YAPI SİSTEMİNDE BURULMA TÜRLERİ BETONARME ELEMANDA BURULMA TASARIMI

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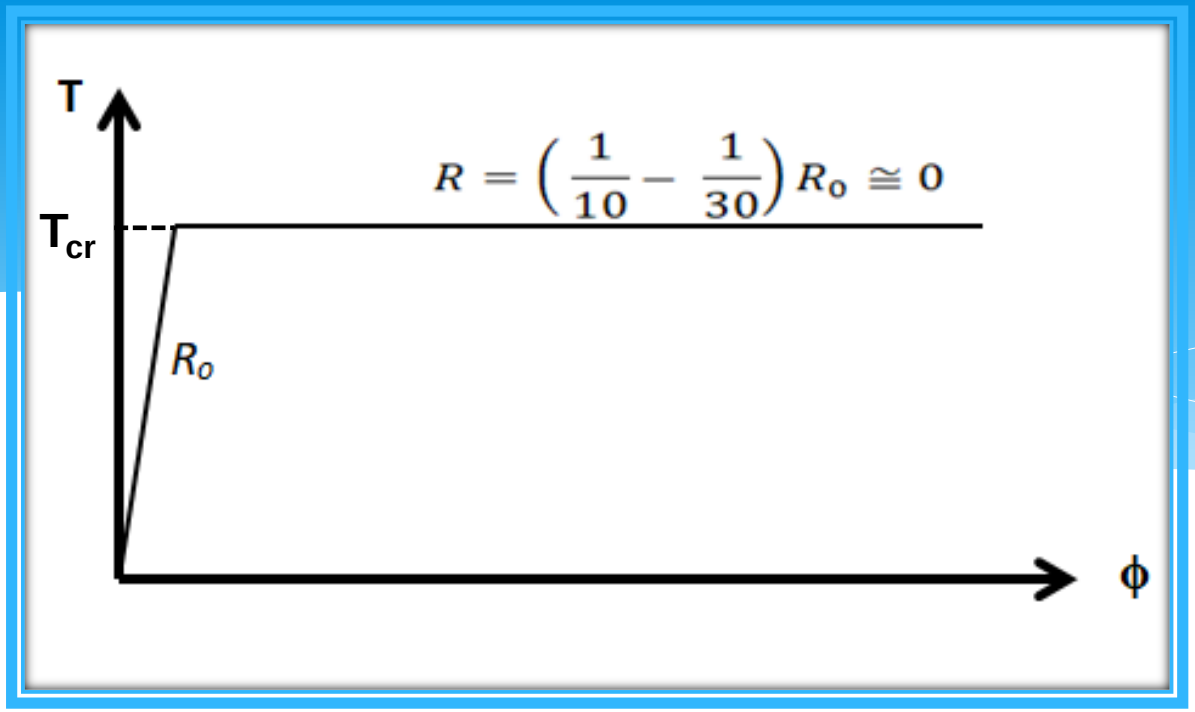
* Önceki dersimizde hiperstatik bir yapı sisteminde yapı elemanına etkiyen burulma momentinin malzemenin doğrusal elastik davrandığı varsayımına göre hesabının gerçekçi sonuç vermediği anlatıldı.

  Nedeni:

* Çatlayan bir betonarme kirişin burulma rijitliği büyük ölçüde azalır.
* Sistemde ihmal edilemeyecek kadar önemli bir uyum meydana gelir.



* PCA 1968 (Prof. Hsu) deneylerinde, burulma çatlamasını belirleyen T_{cr} düzeyine kadar davranışın doğrusal olduğu,
* deney elemanında burulma çatlaması oluşması ile burulma rijitliği (T- ϕ eğrisinin eğimi) hızla azalarak deformasyonların arttığı ve davranışın yaklaşık olarak şekildeki gibi elasto-plastik bir davranış gibi kabul edilebileceği anlatıldı.

* Bu aşamadan sonra elastisite teorisine dayanan yöntemlerle hesaplanan burulma momenti gerçek değerlerin çok üstüne çıkmaktadır.
* Dolayısıyla betonarme elemanların burulma hesabında burulma çatlamasının mutlaka dikkate alınması gerekir.

* Betonarme elemanların burulma hesabında başlıca iki aşama vardır.
* Birinci aşamada yapı sisteminde meydana gelen burulma momenti türünün belirlenmesi ve hesaplanması.
* İkinci aşamada kesitin taşıyabileceği burulma momentinin hesabı yani kesitin burulma momenti taşıma gücü hesabının yapılması gerekir.
* Yapı sistemine bağlı olarak betonarme kirişlerde iki tür burulma oluşur.
* (a) denge burulması (b) uygunluk burulması

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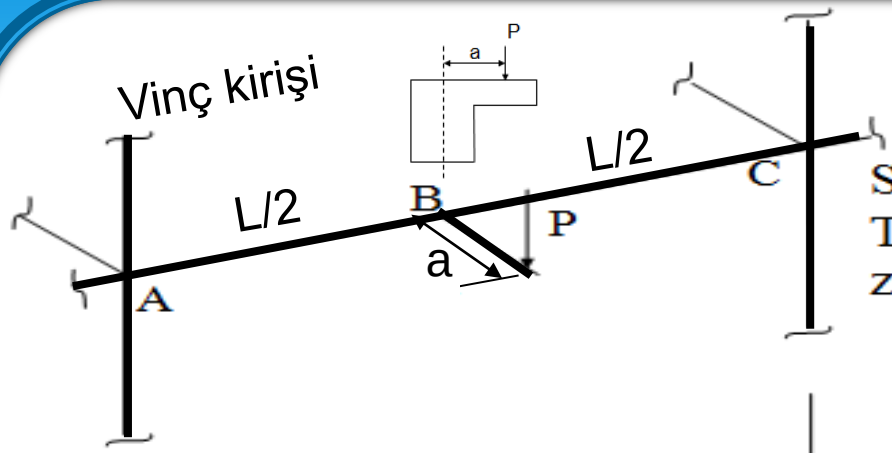
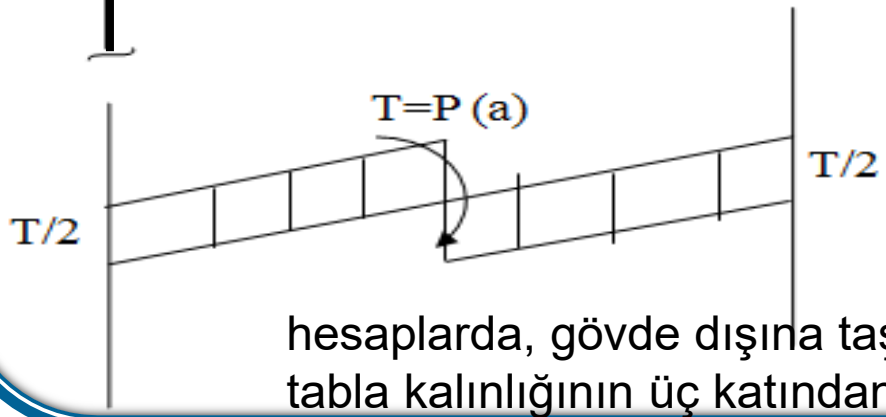
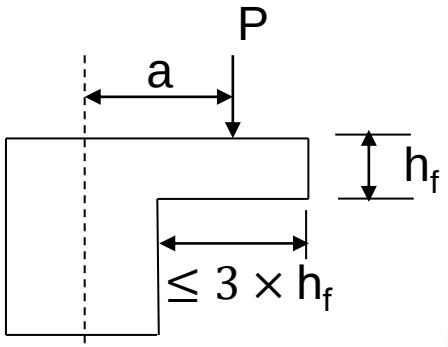


Sabit burulma momenti T=P(a) statik denge için zorunludur.





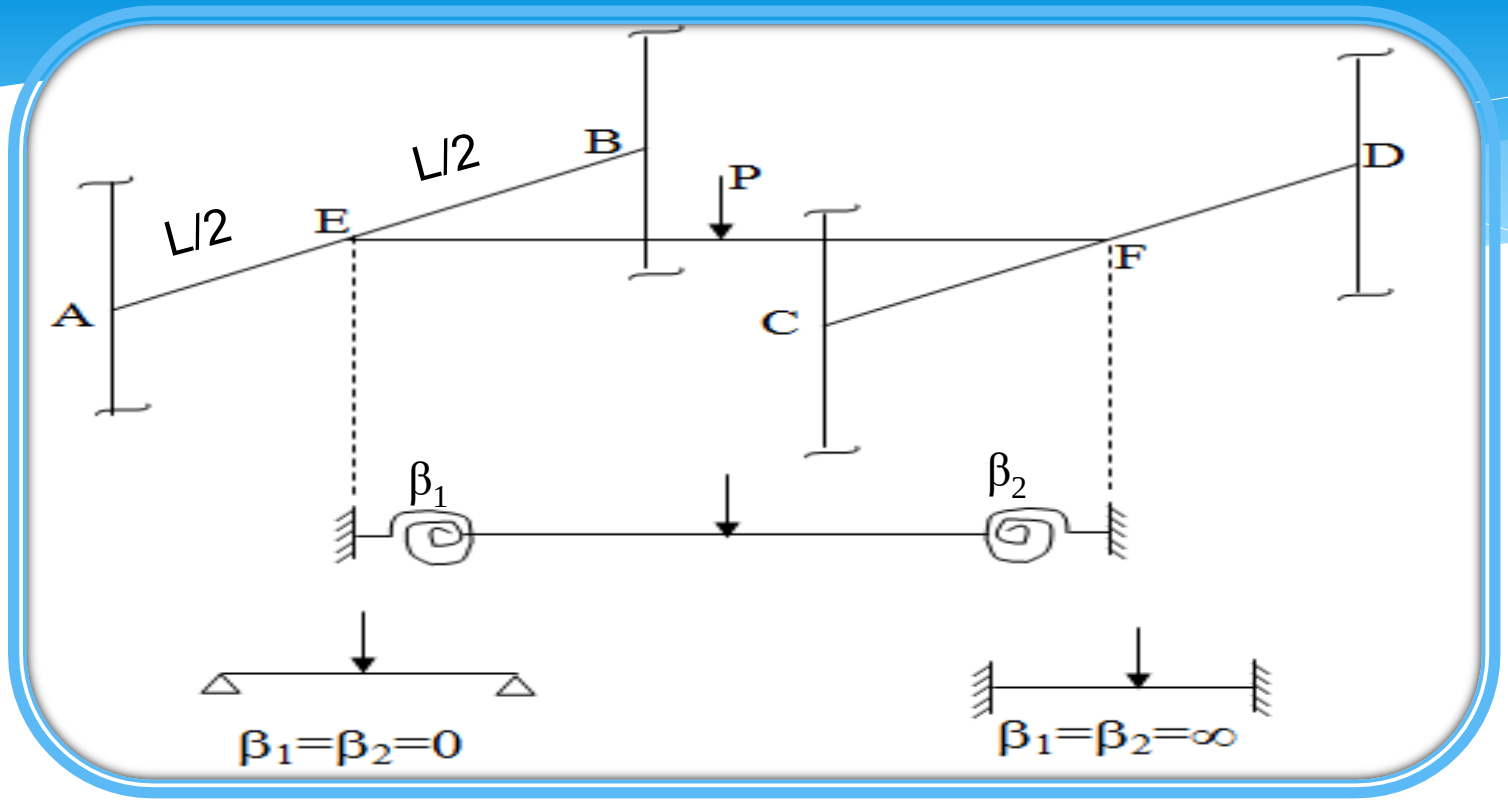
hesaplarda, gövde dışına taşan tabla genişliği, tabla kalınlığının üç katından fazla alınmamalıdır.

a) Denge Burulması:

Yapı sistemi veya elemanında dengeyi sağlayabilmek için burulma momentine gereksinme varsa, burulma denge burulmasıdır. Sözü edilen gereksinme, elastik aşamada değil taşıma gücü aşamasındaki gereksinmedir.

Denge burulmasında, burulma momenti sistemin ayrılmaz bir parçasıdır. Kirişin kritik kesitleri, oluşan burulma momentlerini karşılayacak şekilde boyutlandırılmalı ve donatılmalıdır.

Denge burulması olan sistemlerde klasik yöntemlerle (doğrusal-elastik) hesaplanan burulma momenti azaltılamaz.

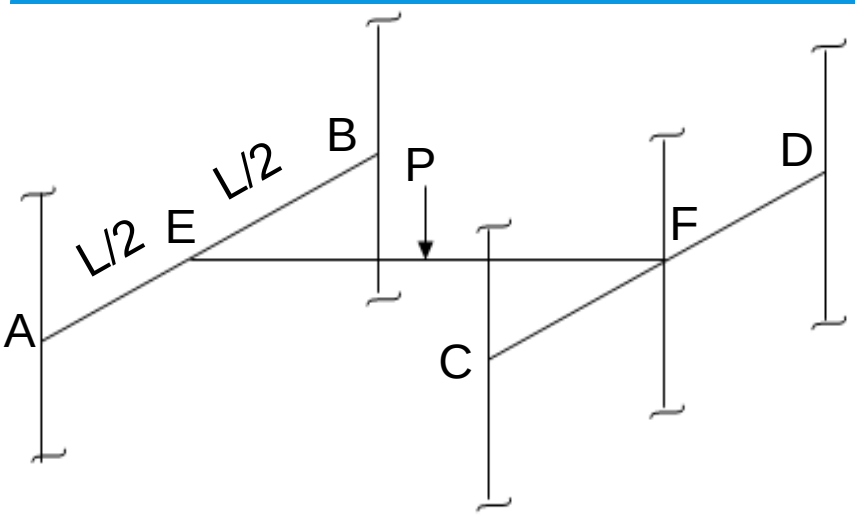


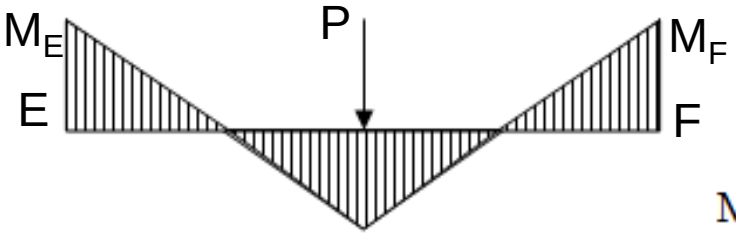
b) Uygunluk Burulması:

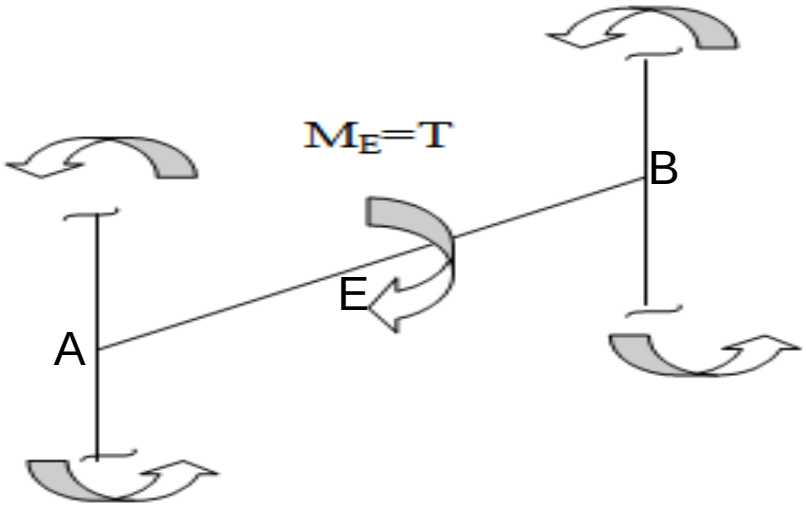
Eğer bir sistemde burulma momentinin bulunması denge için zorunlu koşul değilse söz konusu burulma uygunluk burulmasıdır.

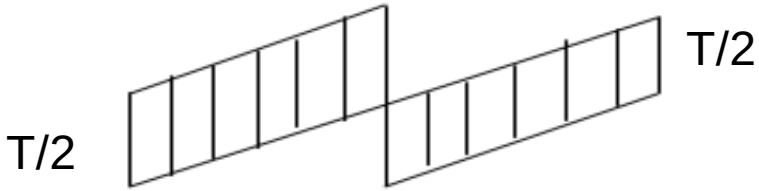
Sistem elastik sınırlar içindeyken denge koşulunda burulma momenti yer almakta ise de, bu aşamadan sonra sistemin stabilitesini bozmadan, belirli noktalarda oluşturulacak plastik mafsallarla denge için burulmaya gereksinme kalmayabilir.

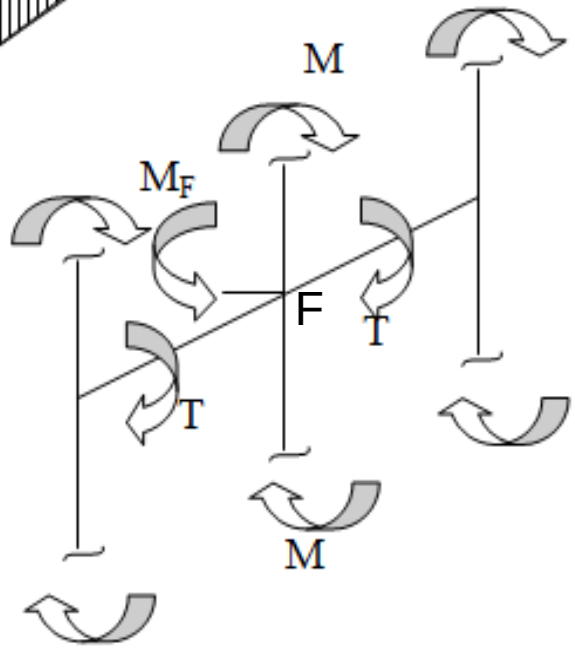
Yapılarda uygunluk burulmasına, denge burulmasına oranla daha sık rastlanır.


