi

$$\Sigma_{\text{tanah}} \frac{Pu}{A} =$$

$$A = \frac{Pu}{\sigma_{\text{tanah}}} = \frac{26179,54}{20000} = 1,3 \text{ m}^2$$

$$B = L = \sqrt{A} = \sqrt{1,3} = 1,14 \sim 1,75 \text{ m}$$

Chek Ketebalan

$$d \geq \frac{Pu}{\phi \frac{1}{6} \sqrt{f'cb}} = \frac{26179,54}{0,6 \cdot \frac{1}{6} \sqrt{30 \cdot 1750}} = 27,3 \sim 300 \text{ mm}$$

9.2. Perencanaan Kapasitas Dukung Pondasi

➤ Pembebanan pondasi

$$\text{Berat telapak pondasi} = 1,75 \times 1,75 \times 0,3 \times 2400 = 2205 \text{ kg}$$

$$\text{Berat tanah} = (1,75 \cdot 1,75 \cdot 1,7) - (0,35 \cdot 0,35 \cdot 1,7) \times 1700 = 8496,6 \text{ kg}$$

$$\text{Berat kolom pondasi} = 0,35 \times 0,35 \times 1,7 \times 2400 = 499,8 \text{ kg}$$

$$Pu = \underline{\underline{26179,54 \text{ kg}}}$$

$$V \text{ total} = 37380,94 \text{ kg}$$

$$e = \frac{\sum M}{\sum V} = \frac{6378,38}{37380,94}$$

$$= 0,17 < 1/6 \cdot B = 0,29 \dots \dots \text{ok!}$$

$$\sigma_{\text{yang terjadi}} = \frac{V_{\text{tot}}}{A} \pm \frac{M_{\text{tot}}}{\frac{1}{6} \cdot b \cdot L^2}$$

$$\Sigma_{\text{tanah 1}} = \frac{37380,94}{1,75 \cdot 1,75} + \frac{6378,38}{1/6 \cdot 1,75 \cdot (1,75)^2} = 19293,10 \text{ kg/m}^2$$

$$\Sigma_{\text{tanah 2}} = \frac{37380,94}{1,75 \cdot 1,75} - \frac{6378,38}{1/6 \cdot 1,75 \cdot (1,75)^2} = 5118,94 \text{ kg/m}^2$$

$$\text{➤ } 19293,10 \text{ kg/m}^2 < 20.000 \text{ kg/m}^2$$

$$\text{➤ } \sigma_{\text{yang terjadi}} < \sigma_{\text{ijin tanah}} \dots \dots \dots \text{Ok!}$$

9.3. Perhitungan Tulangan Lentur

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$$\begin{aligned} M_u &= \frac{1}{2} \cdot q_u \cdot t^2 \\ &= \frac{1}{2} \cdot 19293,10 \cdot (0,7)^2 = 4726,81 \text{ kgm} = 4,727 \cdot 10^7 \text{ Nmm} \end{aligned}$$

$$M_n = \frac{4,727 \cdot 10^7}{0,8} = 5,909 \cdot 10^7 \text{ Nmm}$$

$$m = \frac{f_y}{0,85 \cdot f_c} = \frac{360}{0,85 \cdot 30} = 14,118$$

$$\begin{aligned} \rho_b &= \frac{0,85 \cdot f_c}{f_y} \cdot \beta \cdot \left(\frac{600}{600 + f_y} \right) \\ &= \frac{0,85 \cdot 30}{360} \cdot 0,85 \cdot \left(\frac{600}{600 + 360} \right) \\ &= 0,0376 \end{aligned}$$

$$\rho_{\max} = 0,75 \cdot \rho_b = 0,0282$$

$$\rho_{\min} = \frac{1,4}{f_y} = \frac{1,4}{360} = 0,0039$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{5,909 \cdot 10^7}{1750 \cdot (300)^2} = 0,375$$

$$\begin{aligned} \rho_{\text{perlu}} &= \frac{1}{m} \left(1 - \sqrt{1 - \frac{2m \cdot R_n}{f_y}} \right) \\ &= \frac{1}{14,118} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14,118 \cdot 0,375}{360}} \right) \\ &= 0,0016 \end{aligned}$$

$$\rho_{\text{perlu}} < \rho_{\min}$$

$$\begin{aligned} A_s_{\text{perlu}} &= \rho_{\min} \cdot b \cdot d \\ &= 0,0039 \cdot 1750 \cdot 300 \\ &= 2047,5 \text{ mm}^2 \end{aligned}$$

$$\text{Dipakai tulangan } D 16 \text{ mm} = \frac{1}{4} \cdot \pi \cdot 16^2 = 200,96 \text{ mm}^2$$

$$\text{Jumlah tulangan} = \frac{2047,5}{200,96} = 10,18 \approx 11 \text{ buah}$$

$$\text{Jarak tulangan} = \frac{1750}{11} = 159,09 \text{ mm}$$

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$$\text{As terpasang} = \frac{1750}{150} \cdot 200,96 = 2344,53 \text{ mm}^2 > \text{As} \dots\text{ok!}$$

Jadi, Dipakai tulangan D 16 – 150 mm

9.4. Perhitungan Tulangan Geser

$$\begin{aligned} V_u &= \sigma \times A_{\text{efektif}} \\ &= 19293,10 \times (0,7 \times 1,75) \\ &= 236.340,475 \text{ N} \end{aligned}$$

$$\begin{aligned} V_c &= 1/6 \cdot \sqrt{f'_c} \cdot b \cdot d \\ &= 479.257,24 \text{ N} \end{aligned}$$

$$\begin{aligned} \emptyset V_c &= 0,6 \cdot V_c \\ &= 287.554,34 \text{ N} \end{aligned}$$

$$\begin{aligned} 3\emptyset V_c &= 3 \cdot \emptyset V_c \\ &= 862.663,03 \text{ N} \end{aligned}$$

➤ $V_u < \emptyset V_c < 3\emptyset V_c \rightarrow$ tidak perlu tulangan geser

Jadi, dipakai sengkang minimum $\emptyset 8 - 200 \text{ mm}$