DAFTAR PUSTAKA

ACI Committee 226. 1988. Use of Fly Ash in Concrete. Farmington Hills, MI: American Concrete Concrete Institute.

ACI Committee 224. 2001. Control of Cracking in Concrete Structures (224R-01), Farmington Hills, Mich: American Concrete Institute.

Adianto, Y. L., & Joewono, T. B. 2006. Penelitian Pendahuluan Hubungan Penambahan Serat Polymeric terhadap Karakteristik Beton Normal. Civil Engineering Dimension, 8(1), 34-40.

Ahmed, H.Q, dkk. 2019. Flexural strength and failure of geopolymer concrete beams reinforced with carbon fibre-reinforced polymer bars. Civil Engineering Department, Salahaddin University, Erbil, Iraq.

Andoyo. 2006. Pengaruh Penggunaan Abu Terbang (Fly Ash) terhadap Kuat Tekan dan Serapan Air pada Mortar. Semarang: Universitas Negeri Semarang.

ASTM C618-93. 1991. "Standard Test Method for Fly Ash and Row or calcined Natural Pozzolan for Use as a mineral Admixture in Portland Cement Concrete," American Society for Testing of Concrete's.

ASTM C39/C39 M-01. 2001. Standard Test Method for Compressive Strength of Cylindrical Concrete Specimen. USA: American Society for Testing and Materials.

ASTM ASTM E8/E8M-09. 2010. Standard Test Methods for Tension Testing of Metallic Materials. USA: American Society for Testing and Materials.

ASTM C270 – 10. 2010. Standard Specification for Mortar for Unit Masonry. ASTM International, 100 Barr Harbour Drive, PO Box c700, West Conshohocken, PA 19428 – 2959, United States.

Badan Standardisasi Nasional. 2002. SNI 03-6825-2002 Metode pengujian kekuatan tekan mortar semen portland untuk pekerjaan sipil. Jakarta : Badan Standarisasi Nasional.

Badan Standardisasi Nasional. 2002. SNI 03-6414-2002 Pengertian dan Manfaat Fly Ash. Jakarta : Badan Standarisasi Nasional.

Badan Standardisasi Nasional. 2014. SNI 03-6882-2014 Spesifikasi Mortar Untuk Pekerjaan Pasangan. Jakarta : Badan Standarisasi Nasional.

Badan Standardisasi Nasional. 2017. SNI 2052:2017 Baja Tulangan Beton. Jakarta : Badan Standarisasi Nasional.

Davidovits J. 1994. "Geopolymers: Man-Made Rock Geosynthesis and the Resulting Development of Very Early High Strength Cement", Journal Of Materials Education, Vol.16, No2&3, pp.91-137. St. Quentin, France.

Davidovits J. 1999. “Chemistry of geopolymeric systems, terminology”, in: The Proceedings of Géopolymère '99 (292), pp 9-39. St. Quentin, France.

Davidovits J. 2013. “Geopolymer Chemistry and Applications”, 3rd Edition, Institut Géopolymère, Saint-Quentin, France, 632 pages.

Ekaputri, J. J. dan Triwulan. 2013. Sodium sebagai Aktivator Fly Ash, Trass dan Lumpur Sidoarjo dalam Beton Geopolimer, Jurusan Teknik Sipil, ITB, Vol 20 No 1, pp.1-10.27.

Ekaputri, J. J., Fujiyama, C., Chijiwa, N., Ho, T. D. dan Nguyen, H. T. 2021. Peningkatan Karakteristik Geopolimer dengan Penambahan Serat PVA (Polyvinyl Alcohol). Civil Engineering Dimension. Vol 23, No. 1 March 2021, pp 28-34.

Ekaputri, J. J., Junaedi, S., dan Wijaya, Y.P. 2017. Pengaruh Suhu Curing dan Fiber Terhadap Geopolymer Berbasis Metakaolin, SCESCM 2016, Bali, Indonesia, Procedia Engineering.

Fansuri, H., Swastika, N. dan Atmaja, L. 2008. Pembuatan dan Karakterisasi Geopolimer dari Bahan Abu Layang PLTU Paiton, Akta Kimindo, Vol. 3 No. 2, hal. 61-66.

Gilbert, R.I., dan Mickleborough, N.C. 1990. Design of Prestressed Concrete. London : Unwin Hyman.