A
L/2
E
L/2
B
P
C
F
D


M_E
E
P
M_F
F


$M_E=T$
B
E
A


T/2
T/2


M
M_F
F
T
T
M

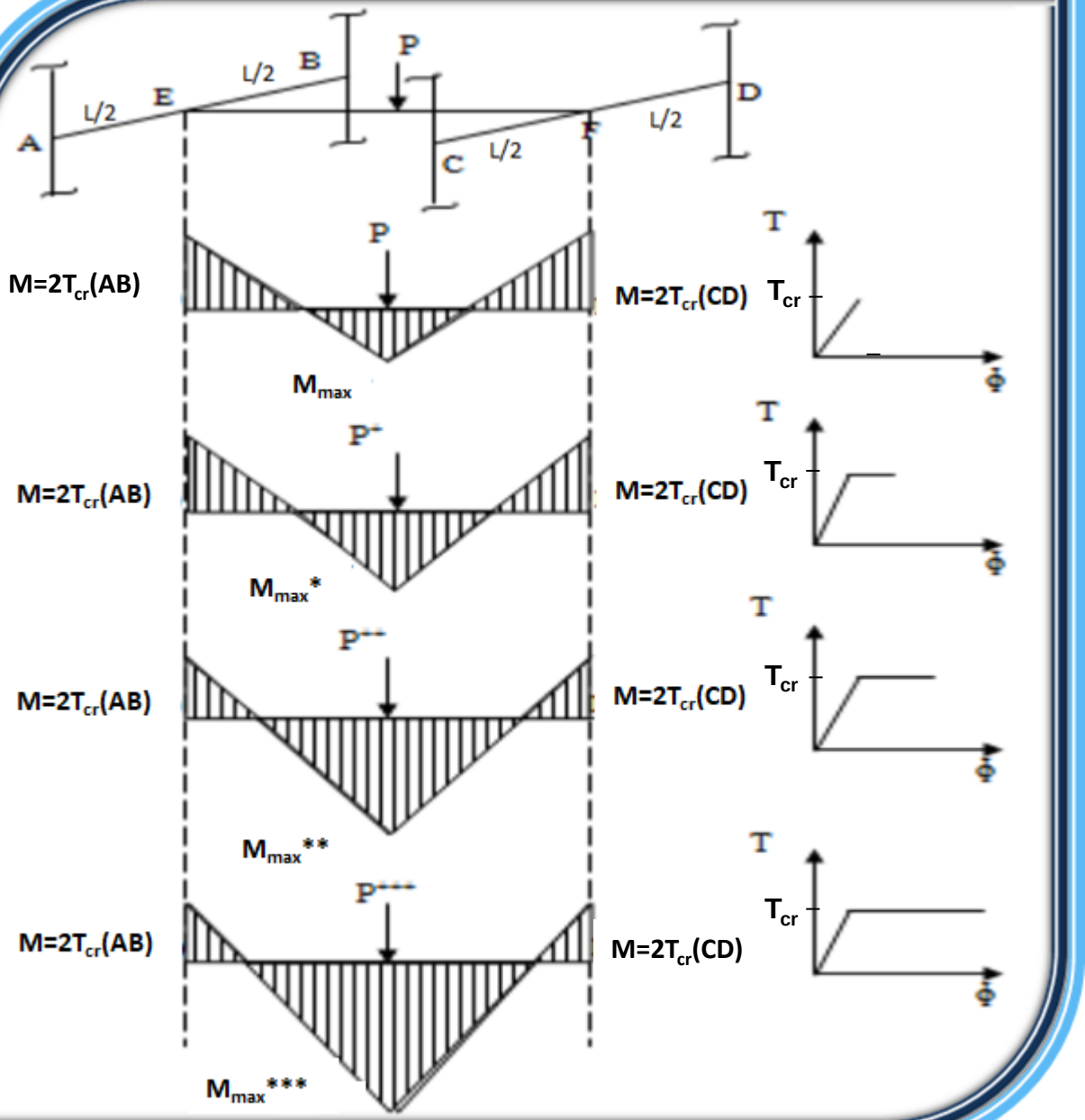
Uygunluk burulmasında, burulma çatlaması ile oluşan plastik mafsallarda burulma momentinin sabit kaldığı varsayılmaktadır.

Bu sabit değer çatlama momentine eşit olacaktır. O halde uygunluk burulmasının söz konusu olduğu durumlarda, burulma momentinin hesabına gerek yoktur.

Bu moment en fazla çatlama burulma momenti ($\mathbf{T_{cr}}$) değerine eşit olarak alınacaktır.

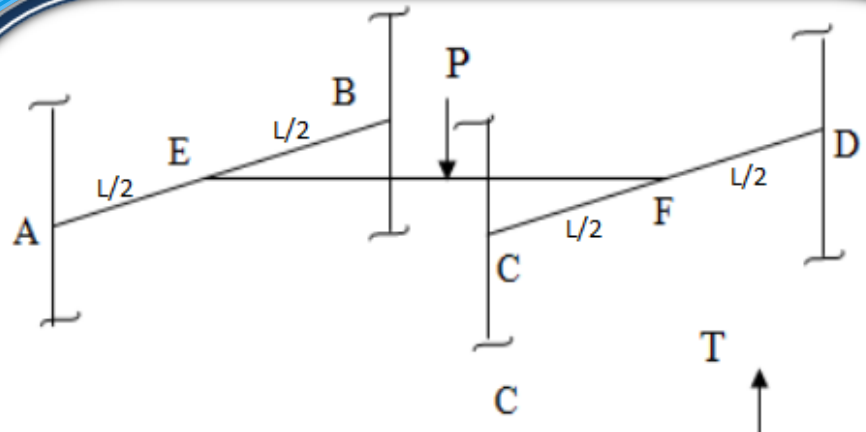
Varılan bu sonuç son derece önemlidir. Bu durumda, pratikte en sık rastlanan burulma türü olan uygunluk burulmasında, burulma momentinin saptanması için üç boyutlu yapısal çözümlemeye gerek kalmamaktadır. Bu çok büyük zaman tasarrufu sağlamakta ve işlemleri kolaylaştırmaktadır.

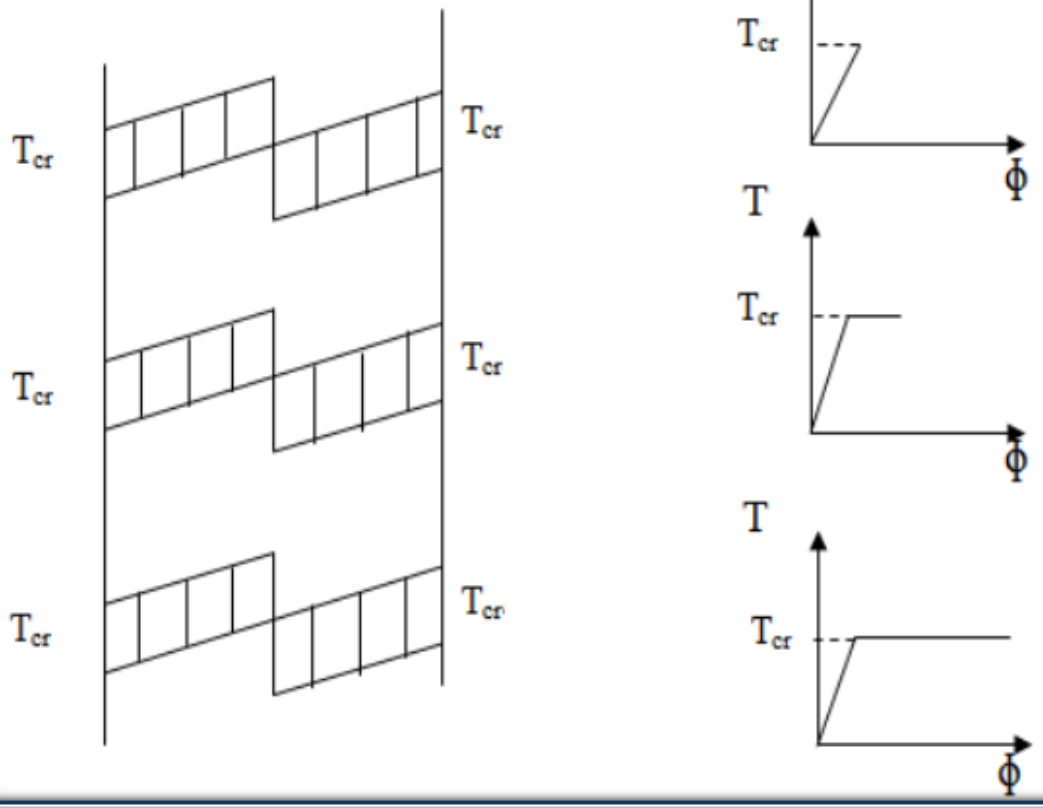
Ancak bu şekildeki bir çözümde "uyumun" neden olacağı değişimler dikkate alınmalı, mafsallaşan kesitlerin dönme kapasitelerinin yeterli olması sağlanmalı ve çatlak genişliği kontrol edilmelidir.



Şekilde, uygunluk burulması durumunda burulma momentinin elemanda nasıl meydana geldiği aşama gösterilmektedir.

$$M_{max}=M_t=A_s f_{yd}(z)$$





AB kirişi üzerindeki max. burulma momenti **P** nin büyüklüğünden bağımsız olup daima sabit kalacaktır.

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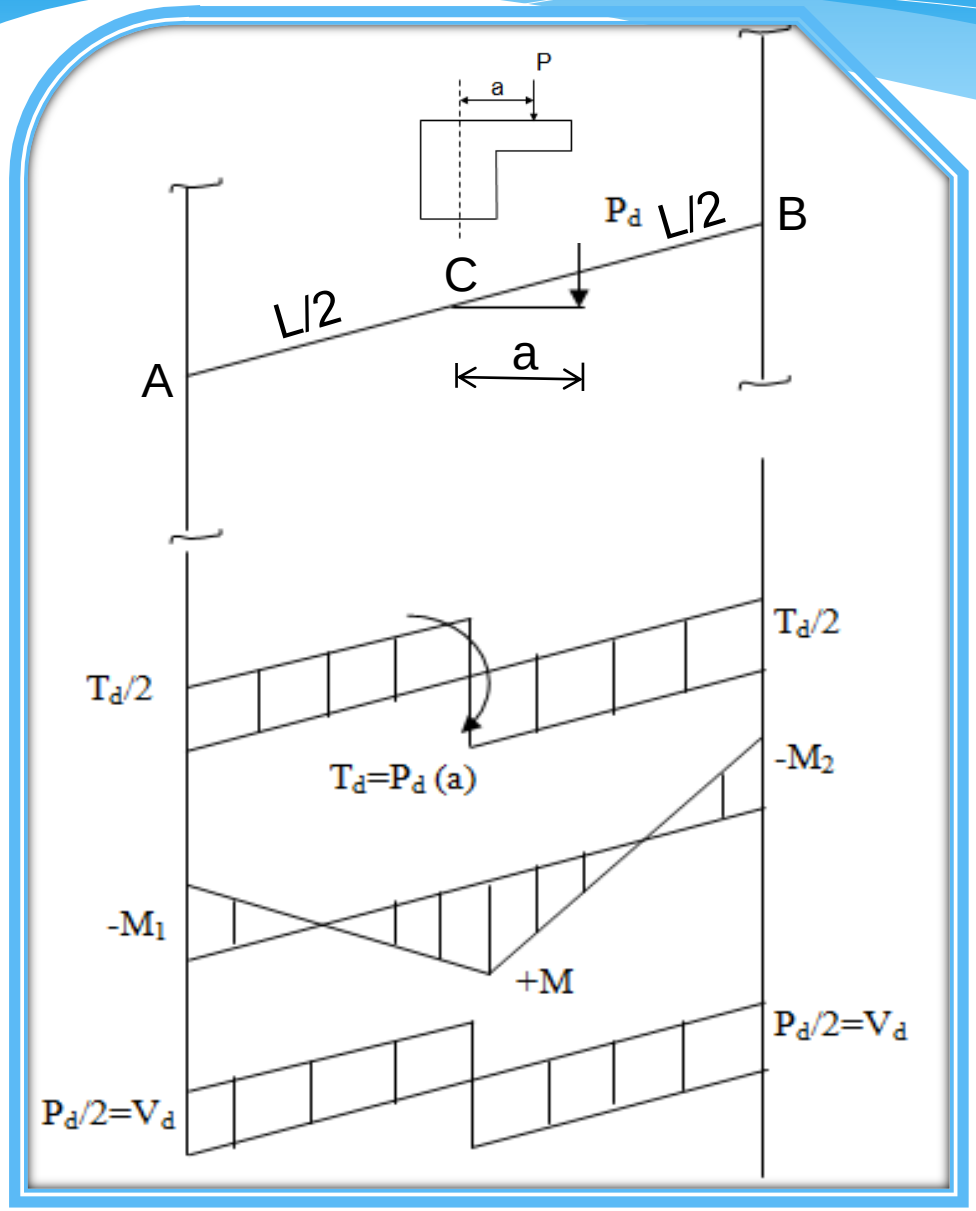
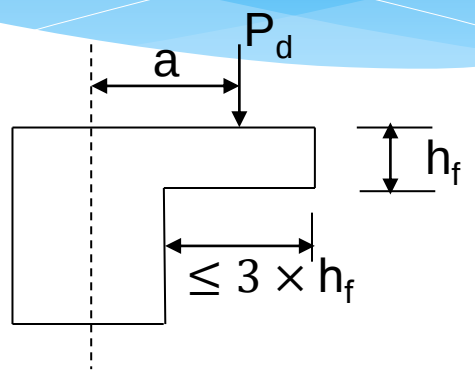




Denge ve uygunluk burulması için yapılacak hesaplar oldukça farklı olduğundan öncelikle burulma türünün saptanması gerekmektedir.

a) Denge burulması

$V_{cr}=0.65\ f_{ctd}\ (b_w\ d)$

$T_{cr}=1.35\ S\ f_{ctd}$

Çatlama Kontrolü:

$$(\frac{T_d}{T_{cr}})^2+(\frac{V_d}{V_{cr}})^2=\psi$$ ($\Psi<1$ ise çatlamamış, $\Psi>1$ ise çatlamış).

T_{cr}=Basit burulma altında çatlama momenti.

V_{cr}=Burulmanın olmadığı durumda eğik çatlama dayanımı.

T_d ve V_d= Uygulanan burulma momenti ve kesme kuvvetinin hesap değeri.

$\Psi<1$ Çatlamamış:

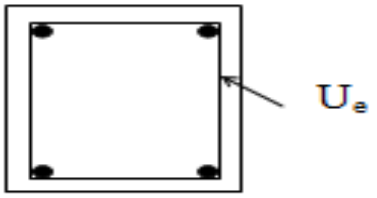
min Donatı:

$$\min \rho_{wo}=\frac{A_o}{s\,b_w}=0.15\frac{f_{ctd}}{f_{ywd}}(1+1.3\frac{T_d}{V_d\,b_w})$$

$\frac{T_d}{V_d\,b_w}\le 1.0$ olmalıdır.

İlave Boyuna Donatı:

$$\min A_{sl}=\min\frac{T_d U_e}{2 f_{yd} A_e}$$



Ψ>1 Çatlamış:

Gövde donatısı gerekli

Gövde ezilmesi kontrol edilmeli

$$\tau=\left(\frac{T_d}{1.35S}+\frac{V_d}{b_w\,d}\right)\leq\tau_{max}=0.22\,f_{cd}$$

Bu denklem sağlanmıyorsa sağlanana kadar boyutlar büyütülmelidir.

$$T_r=T_d=2\frac{A_{ot}}{s}(A_e)(f_{ywd}) \quad \text{TS 500-2000}$$

$$\frac{A_{ot}}{s}=\frac{T_d}{2A_e f_{ywd}}$$

$$\frac{A_{ov}}{s}=\frac{V_d-V_c}{f_{ywd}\,d\,(n)}$$

$$\frac{A_o}{s}=\frac{A_{ot}}{s}+\frac{A_{ov}}{s}\geq\frac{A_o}{s}\,(\min)$$

$$\frac{A_{0v}}{s}=\frac{V_d-0.5f_{ctd}(b_w d)}{f_{ywd}d(n)}$$

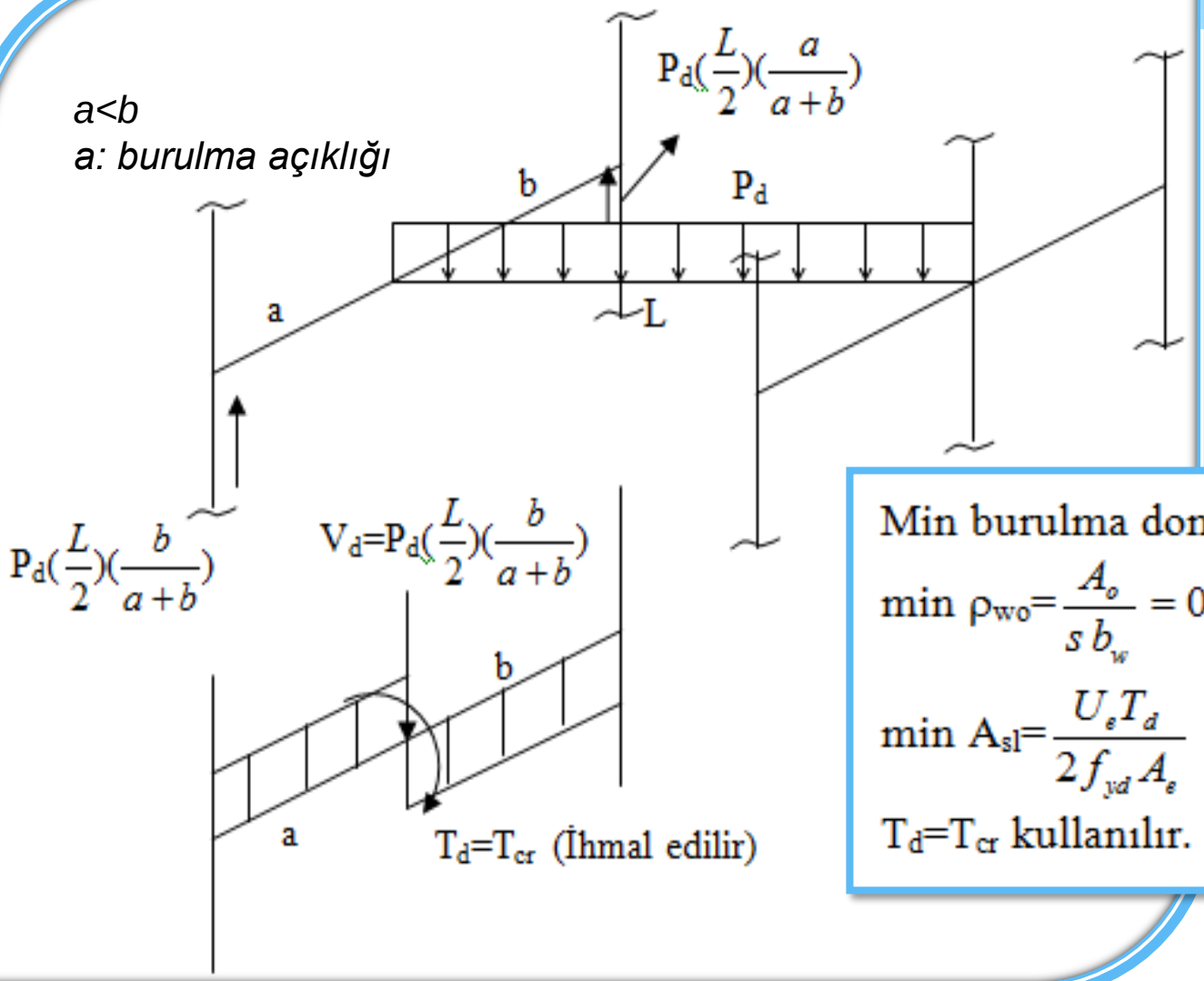
n=kesme etriyesi kol sayısı
basit etriye n=2; $A_{sw}=2A_{ov}$

$$\frac{A_o}{s}\geq 0.15\frac{f_{ctd}}{f_{ywd}}\left(1+1.3\frac{T_d}{V_d\,b_w}\right)b_w$$

b) Uygunluk Burulması

a<b

a: burulma açıklığı

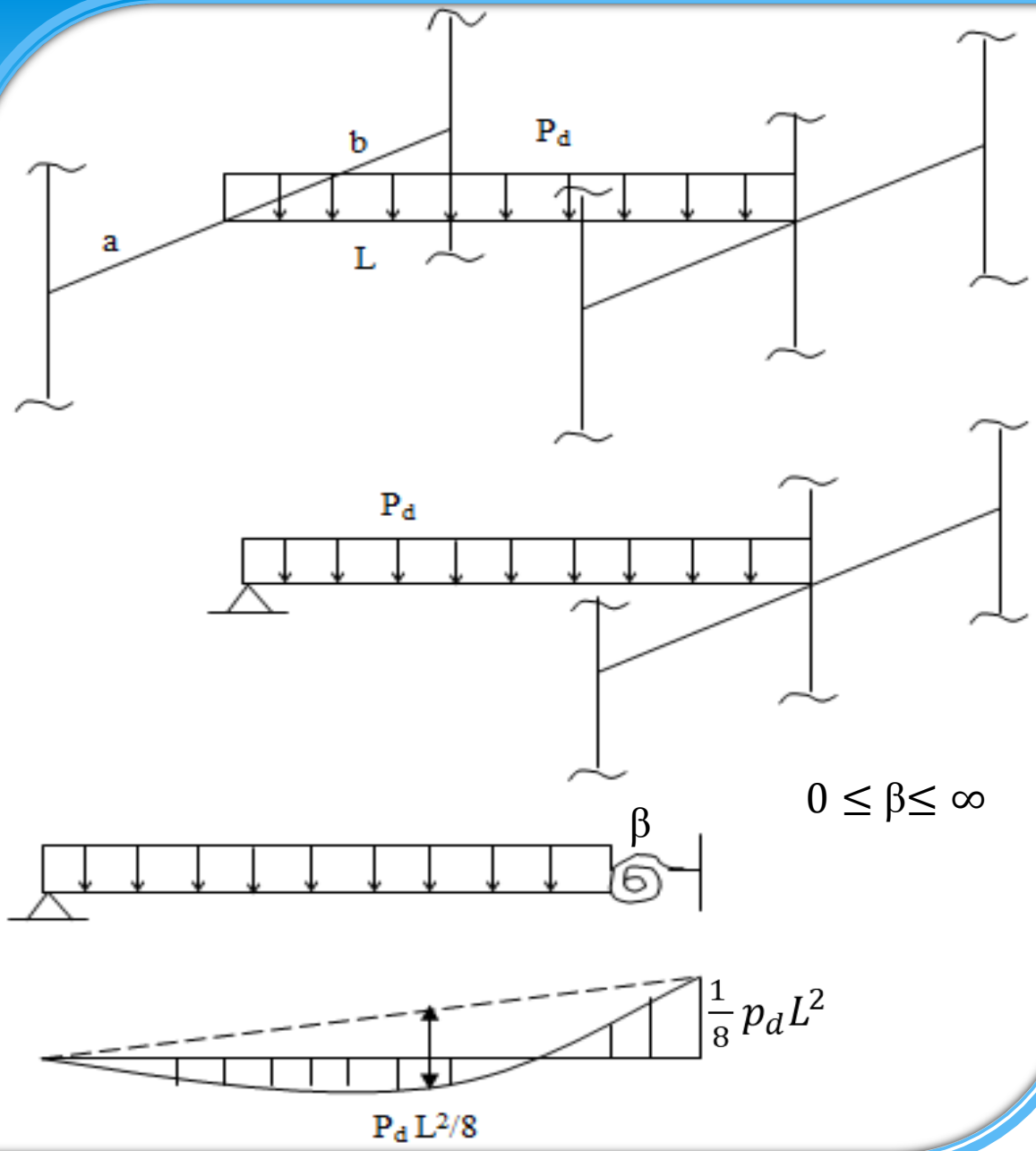


Min burulma donatısı sağlanır;

$$\min \rho_{wo}=\frac{A_o}{s\,b_w}=0.15\frac{f_{ctd}}{f_{ywd}}\left(1+1.3\frac{T_d}{V_d\,b_w}\right)$$

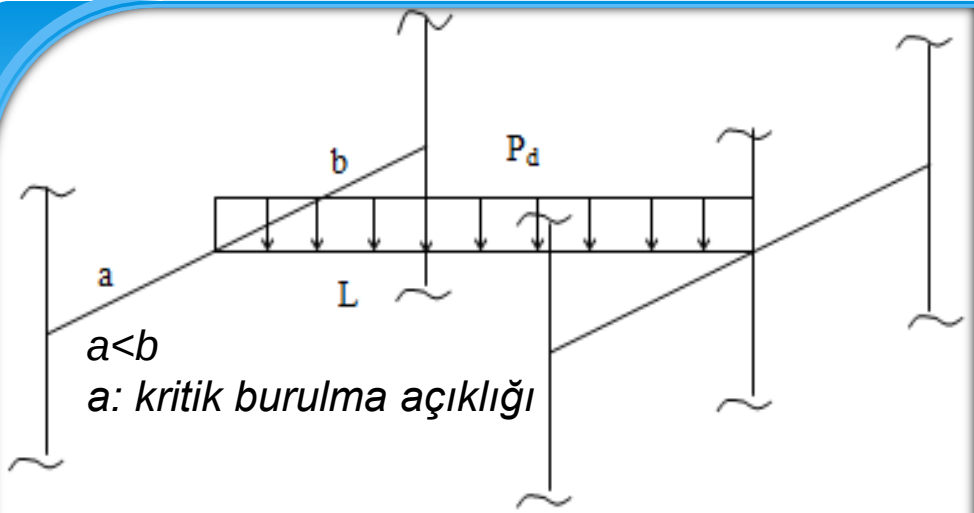
$$\min A_{sl}=\frac{U_e T_d}{2 f_{yd} A_e}$$

$T_d=T_{cr}$ kullanılır.



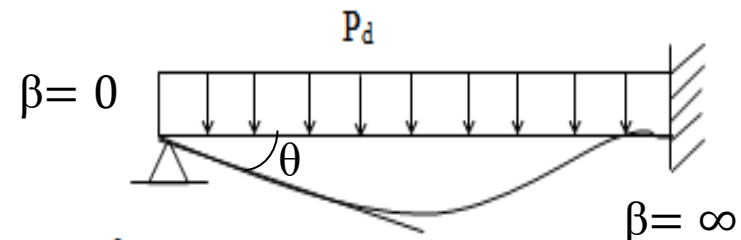
$$M = -\frac{1}{8} P_d L^2$$

$$M = -\frac{1}{10} P_d L^2$$

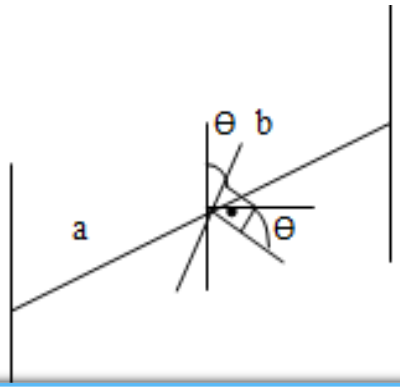


a<b

a: kritik burulma açıklığı



$$\theta = \frac{P_d L^3}{48 E I}$$



a<b

a: kritik burulma açıklığı

$$\text{Birim Dönme, } \phi = \frac{\theta}{a} \leq 10 * 10^{-3} \text{ rad/m.}$$

Bu koşul sağlanmazsa

boyutlar değiştirilmelidir.

ÖNEMLİ

Burulma açıklığı kiriş yüksekliğinin 3 katından ($a \leq 3 \times h$) küçük ise dönme açısının kontrol edilmesi gerekir

Detaylandırma:

Burulma için gerekli boyuna donatı, olabildiğince kesit çevresine dağıtılmalı ve köşelerdeki çubuk çapı, en az 12 mm olmalıdır. Ayrıca iki çubuk arasındaki uzaklık 300 mm'yi geçmemelidir.

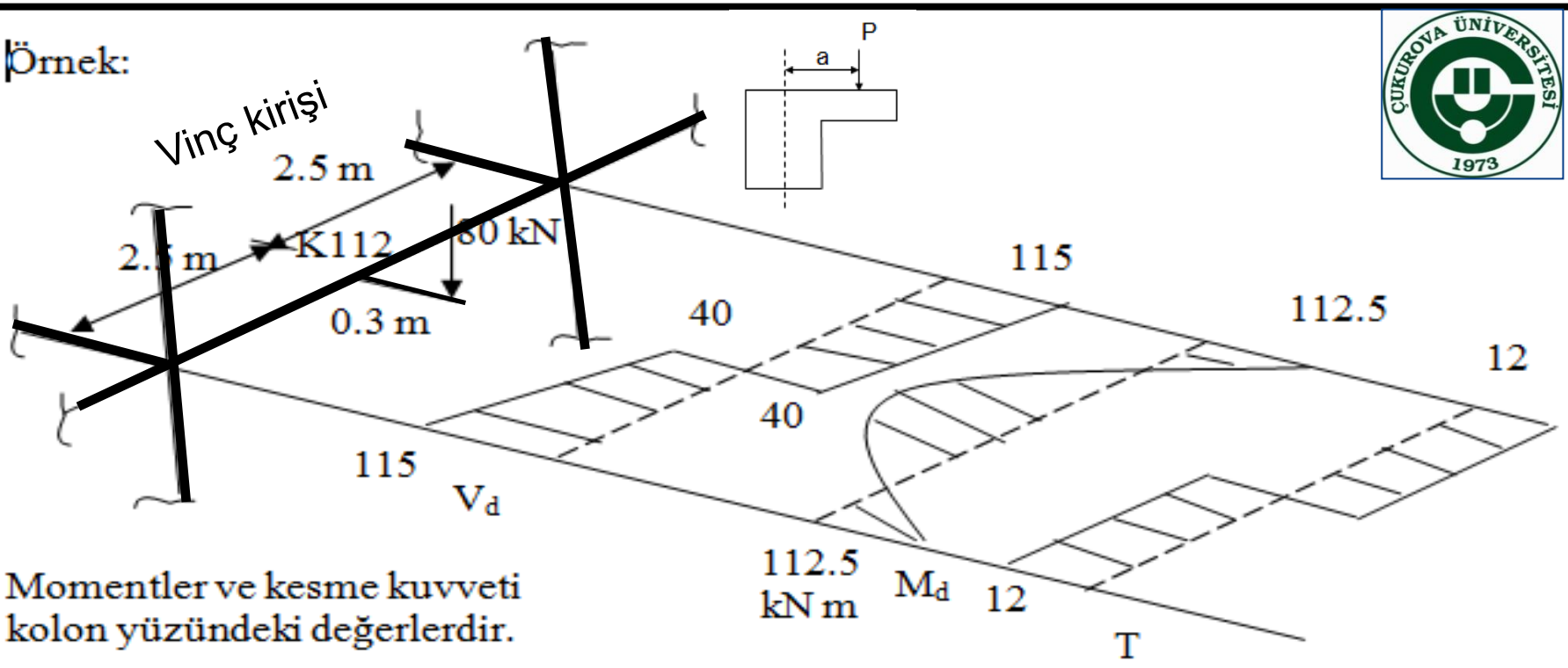
Etriye çapı en az 8 mm olmalı ve etriye aralığı, aşağıdaki koşulları sağlamalıdır. Çok kollu etriye düzenlendiğinde, iç kollar burulma donatısı olarak göz önüne alınamaz.

$s \leq d/2$

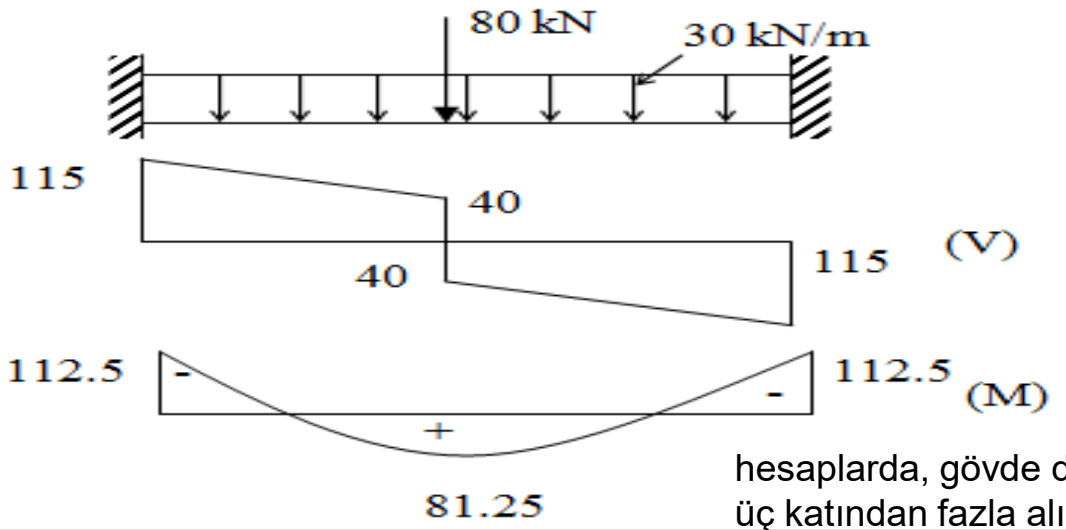
$s \leq U_e/8$

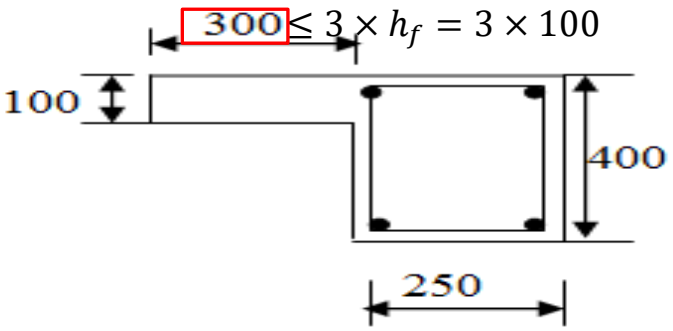
$s \leq 300$ mm

Örnek:



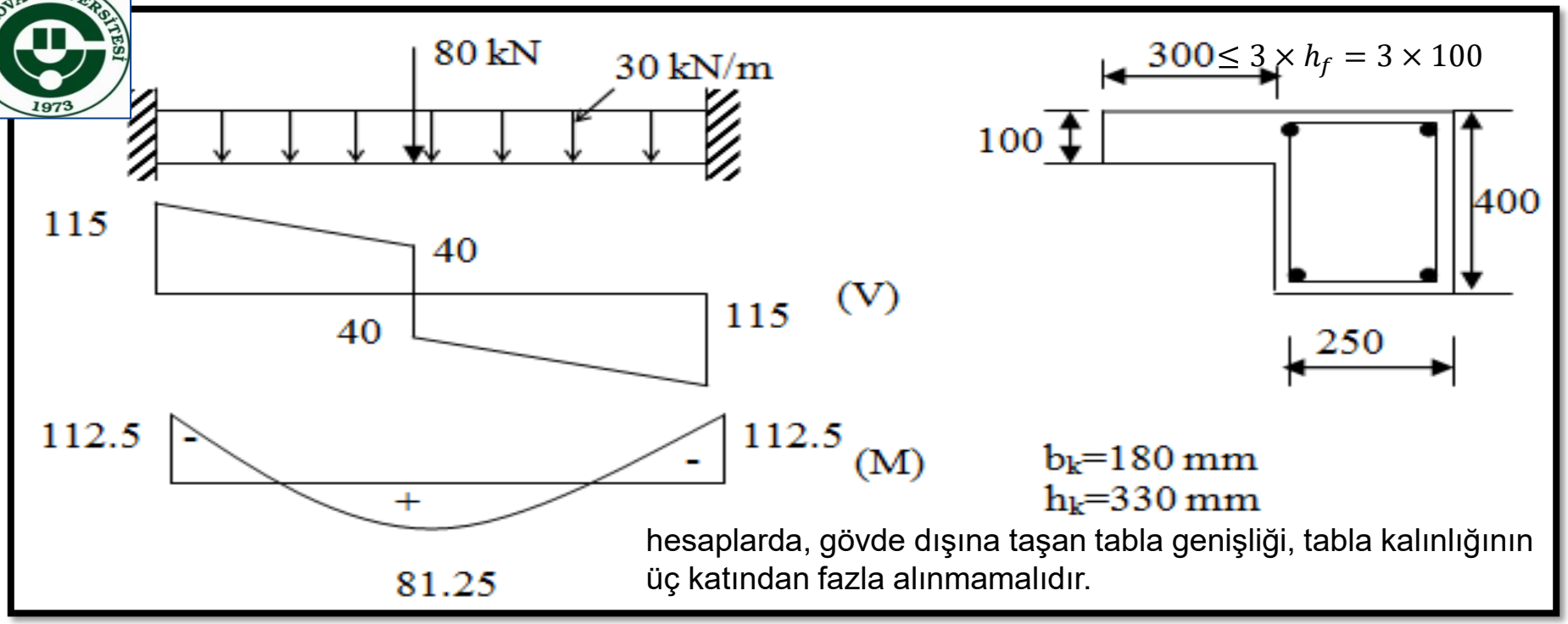
Momentler ve kesme kuvveti kolon yüzündeki değerlerdir.





b_k=180 mm
h_k=330 mm

hesaplarda, gövde dışına taşan tabla genişliği, tabla kalınlığının üç katından fazla alınmamalıdır.



hesaplarda, gövde dışına taşan tabla genişliği, tabla kalınlığının üç katından fazla alınmamalıdır.