Hardjito, D. 2001. Abu Terbang Solusi Pencemaran Semen. Artikel Harian Sinar Harapan, Kupang.

Hardjito, D, dkk. 2004. Factor Influencing the Compressive Strength of Fly ash Based Geopolymer Concrete. Perth, Australia.

Kalaivani M., dkk. 2020. Performance evaluation of fly ash/slag based geopolymer concrete beams with addition of lime. Department of Civil Engineering, K.S. Rangasamy College of Technology, Tamilnadu, India.

Komnitsas, K., dan Zaharaki, D. 2007. Geopolymerisation: A Review and Prospects for the Minerals Industry. Minerals Engineering, 20, 1261-1277.

Laskar, S.M., dan Sudip Talukdar. 2019. A study on the performance of damaged RC members repaired using ultra-fine slag based geopolymer mortar. Department of Civil Engineering, Indian Institute of Technology Guwahati, India.

MacKenzie, Brian. 2005. “101 Performance Evaluation Tests”. London : Electric Word plc.

Malhotra, V.M. 2002. Introduction: Sustainable Development and Concrete Technology. ACI Concrete International. 24 (7), p. 22.

McCormac, Jack C. 2005. Beton Bertulang Dasar 1. Bandung: PT Penerbit Erlangga.

Nawy, Edward G. 1998. Reinforced Concrete: A Fundamental Approach (Bambang Suryatmojo, Trans.). Bandung: Refika Aditama. (Karya asli diterbitkan 1985)

Nawy, Edward G. 2008. Beton Bertulang – Suatu Pendekatan Dasar, PT Refika Aditama, Bandung.

Nawy, E. G. 2010. Beton Bertulang; Suatu Pendekatan Dasar. Surabaya: ITS Press

Ogur, E. 2005. Polyvinyl Alcohol: Materials, Processing and Applications, Springer Vol. 16 Number 12 ISSN: 0809-3144.

Rodgers, Lucy. 2018. Climate change: The massive CO2 emitter you may not know about. BBC News, 17 Dec 2018. Access at https://www.bbc.com/news/science-environment-46455844 29 June 2021.

Shalumon, K.T. et al. 2010. Sodium Alginate/Poly-Vinyl Alcohol/Nano ZnO Composite Nanofibers for Antibacterial Wound Dressings. Elsevier: International Journal of Biological Macromolecules 49 (2011) 247-254.

Soroushian dan Bayasi. 1987. Fibre Reinforced Concrete Design and Application, Seminar Proceeding Composite And Structure Centre, Michigan State University.

Tjokrodimuljo, K. 1996. Teknologi Beton. Jurusan Teknik Sipil. Fakultas Teknik Universitas Gadjah Mada: Yogyakarta.

Xu, H., dan Van Deventer, J. 2003. The Geopolymerisation of Alumino-Silicate Minerals. International Journal of Mineral Processing, 247-266.

Zhang, Hai Yan, dkk. 2019. Mechanical behavior of concrete beams shear strengthened with textile reinforced geopolymer mortar. Department of Civil Engineering, South China University of Technology, Guangzhou, PR China.

In 2016, world cement production generated around 2.2 billion tonnes of CO2 - equivalent to 8% of the global total. (Rodgers, 2018)

Produksi batu bara indonesia pada 2020 menurun menjadi 563 juta ton dalam “5 Negara Penghasil Batu Bara Terbesar Di Dunia, 01 APRIL 2021”

(http://www.apbi-icma.org/news/4756/5-negara-penghasil-batu-bara-terbesar-di-dunia, akses tgl. 29 June 2021)

Sulaem MusaddiqLaskarSudipTalukdar (2019) A study on the performance of damaged RC members repaired using ultra-fine slag based geopolymer mortar, Construction and Building Materials, Volume 217, 30 August 2019, Pages 216-225, https://doi.org/10.1016/j.conbuildmat.2019.05.033

M.Kalaivaniag. Shyamalabs. Rameshak. Angusenthilar. Jagadeesan (2020) Performance Evaluation of Fly Ash/Slag Based Geopolymer Concrete

Beams With Addition of Lime, Materialstoday Proceedings, Volume 27, Part 1, 2020, Pages 652-656. https://doi.org/10.1016/J.MATPR.2020.01.596