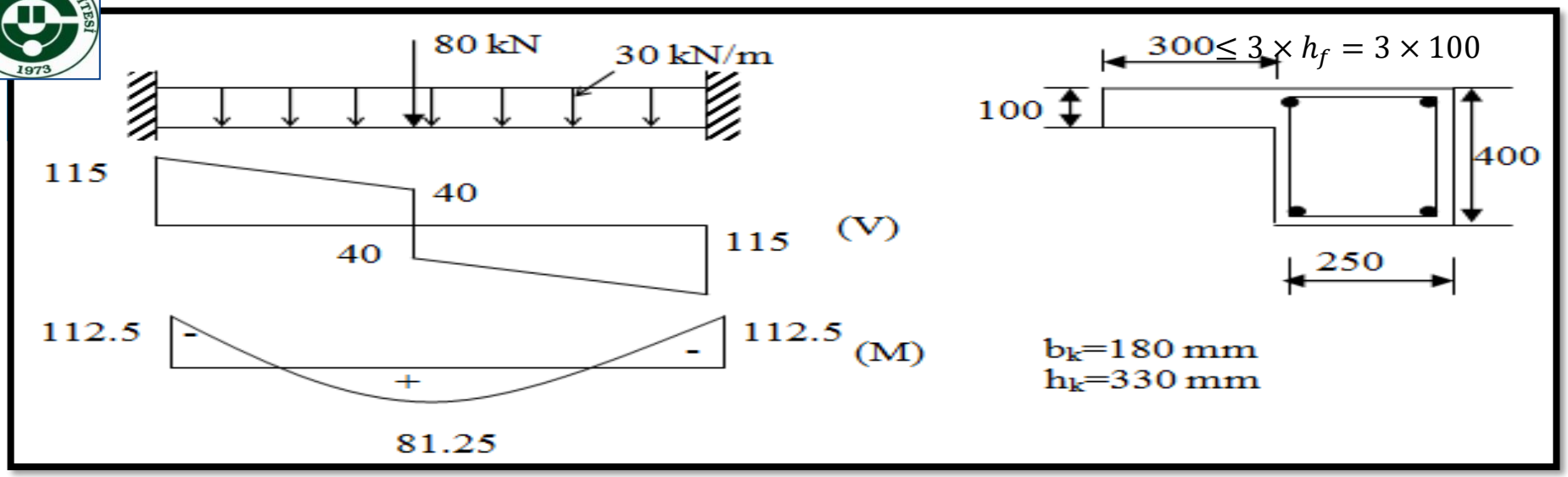
Bilinen:

Malzeme C20, S420, f_{ctd}=1 N/mm^2, f_{ywd}=191 N/mm^2

Hesap yükleri: p_d=30 kN/m, P_d=80 kN

Kiriş boyutları: 25*40 (d=36.5 cm)

Mesnet için verilen değerler kolon yüzündeki değerlerdir.



Çözüm:

a) Burulma, denge burulmasıdır.

b) K112 L kirişidir. x_1=25 cm, y_1=40 cm, x_2=10 cm, y_2=30 cm

$b_k=b_w-2*3.5=18$ cm, $h_k=h-2*3.5=33$ cm

$A_e=b_k h_k=18*33=594$ cm^2, $U_e=2(b_k+h_k)=102$ cm

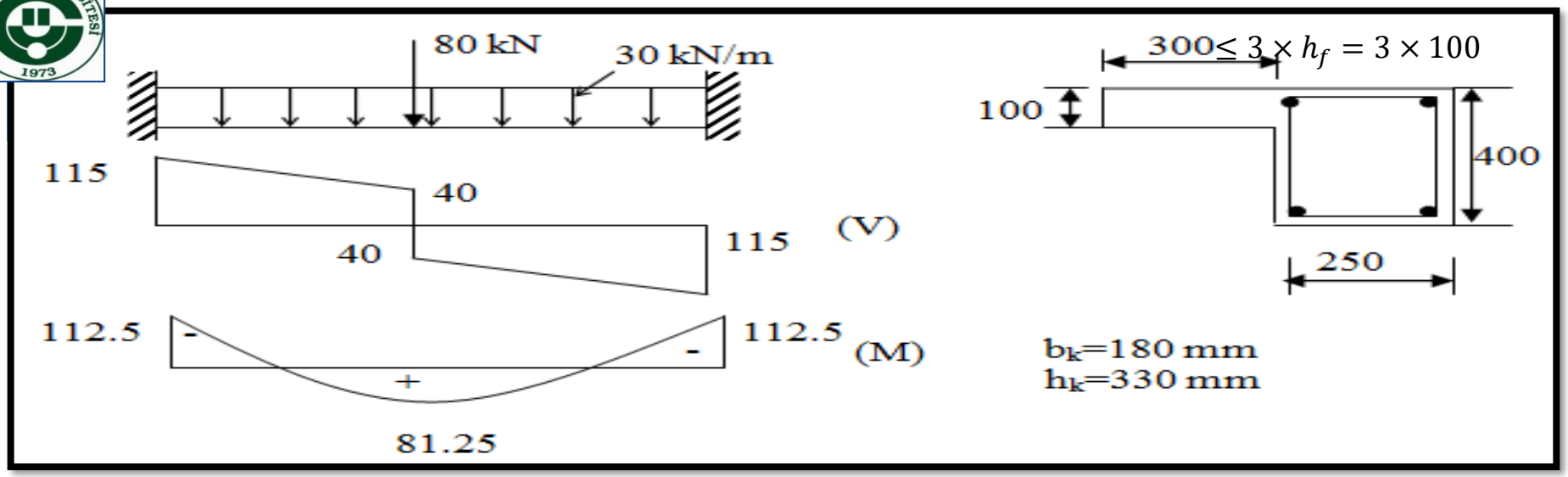
c) $T_{cr}=1.35S\, f_{ctd}$ TS 500 de $S=(\frac{1}{3})\,\Sigma x_i^2\, y_i$

$1.35S=0.45(25^2*40+10^2*30)=12600$ cm^3

$T_{cr}=1.35S\, f_{ctd}=1*12600*10^{-3}=12.6$ kN m

$V_{cr}=0.65\, f_{ctd}\, b_w\, d=0.65*1*250*365*10^{-3}=59.3$ kN

$V_c=0.8\, V_{cr}=47.4$ kN



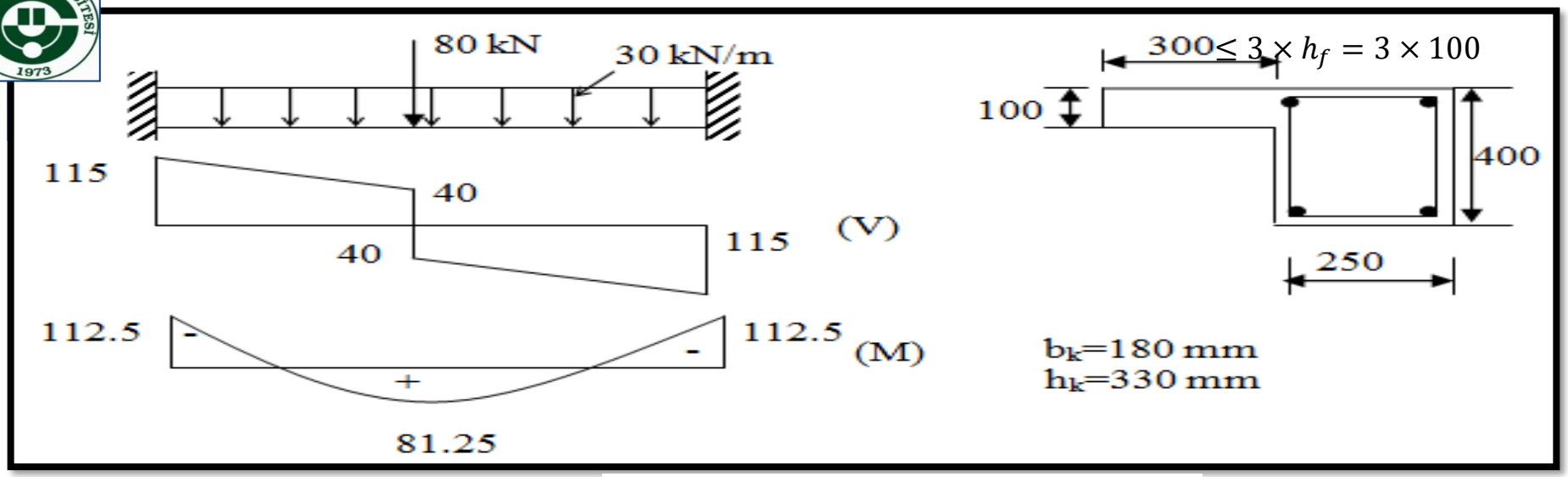
d) T_d=12 kN m

V_d= 102 kN (kolon yüzünden d uzaklığında) $V_d = 112.5 - 30 \times 0.365 = 102\ kN$

$$\tau = \frac{V_d}{b_w d} + \frac{T_d}{1.35S} = \frac{102^* 10^3}{250^*365} + \frac{12^*10^6}{12600^*10^3} = 2.03\ N/mm^2$$

τ_{max}=0.22 f_{cd}=0.22*13=2.86 > 2.03 N/mm²

$$\left(\frac{T_d}{T_{cr}}\right)^2 + \left(\frac{V_d}{V_{cr}}\right)^2 = \left(\frac{12}{12.6}\right)^2 + \left(\frac{102}{59.3}\right)^2 = 3.86 > 1\ kesit\ çatlamıştır$$

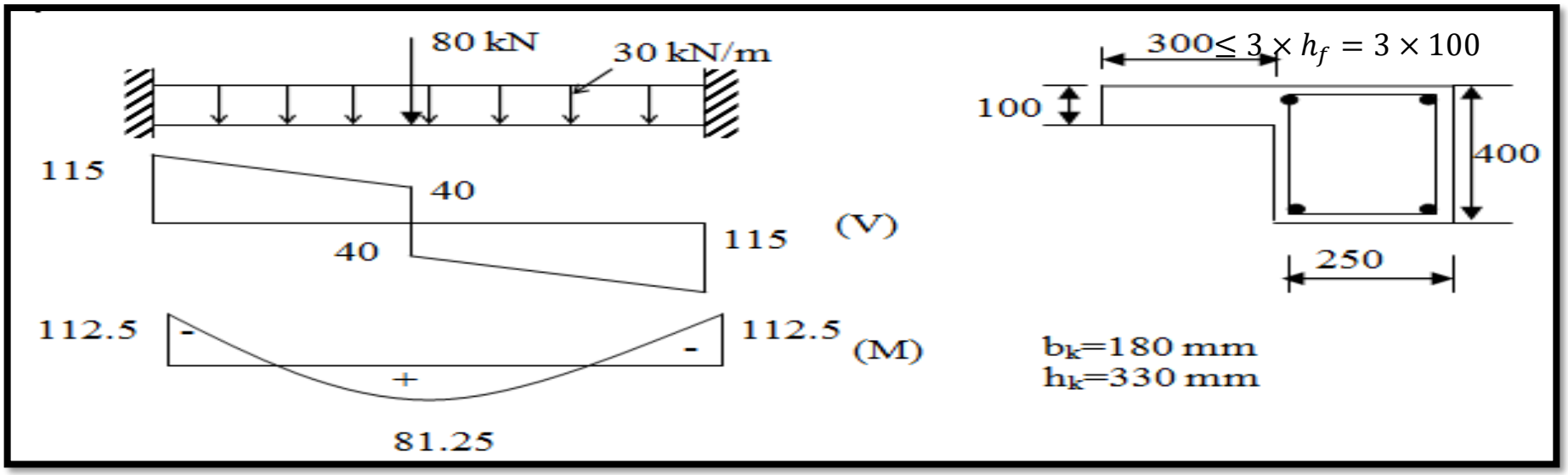


e) $$\frac{A_o}{s}=\frac{V_d-V_c}{2f_{ywd}(d)}+\frac{T_d}{2A_e f_{ywd}}$$

$$\frac{A_o}{s}=\frac{A_{ot}}{s}+\frac{A_{ov}}{s}\geq\frac{A_o}{s}(\min)$$

$$\frac{A_o}{s}=\frac{(102-47.4)*10^3}{2*191*365}+\underbrace{\frac{12*10^6}{2*594*10^2*191}}_{\frac{A_{ot}}{s}=0.528}=$$ **0.92 mm²/mm**

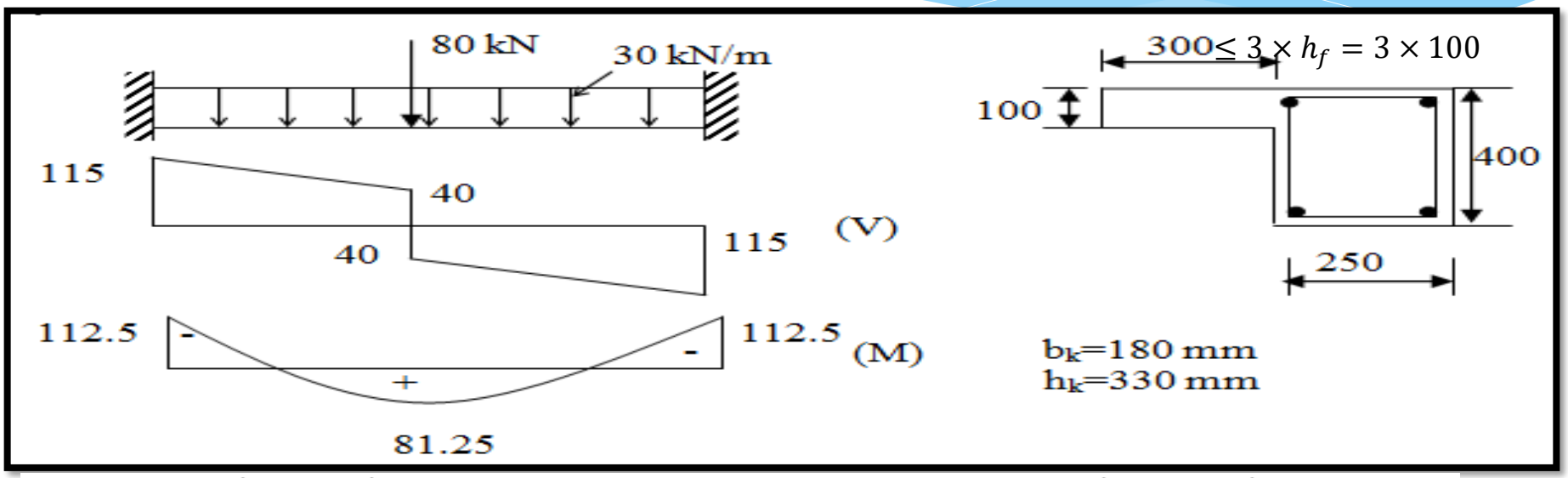
$$\min\frac{A_o}{s}=0.15\frac{1}{191}(1+1.3\frac{12*10^3}{102*250})250=$$ **0.32 mm²/mm < 0.92 mm²/mm**

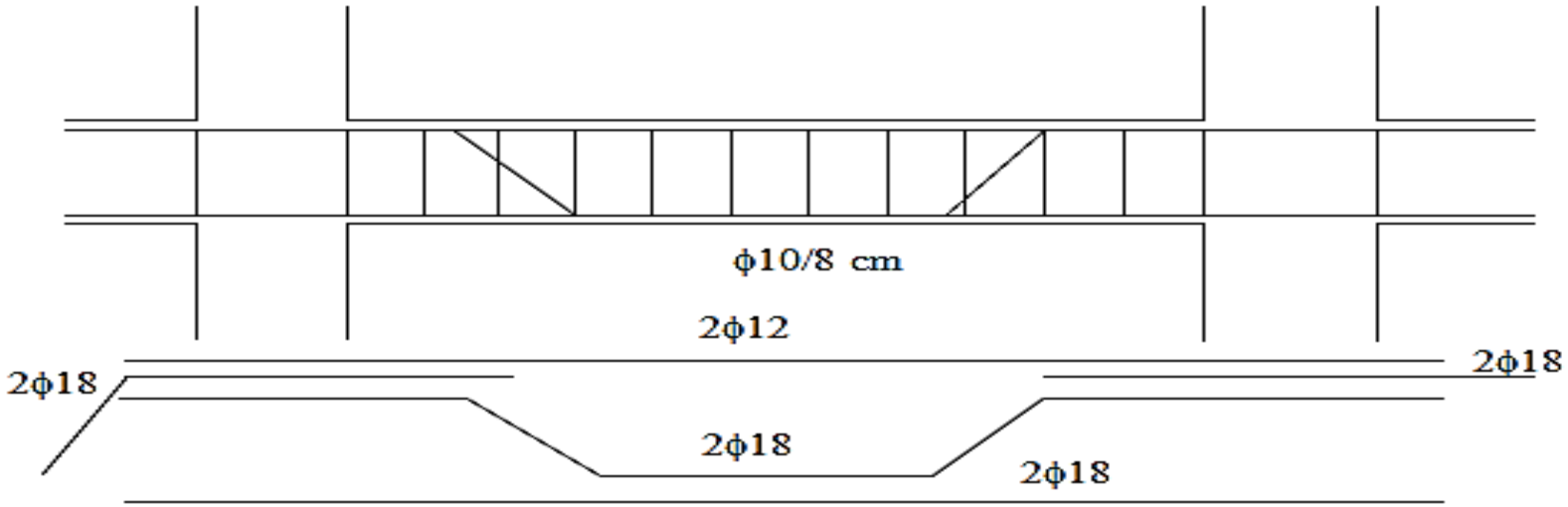


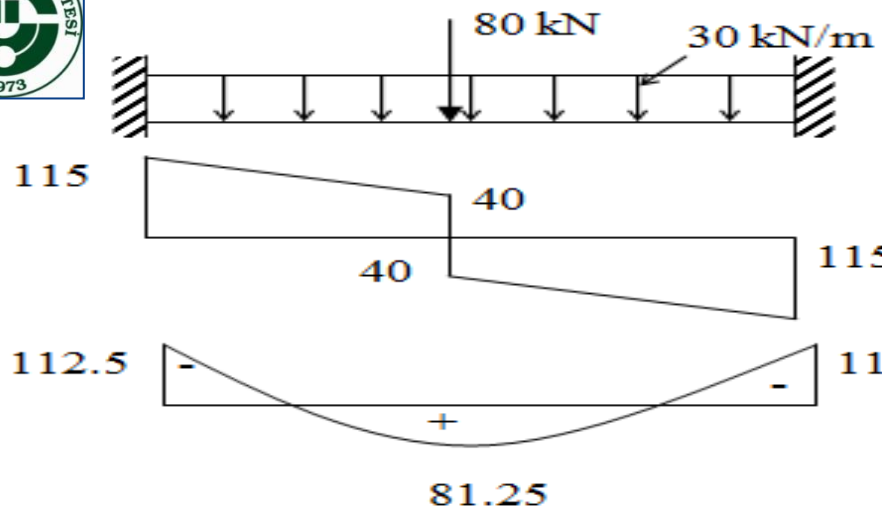
ϕ10 seçilirse; A_0=78.5 mm² - buradan s=84.4 mm (ϕ10/8 cm)

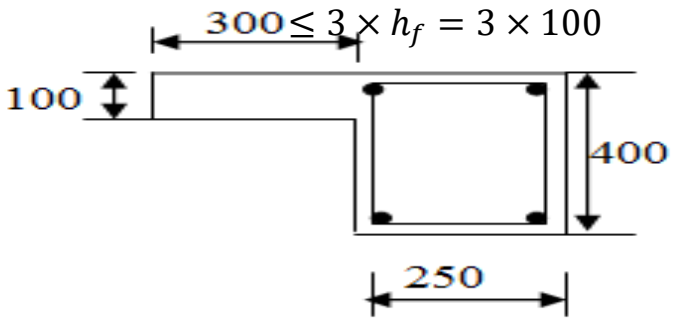
$$A_{sl} = \frac{A_{ot}}{s} U_e \frac{f_{ywd}}{f_{yd}} = 280 \text{ mm}^2 \qquad A_{sl} = 0.528 \times 1020 \times \frac{191}{365} \cong 280\ mm^2$$

Boyuna donatı alt ve üstte yerleştirilecektir. Her bir yüzde $A_{sl}/2$=140 mm²


80 kN
30 kN/m
115
40
40
115
(V)
112.5
-
+
-
112.5
(M)
81.25
300≤ 3 × h_f = 3 × 100
100
400
250
b_k=180 mm
h_k=330 mm


ϕ10/8 cm
2ϕ12
2ϕ18
2ϕ18
2ϕ18
2ϕ18
2ϕ18





b_k=180 mm
h_k=330 mm

f) Eğilme hesabı

+M=81.25 kN m As= $\frac{M_d}{f_{yd}\,jd}$ =678 mm²

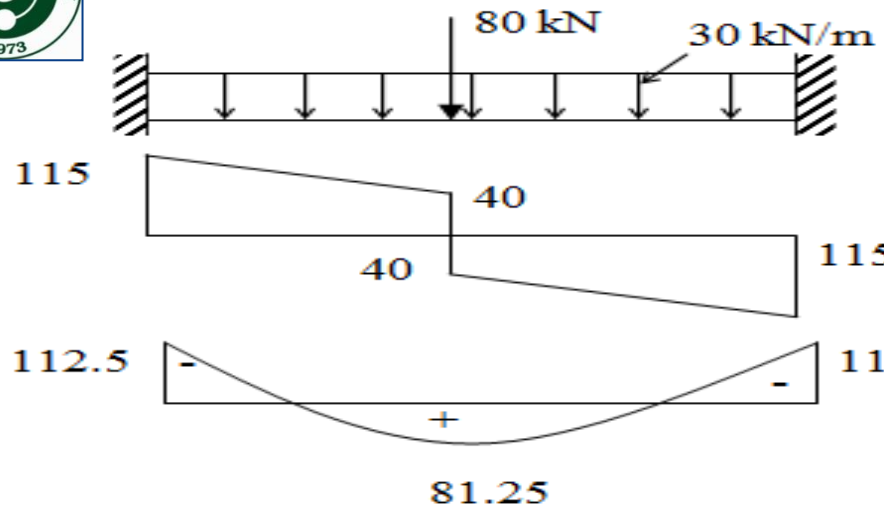
-M=112.5 kN m K=374.62 mm²/kN<K_L=380 mm²/kN (Çift Donatı)

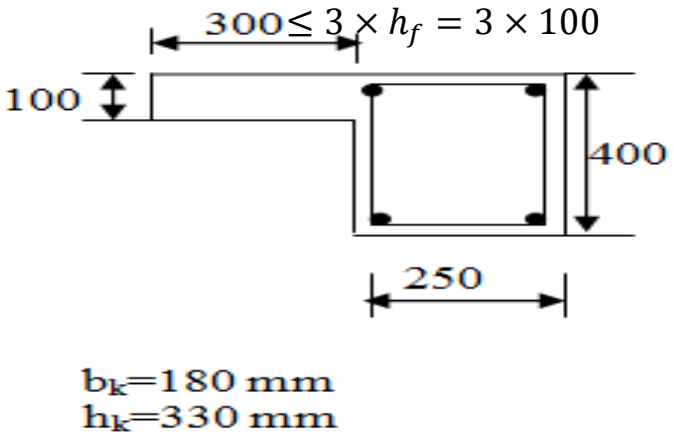
M_1= $\frac{b_w d^2}{K_L}$ =87.6 kNm, M_2=25 kNm

$$A_{s1}=\frac{M_1}{f_{yd}\,jd}=\frac{87.6*10^6}{365*0.86*365}=765\ \text{mm}^2$$

$$A_{s2}=\frac{M_2}{f_{yd}\,(d-d')}=208\ \text{mm}^2$$

A_s= A_{s1}+ A_{s2}=973 mm²





Eğilme+burulma için gerekli boyuna donatı;

Açıklıkta:

Altta 678+140=818 mm^2 (2ϕ18 düz, 2ϕ18 pilye)=1016 mm^2

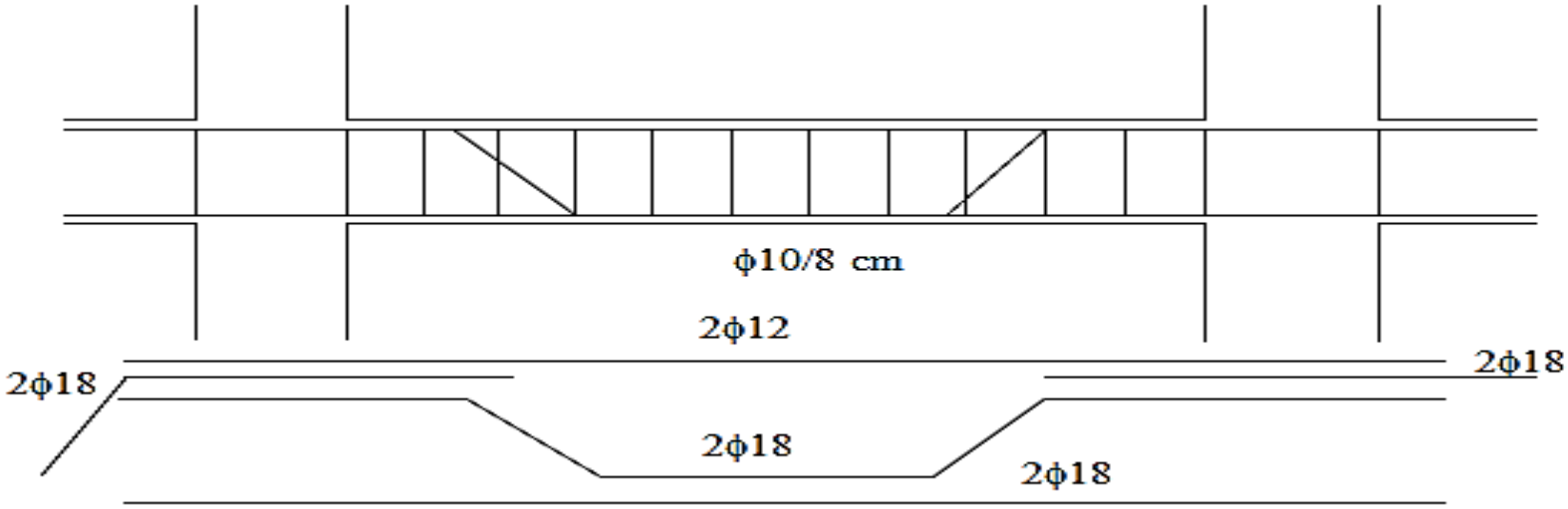
Üstte 0+140=140 mm^2 (Var olan) 2ϕ12

Mesnette:

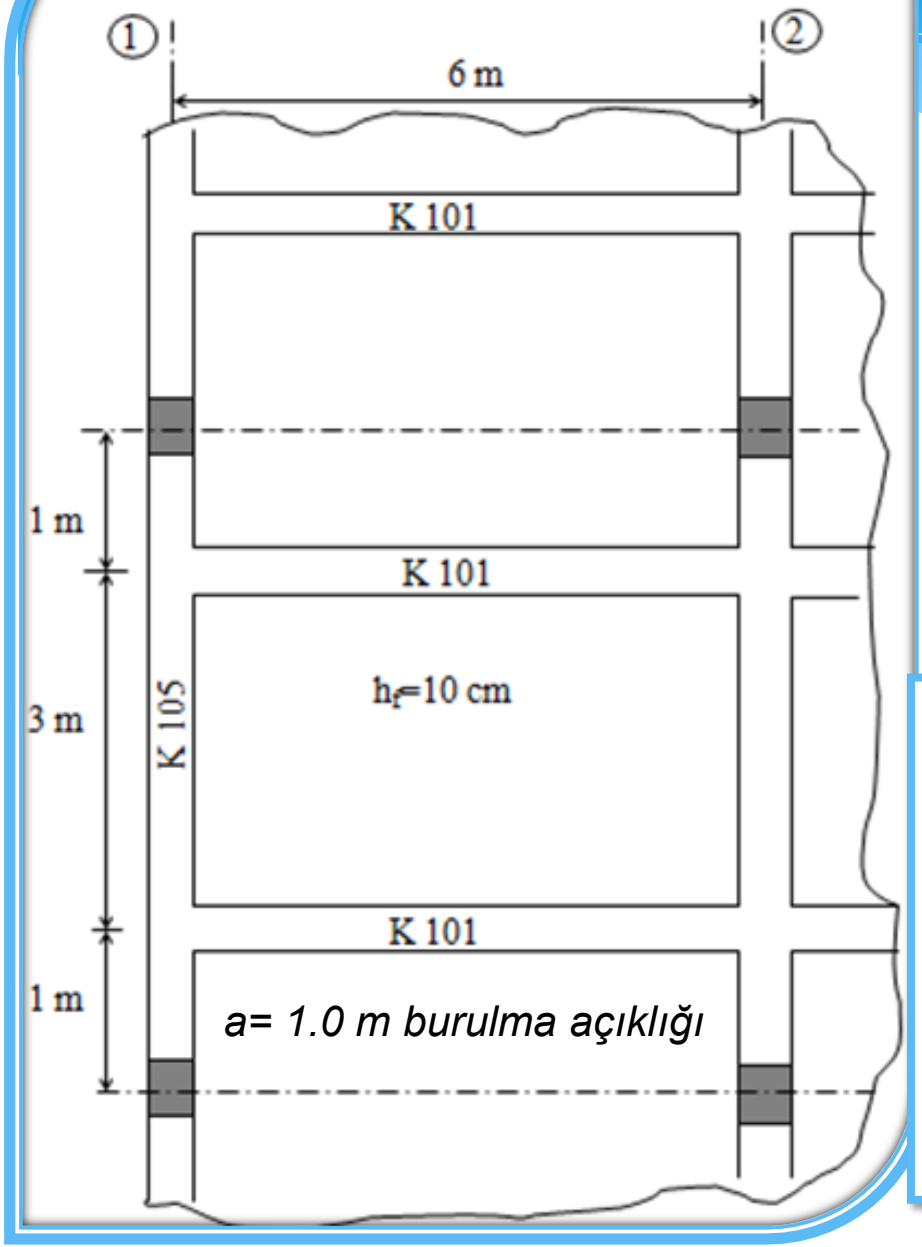
Altta 208+A_{sl}/2=208+140=348 mm^2 (Var olan 2ϕ18=508 mm^2)

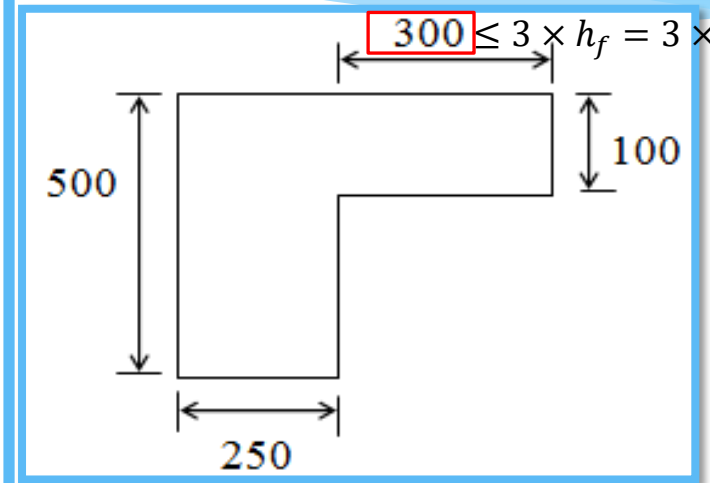
Üstte As+A_{sl}/2=973+140=1113 mm^2 (Var olan 4ϕ18 pilye+2ϕ12 montaj=1232 mm^2)

Donatı detayı



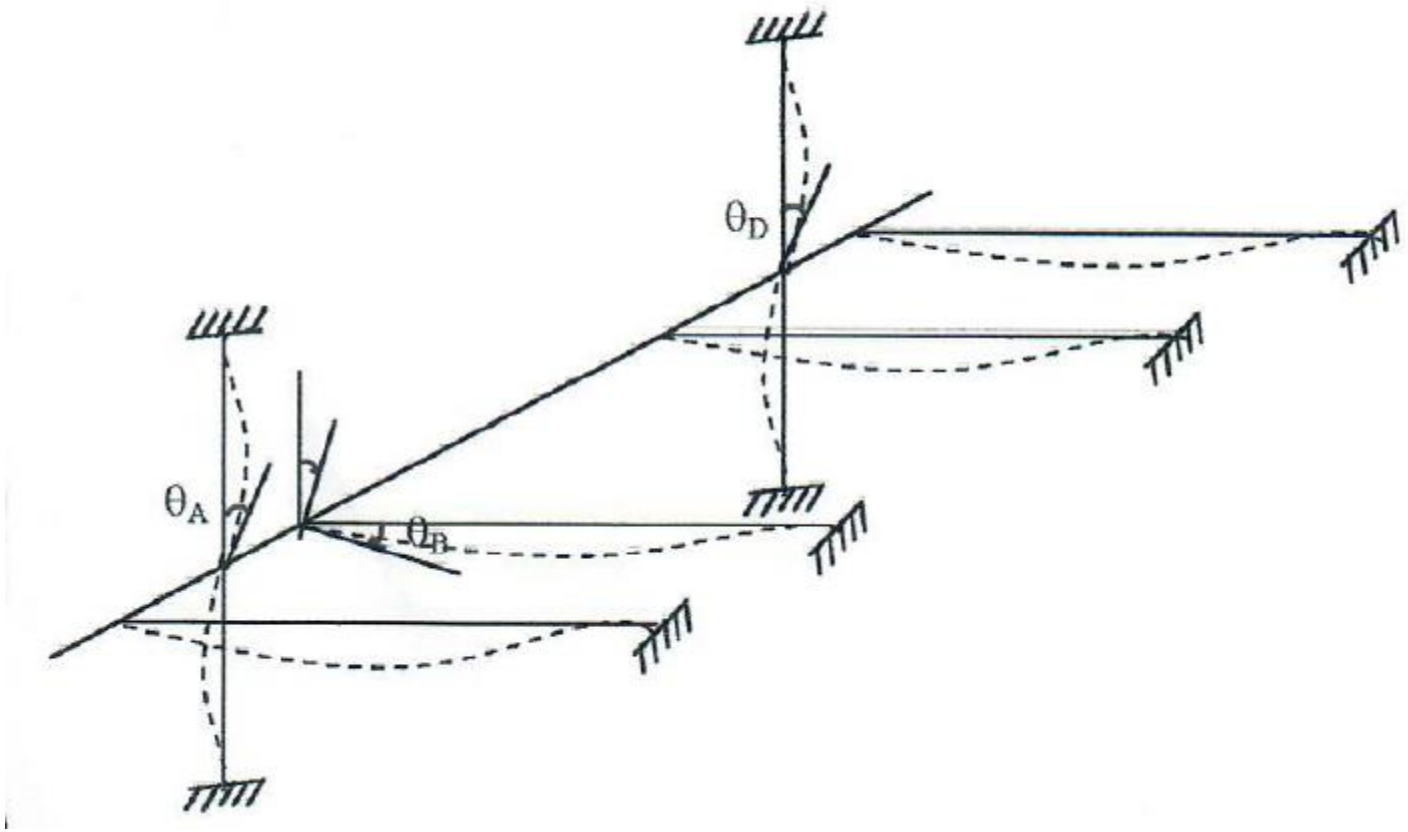
Örnek:

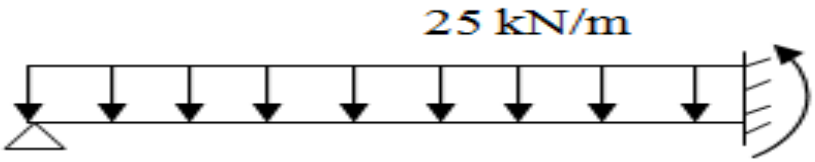




74

Bilinen: Kirişler 25*50 cm (d=46.5 cm)
Kolonlar 60 cm, L=3 m
Döşeme kalınlığı h_f=10 cm
Kiriş hesap yükleri:
K101 P_d=25 kN/m, K105 P_d=15 kN/m
Malzeme C20, S220 (f_{ctd}=1 N/mm^2, f_{ywd}=191 N/mm^2)
İstenen: K101 ve K105 kirişlerinin donatı hesabı


θD
θA
θB



K101

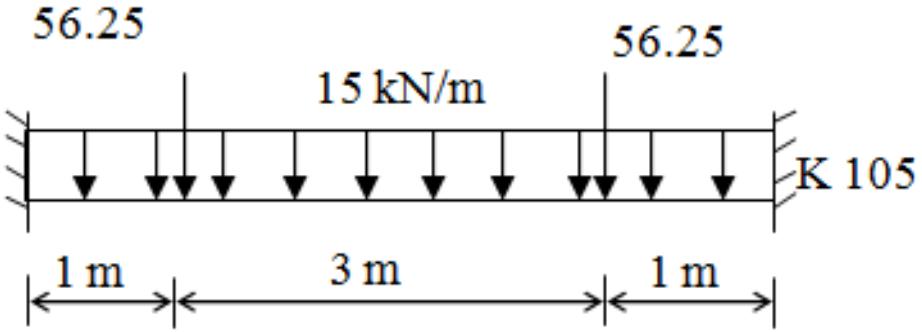
$$M=-\frac{P_d\,l^2}{8}=-\frac{25*6^2}{8}=-112.5\ \text{kN m}$$

Mesnet yüzünde: $+M=112.5-\frac{93.75*0.25}{3}=105\ \text{kN m}$

$$V_{sağ}=-\frac{25*6}{2}+\frac{0-112.5}{6}=-93.75\ \text{kN}$$

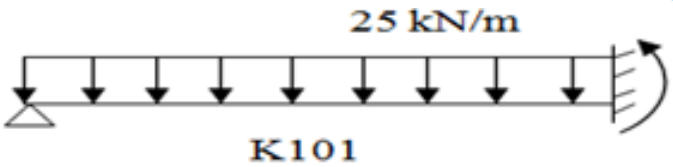
$$V_{sol}=\frac{25*6}{2}+\frac{-112.5}{6}=56.25\ \text{kN}$$

$+M=63.3$ kN m ($x=2.25$ m)