Desain Penampang Benda Uji

Data perencanaan

Kuat tekan beton	f'c	=	20	MPa
Tegangan leleh baja	fy	=	336.75	MPa
Modulus Elastis Beton	Ec	=	21019	MPa
Modulus Elastis Baja	Es	=	200000	MPa

Asumsi tinggi penampang yang disyaratkan ACI untuk lendutan :

Panjang bentang Ln = 3.0 m = 3000 mm

$$h = \frac{Ln}{16}$$

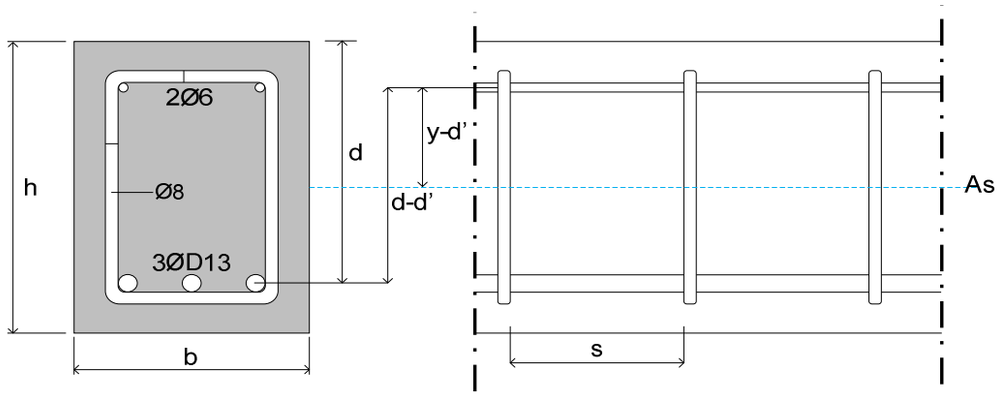
= 187.5 mm ≈ 200 mm

Tinggi Efektif Balok d = 150 mm

r = b/d , ---------- dimana : r = 0.25 & 0.6

b = 90 mm ≈ 150 mm

Perhitungan momen desain luar akibat beban (M_u)



Mu = Φ Mn

$$Mu = \Phi * As * fy * \left(d - \frac{a}{2} \right)$$ faktor reduksi untuk lentur Φ = 0.9

dimana :

ρ_{max} = 0.75 ρb

$$\rho b = \beta_1 * \frac{0.85\ fc}{fy} * \frac{600}{600 + fy}$$ untuk β1 = 0.85 dimana f'c < 28 Mpa

$$= 0.85 * \frac{0.85 * 20}{336.75} * \frac{600}{600 + 336.75}$$

= 0.042910171 * 0.6405 = 0.027484497

= 0.75 * 0.027484497 = 0.020613373

As = ρb*b*d

= 0.020613373 * 150 * 150

= 463.8008848 mm^2

$$a = \frac{As * fy}{0.85 * f'c * b}$$

$$= \frac{463.800885 * 336.75}{0.85 * 3000} = 61.2489992 \text{ mm}$$

$$Mu = 0.90 * 463.8008848 * 336.75 * \left(150 - \frac{61.2489992}{2} \right)$$

= 140566.453 * 44.3755004

= 6237706.699 Nmm

= **6.2377067** kNm

Mu = 0.35 P + 0.81

$P = \frac{6.2377067 - 0.81}{0.35} =$ **15.5077334 kN**

Momen tahanan nominal yang diperlukan :

$Mn = \frac{Mu}{\Phi} = \frac{6237706.699}{0.9}$

= 6930785.221 Nmm

= **6.93078522** kNm

Mn = 0.35 P + 0.81

$Pu = \frac{6.93078522 - 0.81}{0.35} =$ **17.4879578 kN**

Asumsikan angka penulangan ρ = 0.35 ρb = 0.00961957

As = ρb * b * d

= 0.00961957 * 150 * 150

= 216.440413 mm^2

Digunakan tulangan 3 ΦD 13

As = 398.196869 mm^2 > As = 216.440413 mm^2 .....**OK**

$\rho = \frac{As}{bd} = \frac{398.196869}{22500} = 0.01769764$

$\rho_{min} = \frac{200}{fy} = \frac{1.4}{336.75} = 0.00409503$

Periksa baja yang disyaratkan :

0.75 ρb = 0.02061337 > ρ = 0.01769764 > ρ_{min} = 0.00409503 .....**OK**

Syarat bahwa tulangan meleleh :

ρ_{maks} = 0.02061337 > ρ = 0.01769764 .....**Tulangan Meleleh**

$a = \frac{As * fy}{0.85 * f'c * b}$

$= \frac{398.196869 * 336.75}{0.85 * 3000} =$ 52.58541 mm

$Mn = As * fy * \left(d - \frac{a}{2}\right)$ digunakan nilai a = 61.249 mm

= 398.196869 * 336.75 * 123.707295

= 16588257.02 Nmm

= **16.588257** kNm

Mu = 0.35 P + 0.81 = 16.588257

$P = \frac{16.58825702 - 0.81}{0.35} =$ **45.0807343 kN**

Mn = 6.93078522 > Mu = 6.2377067 kNm .....**Analisis Tulangan Tunggal**

persentasi desain lebih $= \frac{6.93078522 - 6.2377067}{6.237706699} =$ 11.111 %

Perencanaan kekuatan geser

Gaya geser maksimum:

Pada pengujian diharapkan retak akibat lentur mendahului retak akibat geser. Untuk memastikan tidak terjadi kegagalan geser sebelum kegagalan lentur terjadi, maka beban geser terbesar .

Vu = 0.50 P + 1.08 kN

= 0.50 * 15.5077334 + 1.08

= 8.83386671 kN = 17.6677334 kN

Kekuatan beton menahan geser:

$$Vc = \left(\frac{\sqrt{fc}}{6} \right) * bw * d$$

= 0.7454 * 150 * 150

= 16771 MPa = 16.771 kN

ΦVc = 0.85 * Vc faktor reduksi untuk geser Φ = 0.85

= 14.2549334 kN

Periksa :

Vu = 17.6677334 > 1/2ΦVc = 7.12746668 kN **.....Diperlukan sengkang**

Desain sengkang

$$Vs = \frac{Vu - \Phi Vc}{\Phi} = \frac{17.6677334 - 14.2549334}{0.85}$$

= 4.0150589 kN

Periksa :

$$Vs < \frac{2}{3} \sqrt{fc} * bw * d = 67082.0393 \text{ Mpa} = 67.082 \text{ kN}$$

Vs = Vu - Vc = 17.6677334 - 16.771 = 0.89722359 kN

Vs = 0.89722359 < 67.082 kN **.....Penampang tidak diperbesar**

Hitung jarak sengkang teoritis

Jarak dari tumpuan d = tinggi efektif balok = 150 mm

direncanakan menggunakan tulangan sengkang = Φ 8

Av = 50.265 mm^2

$$s = \frac{Av * fy * d}{Vs} = \frac{50.265 * 336.75 * 150}{897.2235933}$$

= 2829.88009 mm

jarak maksimum s = d/2 = 75 mm

$$Av_{min} = \frac{1}{3} * \frac{bw\ s}{fy} = 11.136 < Av = 50.265 \text{ mm}^2$$ **.....OK**

Maka digunakan sengkang = Φ 8 - 90 mm pada daerah 1/3 bentang tepi

= Φ 8 - 175 mm pada daerah 2/3 bentang tengah

Kontrol Inersia penampang terhadap lendutan

Radius modulus atau angka ekivalen

$$n = \frac{Es}{Ec} = \frac{200000}{21019.039} = 9.51518288$$

Luas 3 ΦD 13 As = 398.196869 mm^2

Luas 2 Φ 8 As' = 100.530965 mm^2

b = 150 mm

d = 150 mm

d' = 32 mm

Ma = 6237706.699 Nmm

Momen Inersia Penampang

$I_g = 1/12 * b * h^3$

= 0.08333333 * 150 * 8000000

= 100000000 mm^4

Letak sumbu netral untuk penampang retak (x)

$$\frac{b * x^2}{2} + (n-1) * As * (x - d') - n * As * (d - x) = 0$$

$$\frac{150 * x^2}{2} + \left(9.51518288 - 1\right) * 100.530965 * \left(x - 32 \right) - 9.5152 *$$

$$398.196869 * \left(150 - x \right) = 0$$

$$\frac{150 * x}{2} + \left(19.0303658 - 1\right) * 100.530965 * \left(x - 32 \right) =$$

$$9.5152 * 398.196869 * \left(150 - x \right)$$

$$75\ x^2 + 1812.61007\ x - 58003.5222 = 568337.405 - 3788.91603\ x$$

$$75\ x^2 - 74.687\ x = 8351.21236$$

$$x + 37.344 = \sqrt{8351.21236 + \left(37.3435073 \right)^2}$$

$$x + 37.344 = 98.7205647$$

$$x = 61.3770574 \text{ mm}$$

Momen inersia penampang retak:

$I_{cr} = (1/3 * b * x^3) + ((n - 1) * A_s' * (x - d')^2) + (n * As * (d - x)^2)$

$1/3 * b * y^3 = 0.33333333 * 150 * 231216.163 = 11560808.13$

$(n - 1) * As' * (x - d')^2 = 8.5152 * 100.530965 * 863.0115 = 738771.978$

$n * As (d - x)^2 = 9.51518288 * 398.196869 * 7854.02596 = 29758244.86$

$I_{cr} = 11560808.13 + 738771.978 + 29758244.86$

$I_{cr} = 42057824.97 \text{ mm}^4$

Modulus keruntuhan lentur beton:

$f_r = 0.7 * \sqrt{Fc}$ 0.70 * 4.5 = 3.13

$$M_{cr} = \frac{f_r * I_g}{y_{beton}} \quad \text{dimana } f_r = 0.70\ \sqrt{f'c}$$

$$M_{cr} = \frac{3.1305 * 42057825}{61.37705738} = 2145130.83 \text{ Nmm}$$

$I_e = (Mcr/Ma)^3 * Ig + 1-(Mcr/Ma)^3 * Icr$

$(Mcr/Ma)^3 * Ig = 0.04067115 * 100000000 = 4067115.46$

$1-(Mcr/Ma)^3 * Icr = 1 - 0.04067115 * 42057825 = 40347284.7$

$I_e = 44414400.13 \text{ mm}^4$

Kontrol Inersia Penampang terhadap retak :

$I_{cr} = 42057824.97 < Ie = 44414400.129 < I_g = 100000000 \text{ mm}^4$ **.....OK !!!**

Perhitungan Retak awal

Radius modulus atau angka ekivalen

$$n = \frac{Es}{Ec} = \frac{200000}{21019.039} = 9.51518288$$

Luas 3 ΦD 13 As = 398.196869 mm^2

Luas 2 Φ 6 As' = 56.5486678 mm^2

b = 150 mm

h = 200 mm

d = 150 mm

d' = 40 mm

f'c = 20 Mpa

Ma = 6237706.699 Nmm

Momen Inersia Penampang

$I_g = 1/12 * b * h^3$

$= 0.08333333 * 150 * 8000000$

$= 100000000\ mm^4$

$y_{dasar} = 1/2\ h$

$= 100\ mm$

Modulus keruntuhan lentur beton:

$f_r = 0.7 * \sqrt{Fc}$ 0.70 * 4.5 = 3.13

$M_{cr} = \frac{f_r * I_g}{y_{beton}}$ dimana f_r = 0.70 $\sqrt{f'c}$

$M_{cr} = \frac{3.1305 * 100000000}{100}$

$= 3130495.17$ Nmm

$=$ **3.13049517** kNm

Mu = 0.35 P + 0.81

$Pcr = \frac{3.13049517 - 0.81}{0.35} =$ **6.6299862** **kN**

$\varphi_{crack} = \frac{f_r * y_{dasar}}{I_g}$

$= \frac{3.13 * 100}{100000000} =$ **3E-06** rad/mm

KURVATURE

fr = 4.90 Mpa (Hasil Pengujian)

$Mcr = \frac{4.90 * 100000000}{100}$

$= 4900000$ Nmm

$=$ **4.9** kNm

Pcr = 11.6857143 kN

φcrack = 0.0000049 rad/mm

Letak sumbu netral untuk penampang retak (x)

$$\frac{b * x^2}{2} + (n-1) * As * (x - d') - n * As * (d - x) = 0$$

$$\frac{150 * x^2}{2} + (9.51518288 - 1) * 56.5486678 * (x - 40) - 9.5152 * 398.196869 * (150 - x) = 0$$

$$\frac{150 * x}{2} + (19.0303658 - 1) * 56.5486678 * (x - 40) = 9.5152 * 398.196869 * (150 - x)$$