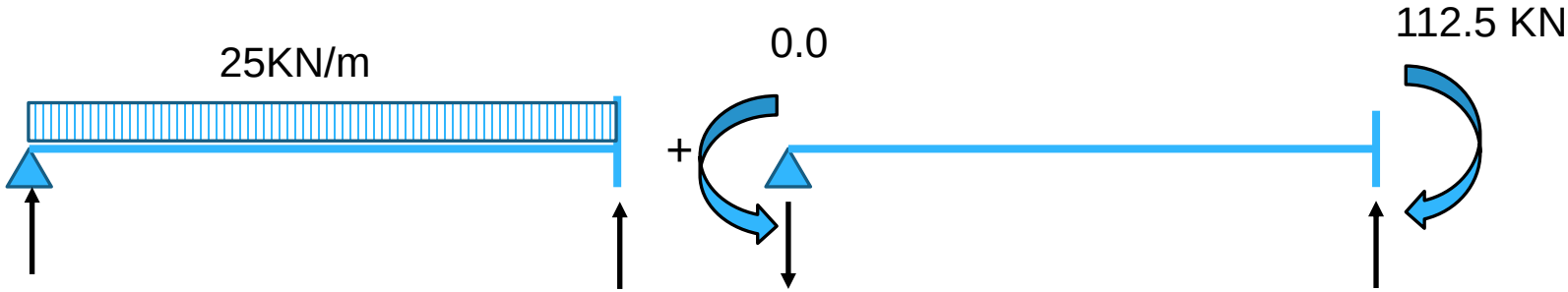


$$M_{ij}=\frac{Pa}{L}(L-a)$$

V=93.75 kN, -M=76.25 kN m



-112.5 KNm

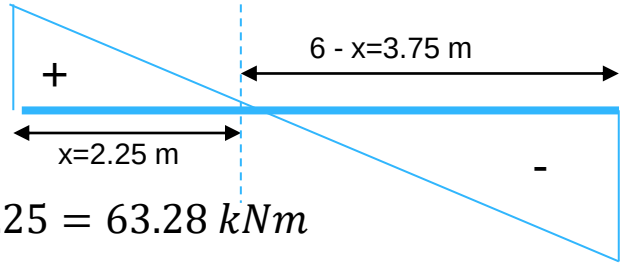


$\frac{25 \times 6}{2} = 75kN$ $\frac{25 \times 6}{2} = 75kN$ $\frac{0 + 112.5}{6} = 18.75kN$ $\frac{0 + 112.5}{6} = 18.75kN$

$75 - 18.75 = 56.25kN$

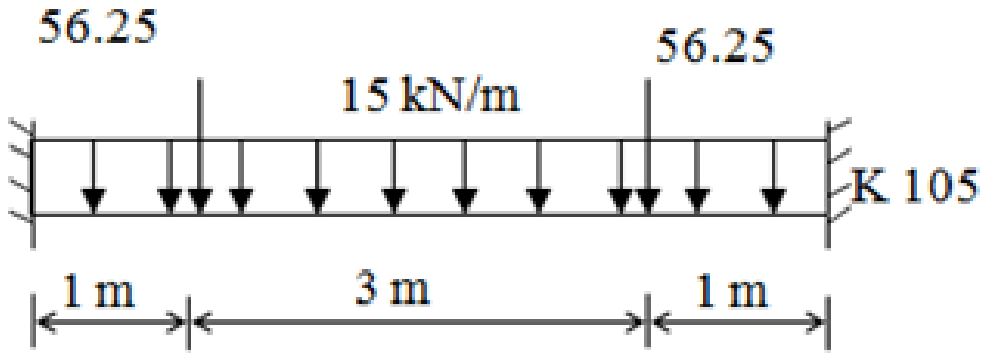
$75 + 18.75 = 93.75\ kN$

$75 - 18.75 = 56.25kN$



$75 + 18.75 = 93.75\ kN$

$M_{açıklık} = \frac{1}{2} \times 56.25 \times 2.25 = 63.28\ kNm$



$$M_{ij}=\frac{Pa}{L}(L-a)$$

V=93.75 kN, -M=76.25 kN m $\quad M_{açıklık} = 27\ kNm$

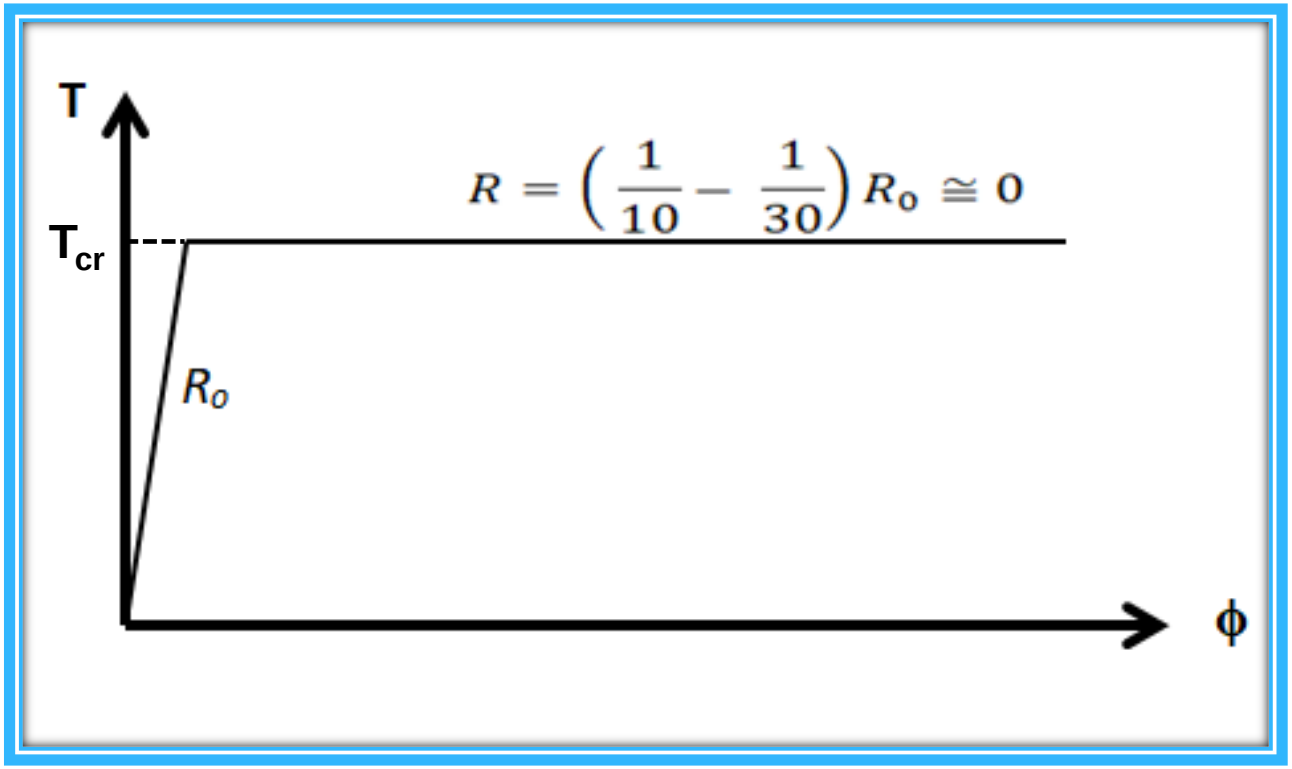
Mesnet yüzünde M_d ve V_d

$$-M = \frac{15\times 5^2}{12}+\frac{56.25\times 1}{5}(5-1) = -76.25\ kNm,\ -M_d = 76.25-\frac{93.75\times 0.6}{3} \cong 58\ kNm$$

$$V = \frac{15\times 5}{2}+\frac{2\times 56.25}{2} = 93.75\ kN, \qquad V_d = 93.75-15\left(\frac{0.60}{2}\right) = 89.25kN$$

$$M_{açıklık} = 93.75\times 2.5-15\times\frac{2.5^2}{2}-56.25\times 1.5-76.25 \cong 27\ kNm$$

Uygunluk burulması söz konusu olduğundan **K105** kirişine uygulanan burulma momenti ihmal edilecek ve K101 kirişinin eğilme momenti hesaplanırken, **K105** kirişinin burulma rijitliğinin sıfır olduğu kabul edilecektir.



K101

M_d=63.3 kN m A_s=790 mm^2 (2ϕ16 düz=400 mm^2, 2ϕ18 pilye=510 mm^2)

-M_d=105 kN m -A_s=1370 mm^2 var olan 4ϕ18 pilye=1020 mm^2

Ek olarak 2ϕ12 montaj=226 mm^2 1ϕ14 ilave=154 mm^2

1400 mm^2

Diğer mesnette (K105 e saplandığı nokta)

-$M=T_{cr}=f_{ctd}$ 1.35S

$$1.35S=\frac{1.35}{3}(x_1^2\, y_1+x_2^2\, y_2)=0.45(25^2*50+10^2*3*10)=15412 \text{ cm}^3$$

-$M=T_{cr}=1*15412*10^{-3}=15.4$ kN m

-M=15.4 kN m -A_s=200 mm^2 var olan pilye=510 mm^2

$$V_d=93.75-\frac{25*0.25}{2}=90.3 \text{ kN}\quad V_{cr}=75 \text{ kN}\quad V_d>V_{cr}$$

$$\min \frac{A_{sw}}{s} = 0.3 \frac{f_{ctd}}{f_{ywd}} b_w = 0.39$$

$$\frac{A_{sw}}{s} = \frac{V_d - V_c}{f_{ywd}(d)} = \frac{(90.3 - 0.8 * 75) * 10^3}{191 * 465} = 0.34 \quad \text{mm}^2/\text{mm}$$ (ϕ8/23 kullanılır.)

K105

$+M_d = 27\ kNm \quad A_s = 338\ mm^2$

$-M_d = 58\ kNm \quad -A_s = 760\ mm^2$

$T_d = T_{cr} = 15.4\ kNm$

$V_d = 89.25\ kN \quad V_{cr} = 75\ kN \quad V_c = 0.8 \times 75 = 60\ kN$

$$\min \frac{A_o}{s} = 0.15 \frac{f_{ctd}}{f_{ywd}} \left(1 + 1.3 \frac{T_{cr}}{V_d b_w}\right) b_w$$

$$= 0.15 \frac{1}{191} \left(1 + 1.3 \frac{15.4 * 10^3}{89.3 \text{x } 250}\right) 250 \cong 0.4$$

Yalnız kesme için gerekli etriye alanı;

$$\frac{A_{os}}{s} = \frac{A_{sw}}{2s} = \frac{V_d - V_c}{2 f_{ywd}(d)} = \frac{(89.3\text{-}60) * 10^3}{2 * 191 * 465} = 0.17 < 0.4$$

$\min \frac{A_o}{s} = 0.4$ $\phi 8/12.5$ veya $\phi 10/20$ cm

TS 500 e göre $s \le d/2 = 23$ cm

$s \le U_e/8 = 122/8 = 15$ cm, $s < 30$

Bu durumda $\phi 8/12.5$ kullanılacaktır.

$$\min A_{sl} = \frac{T_d U_e}{2 f_{yd} A_e}, = 635 \text{ mm}^2 \qquad T_d = T_{cr}$$

Boyuna Donatı:

Açıklıkta Altta= $A_s + A_{sl}/2 =$ **338 + 318 =656 mm²**

(3ϕ14 düz+2ϕ16 pilye=864)

Üstte=$0 + A_{sl}/2 = 0 + 318 = 318$ mm²

3ϕ12 (montaj dahil)=340 mm²

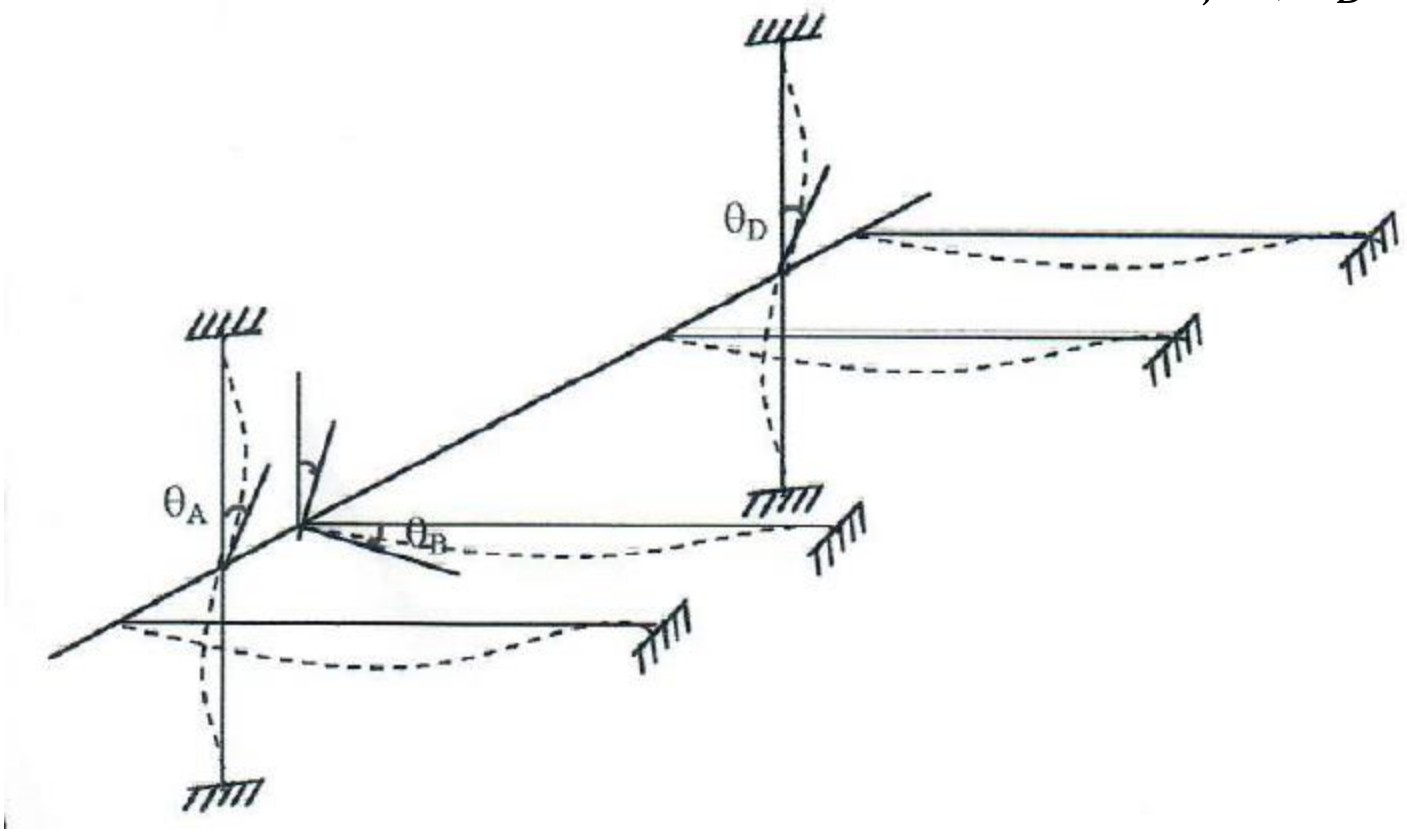
Mesnette Altta=$0 + A_{sl}/2 = 0 + 318 = 318$ mm²

Var olan 3ϕ14=462 mm²

Üstte=$A_s + A_{sl}/2 =$ **760+318=1078mm²**

Var olan 4ϕ16+3ϕ12=1143 mm²

Burulma açıklığı 3h=150 cm den küçük olduğundan dönme açısının kontrol edilmesi gerekir. Kıoı kirişinin her iki ucu da mafsallı kabul edilirse mesnetteki dönme açısı, $\theta_B = \frac{P_d L^3}{24EI}$



$\theta_B = \frac{P_d L^3}{24\,EI}$

Kıoı kirişinin her iki ucu da mafsallı kabul edilirse mesnetteki dönme açısı, $\theta_B = \frac{P_d L^3}{24EI}$

$I_{K101} = 25*(50)^3/12 = 2.6*10^5\ cm^4$ $\quad E = 2850\ kN/cm^2$

$EI = 74.1*10^7\ kN\ cm^2$ olur. $\quad P_d = 0.25\ kN/cm$

$$\theta_B = \frac{0.25*(600)^3}{24*74.1*10^7} = 3.04*10^{-3}\ rad$$

a= 1.0 m burulma açıklığı

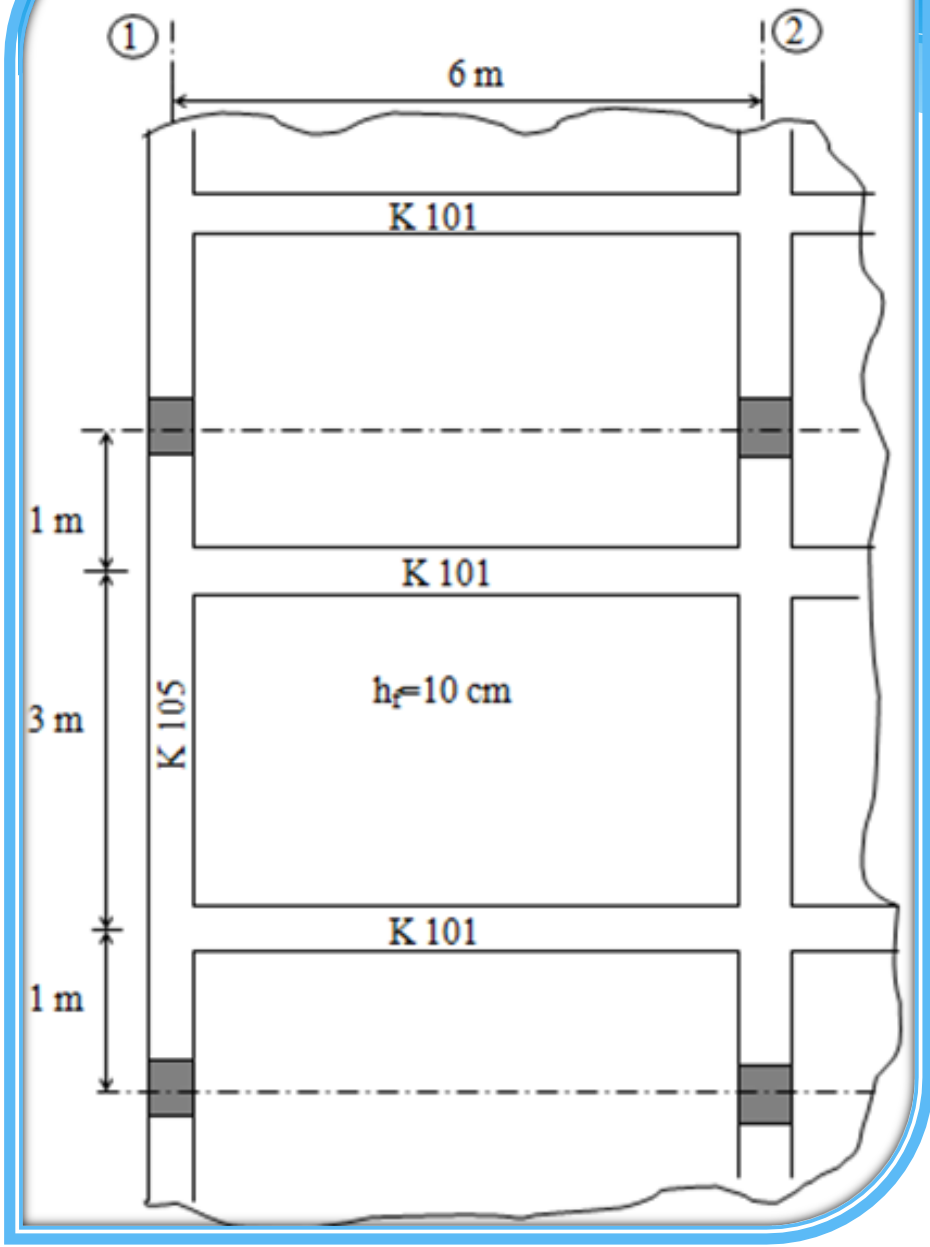
$\phi = \theta_B/1\ m = 3.04*10^{-3}\ rad/m < 10*10^{-3}\ rad/m$