$$75\ x^2 + 1019.59316\ x - 40783.7265 = 568337.405 - 3788.91603\ x$$

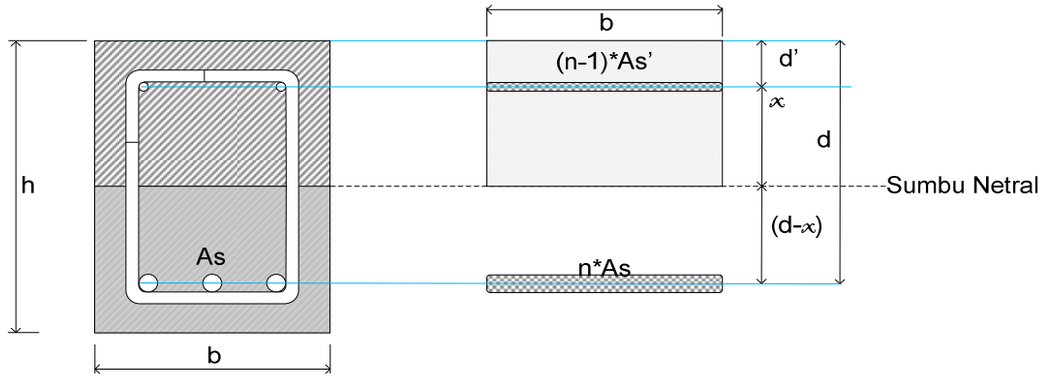
$$75\ x^2 - 64.113\ x = 8121.61508$$

$x + 32.057 = \sqrt{8121.61508 + \left[32.056728 \right]^2}$

$x + 32.057 = 95.6517061$

$x = 63.5949782$ mm

Momen inersia penampang retak:



$I_{cr} = (1/3 * b * x^3) + ((n - 1) * A_s' * (x - d')^2) + (n * As * (d - x)^2)$

$1/3 * b * y^3 = 0.33333333 * 150 * 257198.522 = 12859926.09$

$(n - 1) * As' * (x - d')^2 = 8.5152 * 56.5486678 * 556.722996 = 268074.508$

$n * As (d - x)^2 = 9.51518288 * 398.196869 * 7465.82779 = 28287394.61$

$I_{cr} = 12859926.09 + 268074.508 + 28287394.61$

$I_{cr} = 41415395.21$ mm^4

Modulus keruntuhan lentur beton:

$f_r = 0.7 * \sqrt{Fc} \quad 0.70 * 4.5 = 3.13$

$M_{cr} = \frac{f_r * I_g}{y_{beton}}$ dimana $f_r =$ 0.70 $\sqrt{f'c}$

$M_{cr} = \frac{3.1305 * 41415395.2}{63.59497819}$

$= 2038693.91$ Nmm

$= \boxed{\mathbf{2.03869391}}$ kNm

$Mu = 0.35 P + 0.81$

$Pcr = \frac{2.03869391 - 0.81}{0.35} = \boxed{\mathbf{3.51055402}}$ **kN**

$I_e = (Mcr/Ma)^3 * Ig + 1-(Mcr/Ma)^3 * Icr$

$(Mcr/Ma)^3 * Ig = 0.03491252 * 100000000 = 3491252.22$

$1-(Mcr/Ma)^3 * Icr = 1 - 0.03491252 * 41415395.2 = 39969479.3$

$I_e = 43460731.52$ mm^4

Kontrol Inersia Penampang terhadap retak :

$I_{cr} = 41415395.21 < Ie = 43460731.522 < I_g = 100000000$ mm^4 **.....OK !!!**

Untuk Perhitungan lendutan secara teoritis dilakukan yaitu :

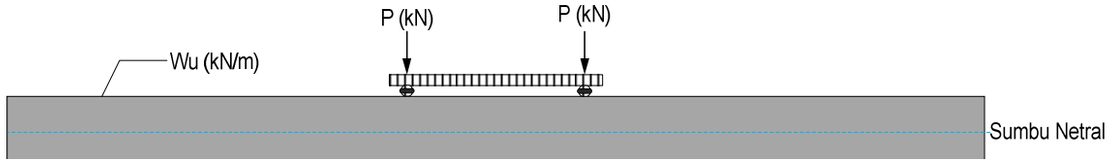
dimana :