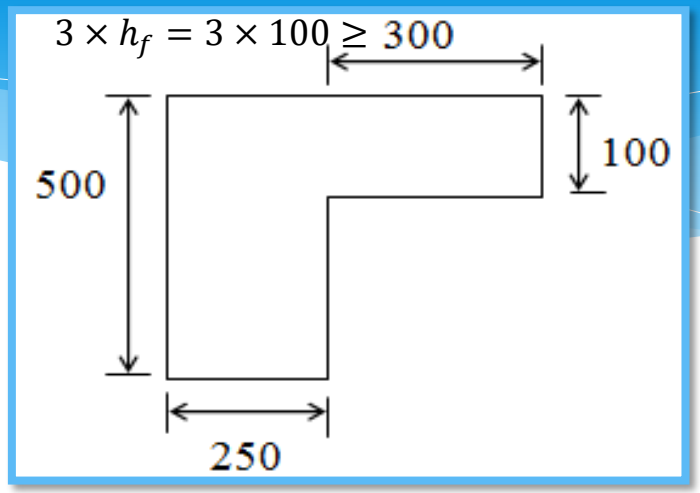
YAPI SİSTEMİNDE BURULMA TÜRLERİ BETONARME ELEMANDA BURULMA TASARIMI

UYGUNLUK BURULMASI

SAP 2000 İLE FARKLI MODELLER ÜZERİNDE ELDE EDİLEN ÇÖZÜM SONUÇLARININ İRDELEMESİ

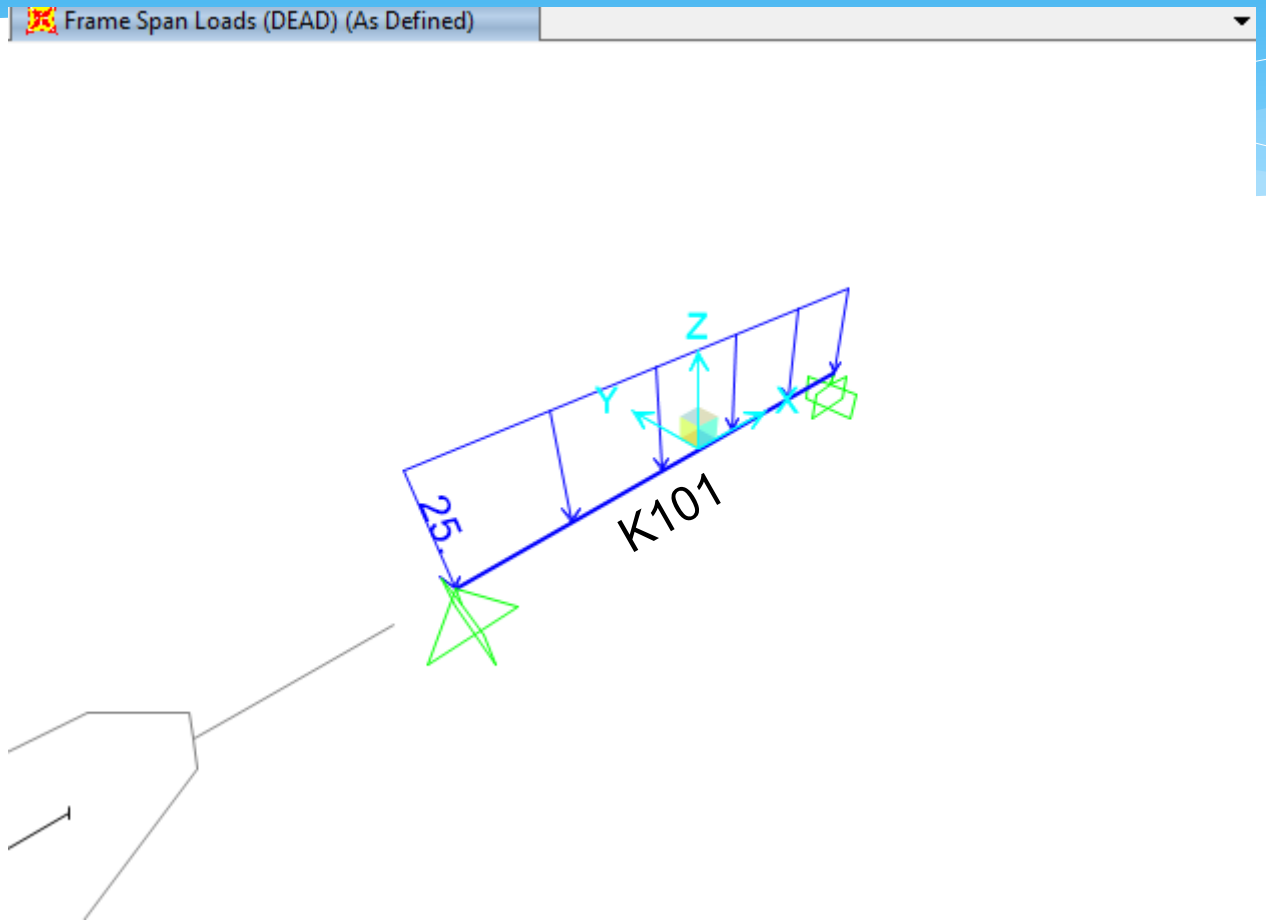
Örnek:

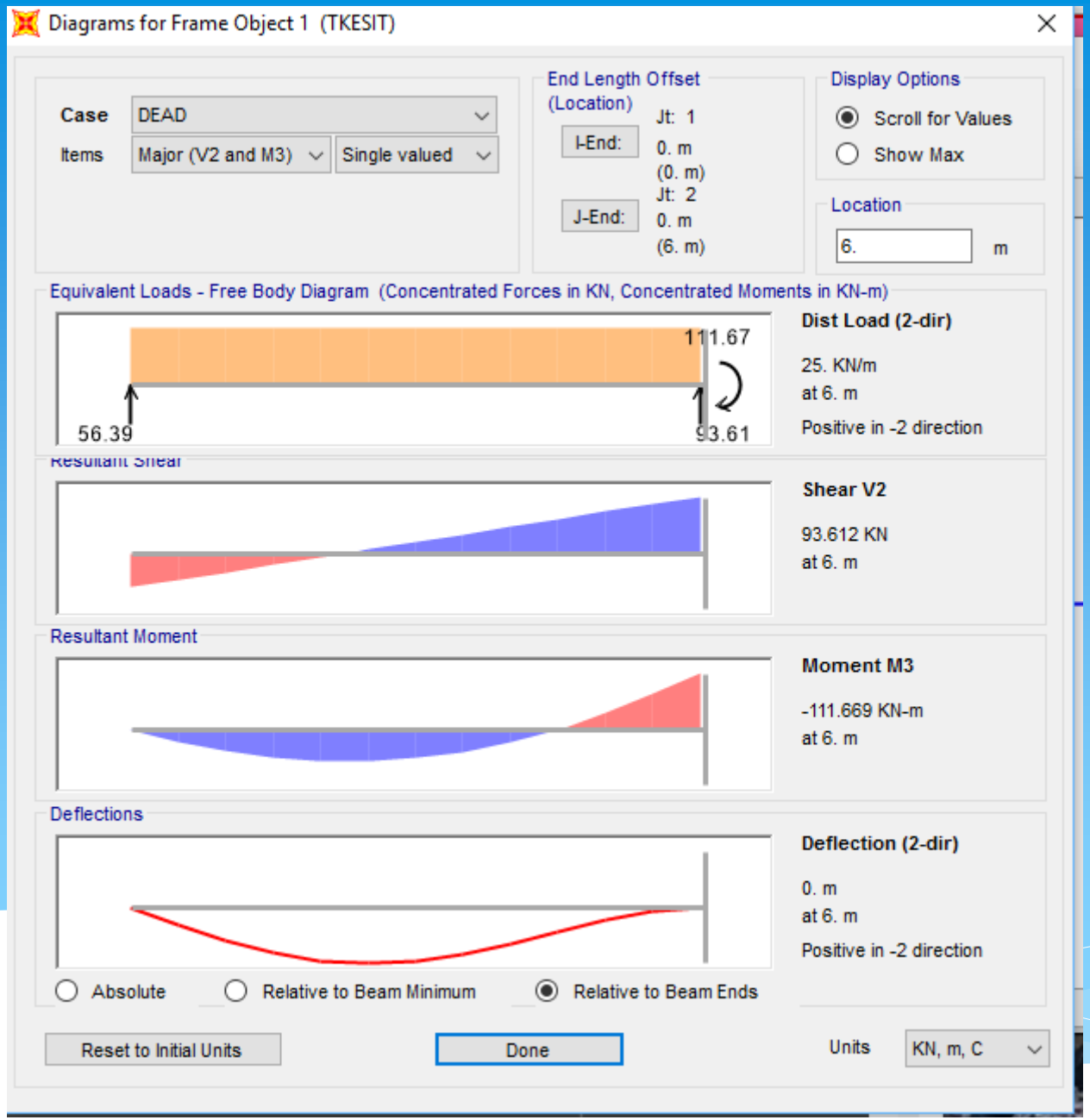


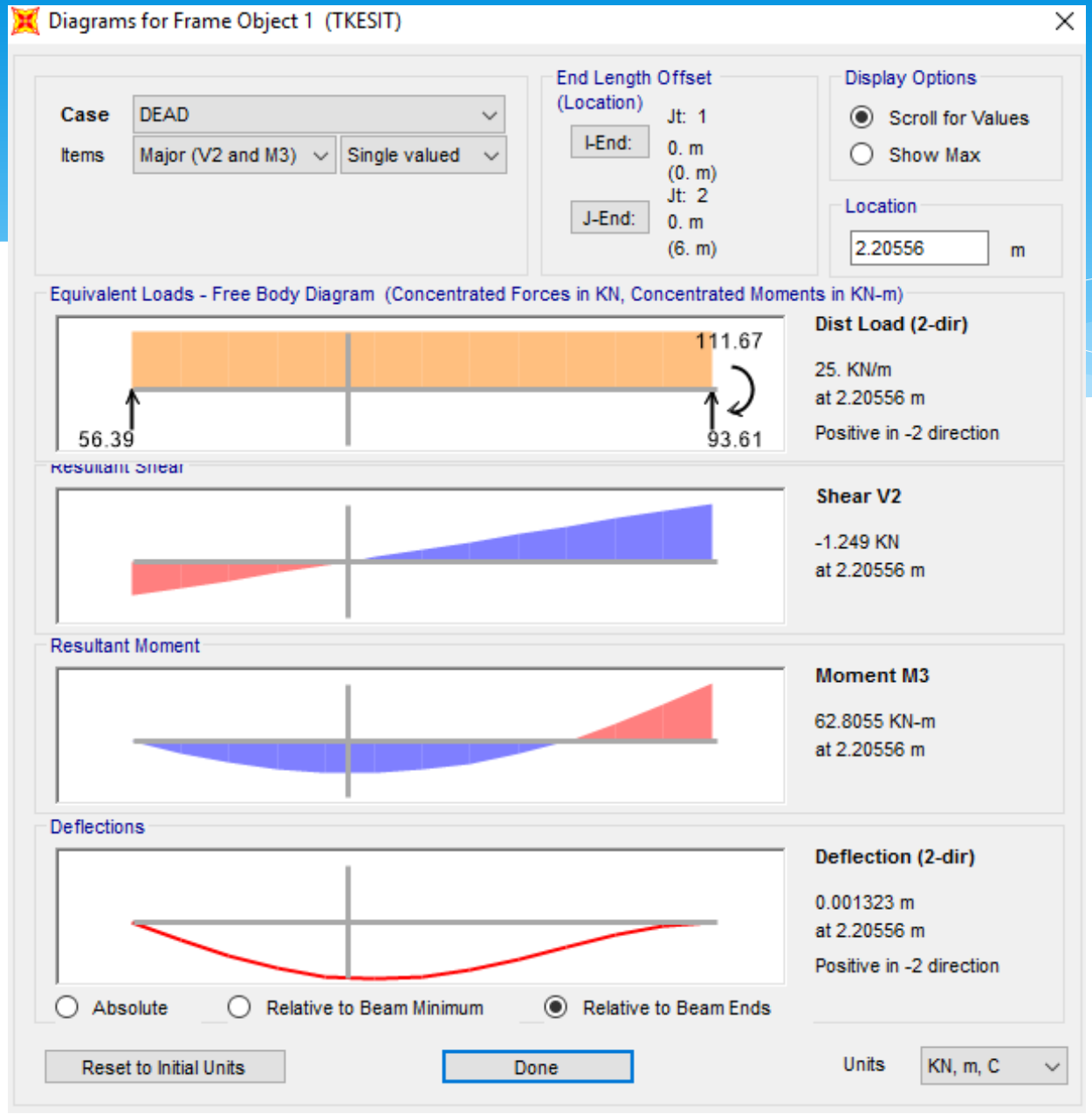


Bu bölümde aynı örnek SAP2000 programı ile farklı modeller kullanılarak analiz edilecek ve elde edilen eğilme, burulma momentleri ve kesme kuvveti değerleri diyagramlar üzerinden irdelenecektir.