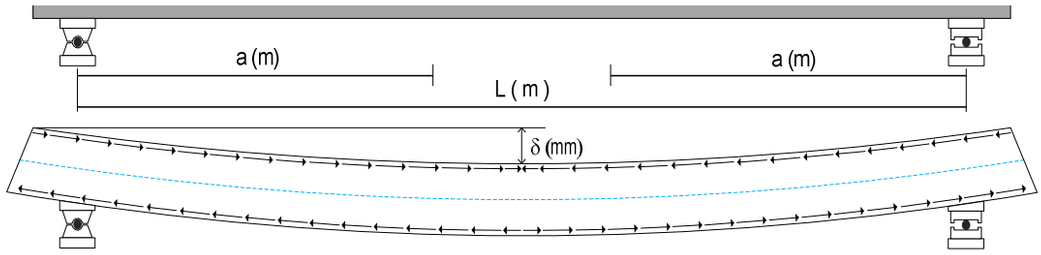
Ec = 21019.039 Mpa = 21.019 kN/mm^2

a = 1200 mm

L = 3000 mm

q = 0.72 kN/m = 0.00072 kN/mm





Lendutan Kondisi sebelum retak

Pcr = **6.6299862** kN

$$\delta = \frac{1}{24} * \frac{P*a}{Ec*Ig} * (3*L^2 - 4a^2) + \frac{5}{384} * \frac{q*L^4}{Ec*Ig}$$

$$\frac{1}{24} * \frac{P*a}{Ec*Icr} = 0.04166667 * \frac{7955.983435}{21.019 * 100000000} = 1.5771E\text{-}07$$

$$(3*L^2 - 4a^2) = 3 * 9000000 - 4 * 1440000 = 21240000$$

$$\frac{5}{384} = \frac{q*L^4}{Ec*Ig} = 0.013 * \frac{0.00072 * 8.1E+13}{21.019039 * 100000000} = 0.3612796$$

δ = 1.5771E-07 * 21240000 + 0.3612796

= **3.7111213** mm

Lendutan Kondisi setelah retak awal leleh

Py = **46.6407883** kN

$$\delta = \frac{1}{24} * \frac{P*a}{Ec*Ie} * (3*L^2 - 4a^2) + \frac{5}{384} * \frac{q*L^4}{Ec*Ie}$$

$$\frac{1}{24} * \frac{P*a}{Ec*Ie} = 0.04166667 * \frac{55968.94601}{21.019 * 41415395.2} = 2.6789E\text{-}06$$

$$(3*L^2 - 4a^2) = 3 * 9000000 - 4 * 1440000 = 21240000$$

$$\frac{5}{384} = \frac{q*L^4}{Ec*Ie} = 0.013 * \frac{0.00072 * 8.1E+13}{21.019039 * 41415395.2} = 0.87233165$$

δ = 2.6789E-06 * 21240000 + 0.87233165

= **57.7727859** mm

Lendutan Kondisi setelah retak pada beban ultimit

Pu = **45.3889266** kN

$$\delta = \frac{1}{24} * \frac{P*a}{Ec*Ie} * (3*L^2 - 4a^2) + \frac{5}{384} * \frac{q*L^4}{Ec*Ie}$$

$$\frac{1}{24} * \frac{P*a}{Ec*Icr} = 0.04166667 * \frac{54466.71192}{21.019 * 41415395.2} = 2.607E\text{-}06$$

$$(3*L^2 - 4a^2) = 3 * 9000000 - 4 * 1440000 = 21240000$$

$$\frac{5}{384} = \frac{q*L^4}{Ec*Icr} = 0.013 * \frac{0.00072 * 8.1E+13}{21.019039 * 41415395.2} = 0.87233165$$

δ = 2.607E-06 * 21240000 + 0.87233165

= **56.2455497** mm

Hitung lebar retak yang terjadi :

β = 1.2 untuk balok umumnya

fy = 336.75 Mpa

f_s = 0.6 fy = 202.05 Mpa

d' = 25 mm

A_t = 398.196869 mm^2

$w = 11 * \beta * f_s * \sqrt[3]{A_t * d'} * 10^{-b}$

$11 * \beta * f_s = 11 * 1.2 * 202.05 = 2667.1$

$\sqrt[3]{A_t * d'} * 10^{-6} = 398.196869 * 25 = \sqrt[3]{9954.92172} * 10\text{-}6$

$= 2.1512E\text{-}05$

$w = 2667.1 * 2.1512E\text{-}05 =$ **0.0573736** mm