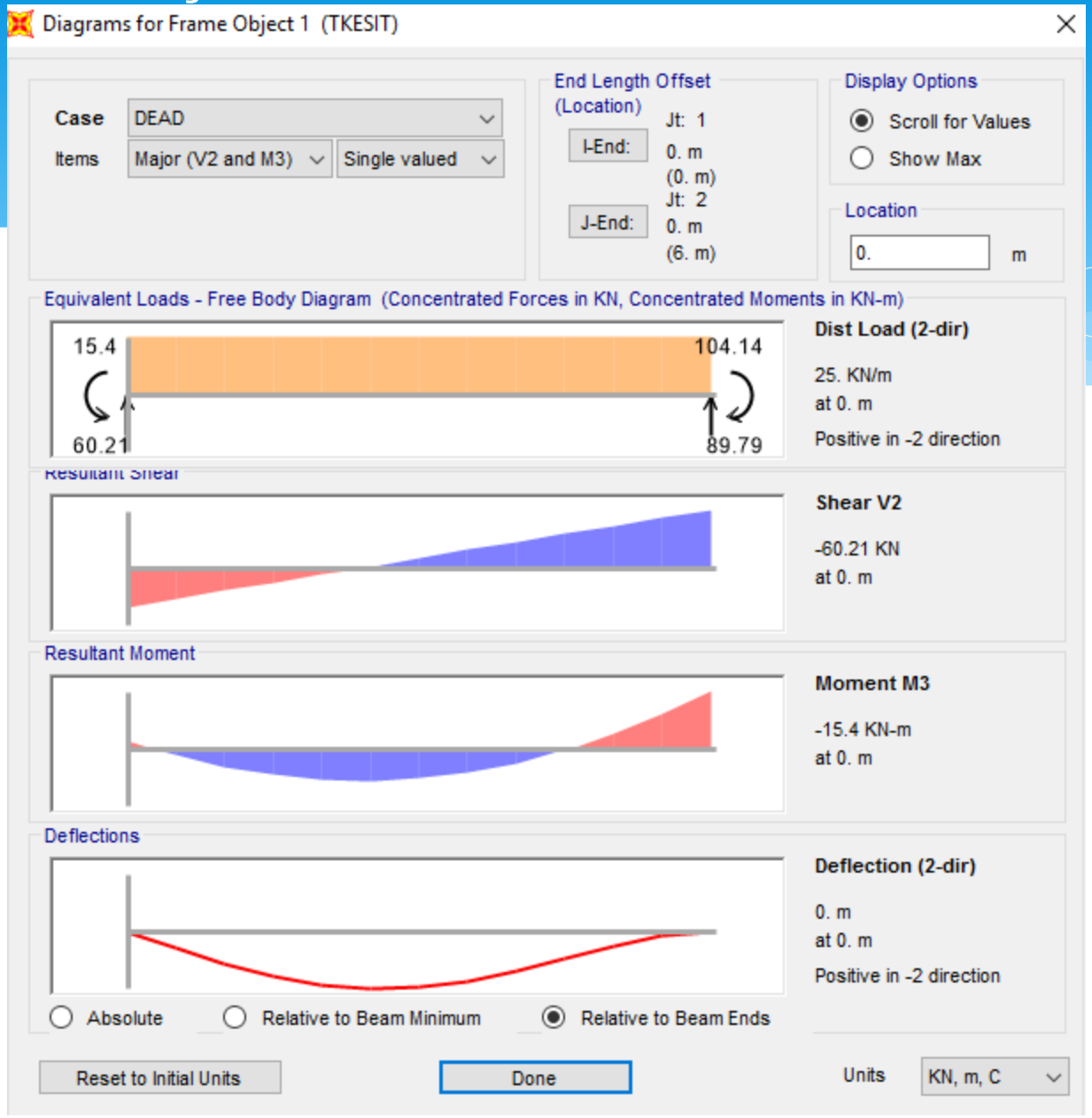
K101 KİRİŞİ TEK AÇIKLIK MODEL



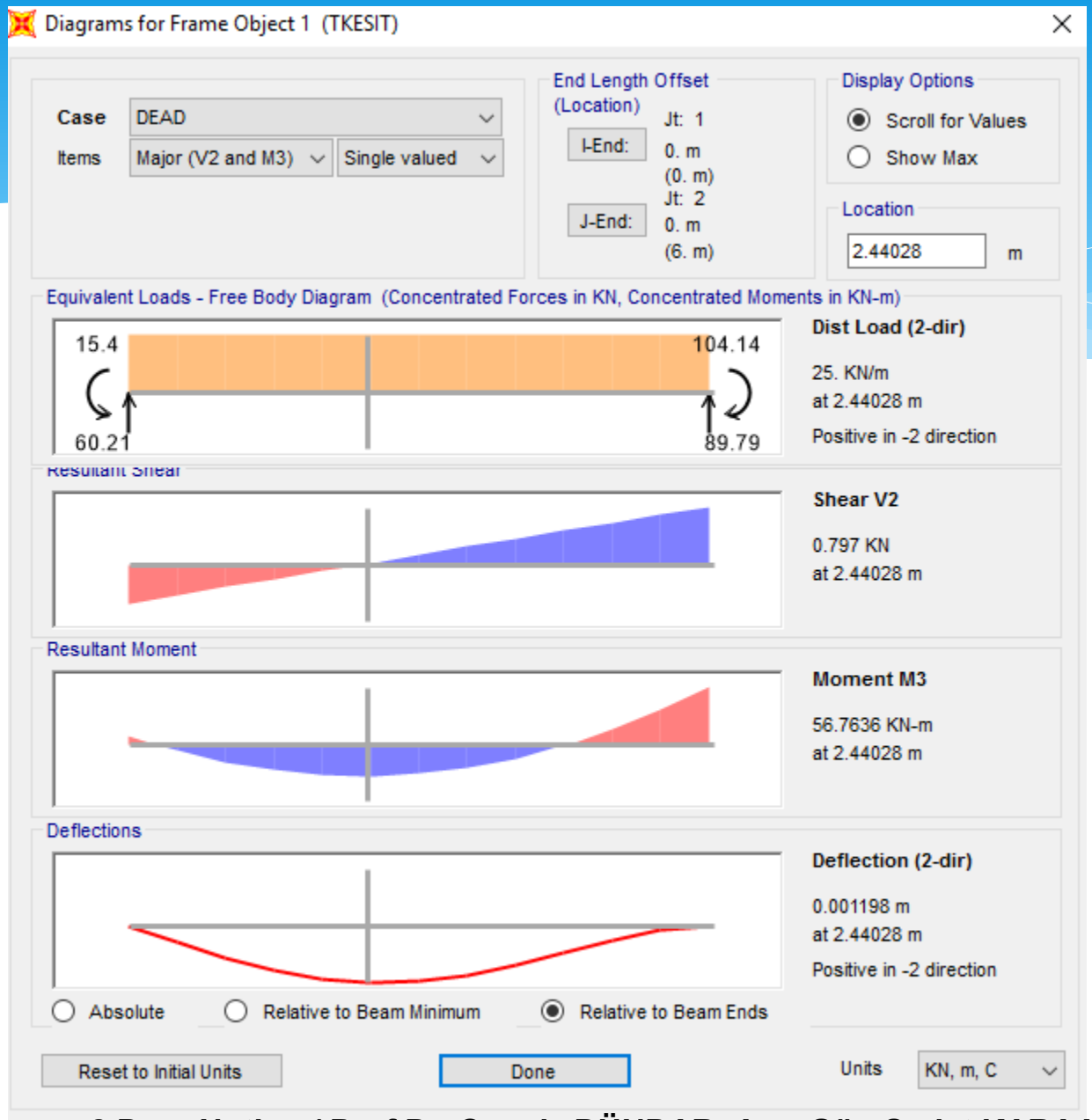

Diagrams for Frame Object 1 (TKESIT)
Case
DEAD
Items
Major (V2 and M3)
Single valued
End Length Offset
(Location)
I-End:
Jt: 1
0. m
(0. m)
J-End:
Jt: 2
0. m
(6. m)
Display Options
Scroll for Values
Show Max
Location
6.
m
Equivalent Loads - Free Body Diagram (Concentrated Forces in KN, Concentrated Moments in KN-m)
111.67
56.39
93.61
Dist Load (2-dir)
25. KN/m
at 6. m
Positive in -2 direction
Shear V2
93.612 KN
at 6. m
Resultant Moment
Moment M3
-111.669 KN-m
at 6. m
Deflections
Deflection (2-dir)
0. m
at 6. m
Positive in -2 direction
Absolute
Relative to Beam Minimum
Relative to Beam Ends
Reset to Initial Units
Done
Units
KN, m, C


Diagrams for Frame Object 1 (TKESIT)
Case
DEAD
Items
Major (V2 and M3)
Single valued
End Length Offset (Location)
I-End:
Jt: 1
0. m
(0. m)
J-End:
Jt: 2
0. m
(6. m)
Display Options
Scroll for Values
Show Max
Location
2.20556
m
Equivalent Loads - Free Body Diagram (Concentrated Forces in KN, Concentrated Moments in KN-m)
111.67
56.39
93.61
Dist Load (2-dir)
25. KN/m
at 2.20556 m
Positive in -2 direction
Shear V2
-1.249 KN
at 2.20556 m
Resultant Moment
Moment M3
62.8055 KN-m
at 2.20556 m
Deflections
Deflection (2-dir)
0.001323 m
at 2.20556 m
Positive in -2 direction
Absolute
Relative to Beam Minimum
Relative to Beam Ends
Reset to Initial Units
Done
Units
KN, m, C

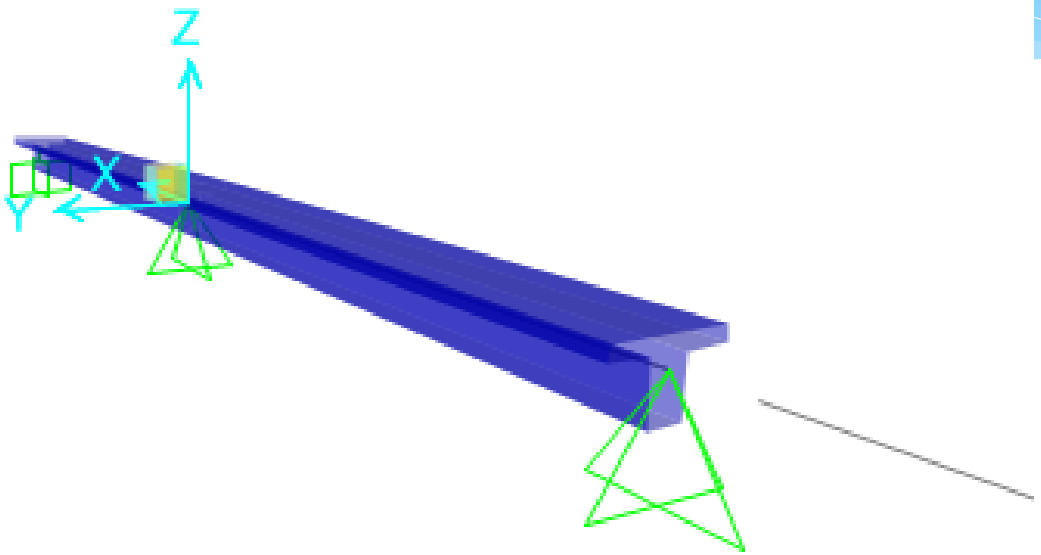
SOL UÇTA K105 ÇATLAMA BURULMA MOMENTİ UYGULANIYOR



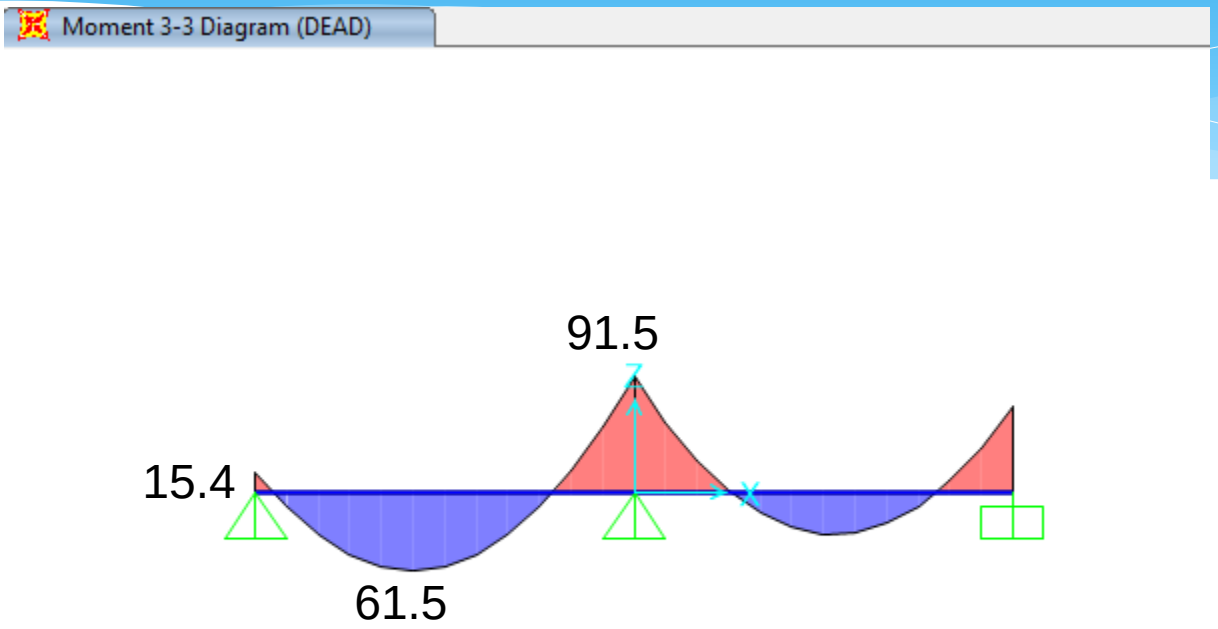
SOL UÇTA K105 ÇATLAMA BURULMA MOMENTİ UYGULANIYOR



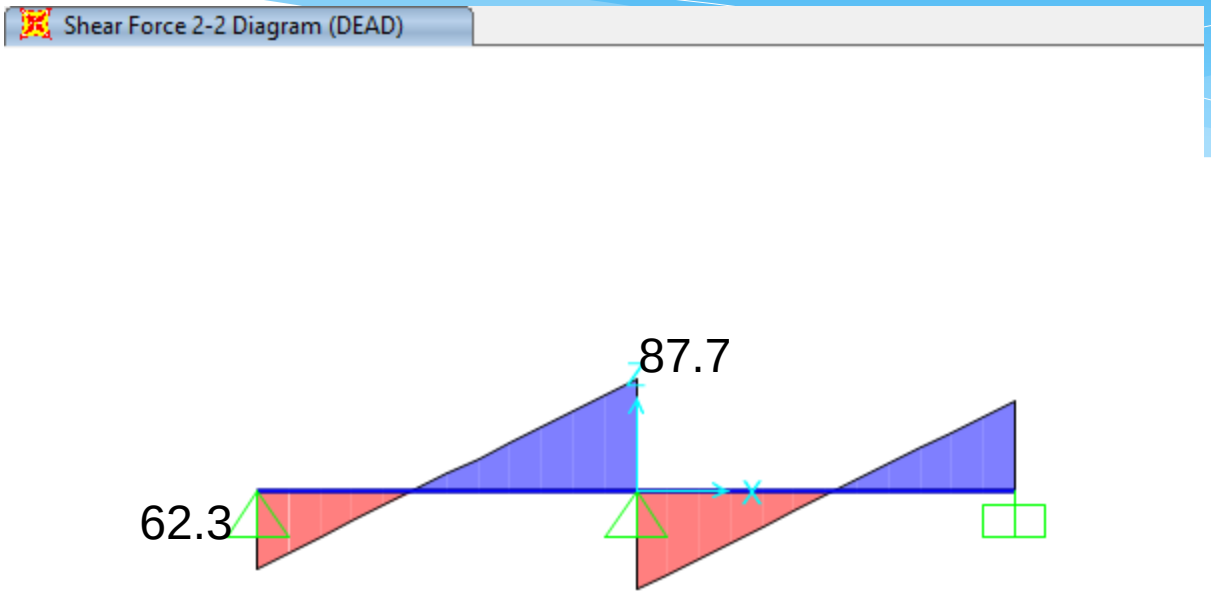
K101 KİRİŞİ 2 AÇIKLIKLI MODEL
T KESİT (K105 e bağlandığı uçta T_{cr}=15.4 kNm



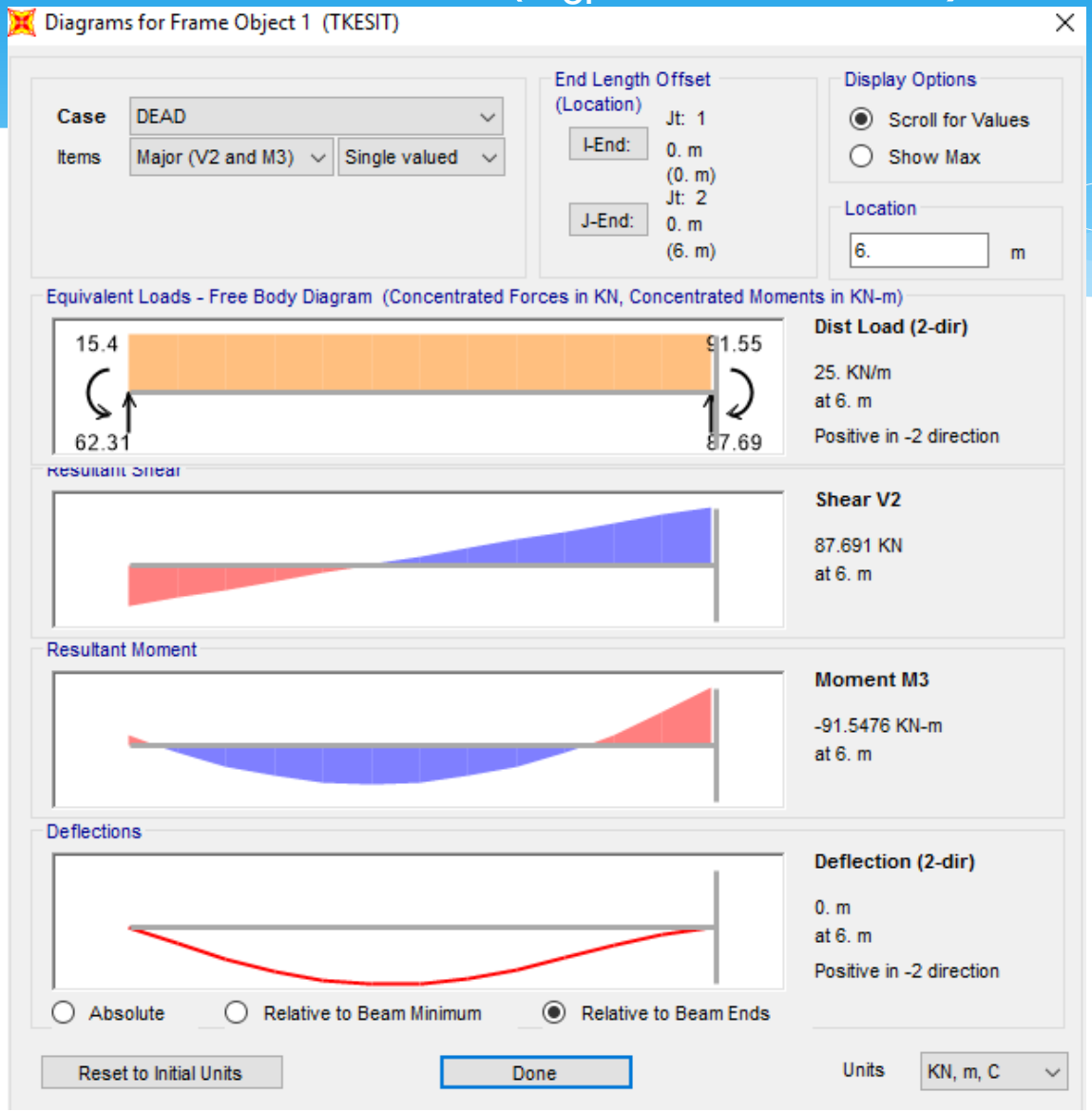
MOMENT DİYAGRAMI (K101)



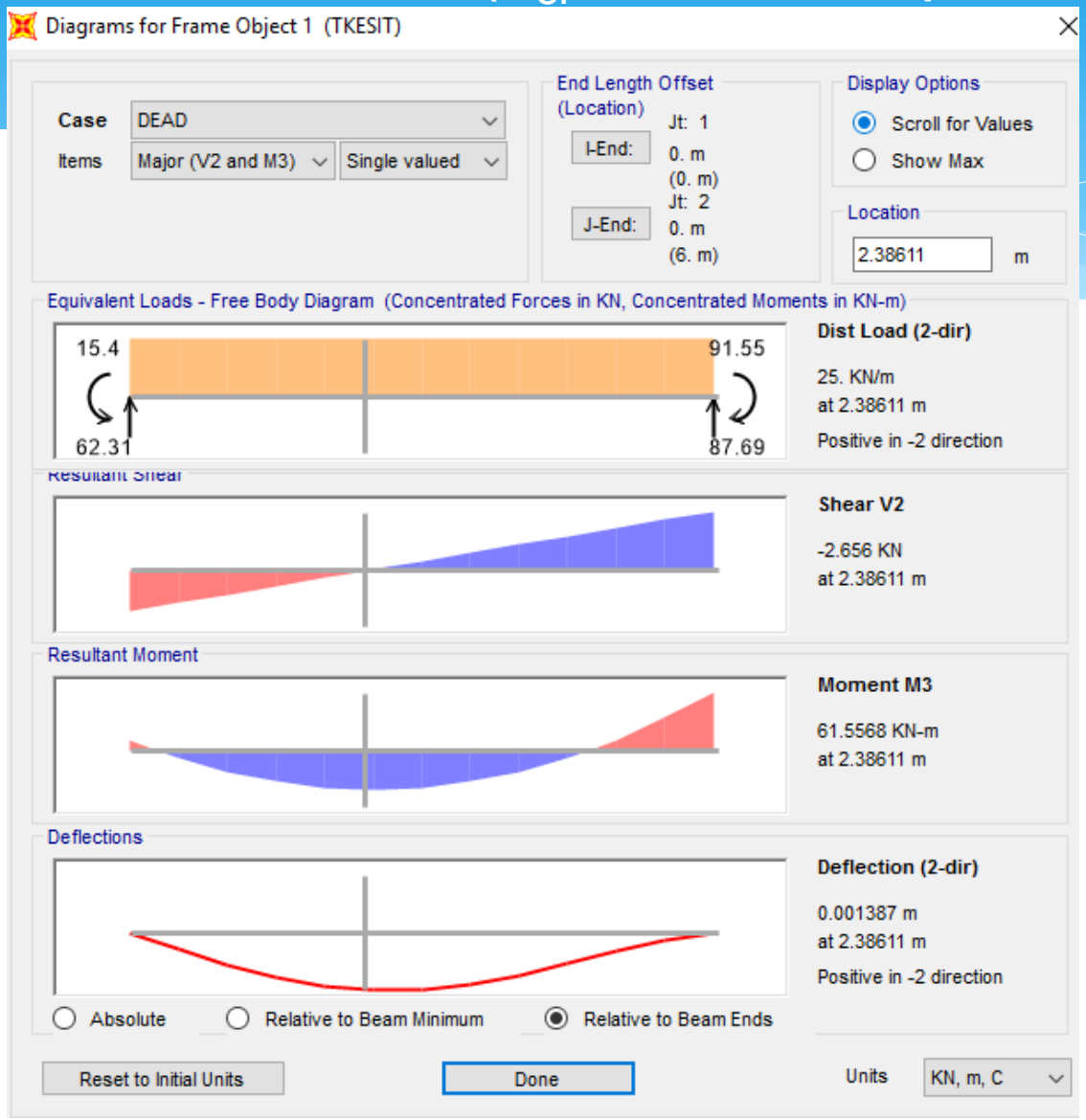
KESME KUVVETİ DİYAGRAMI (K101)



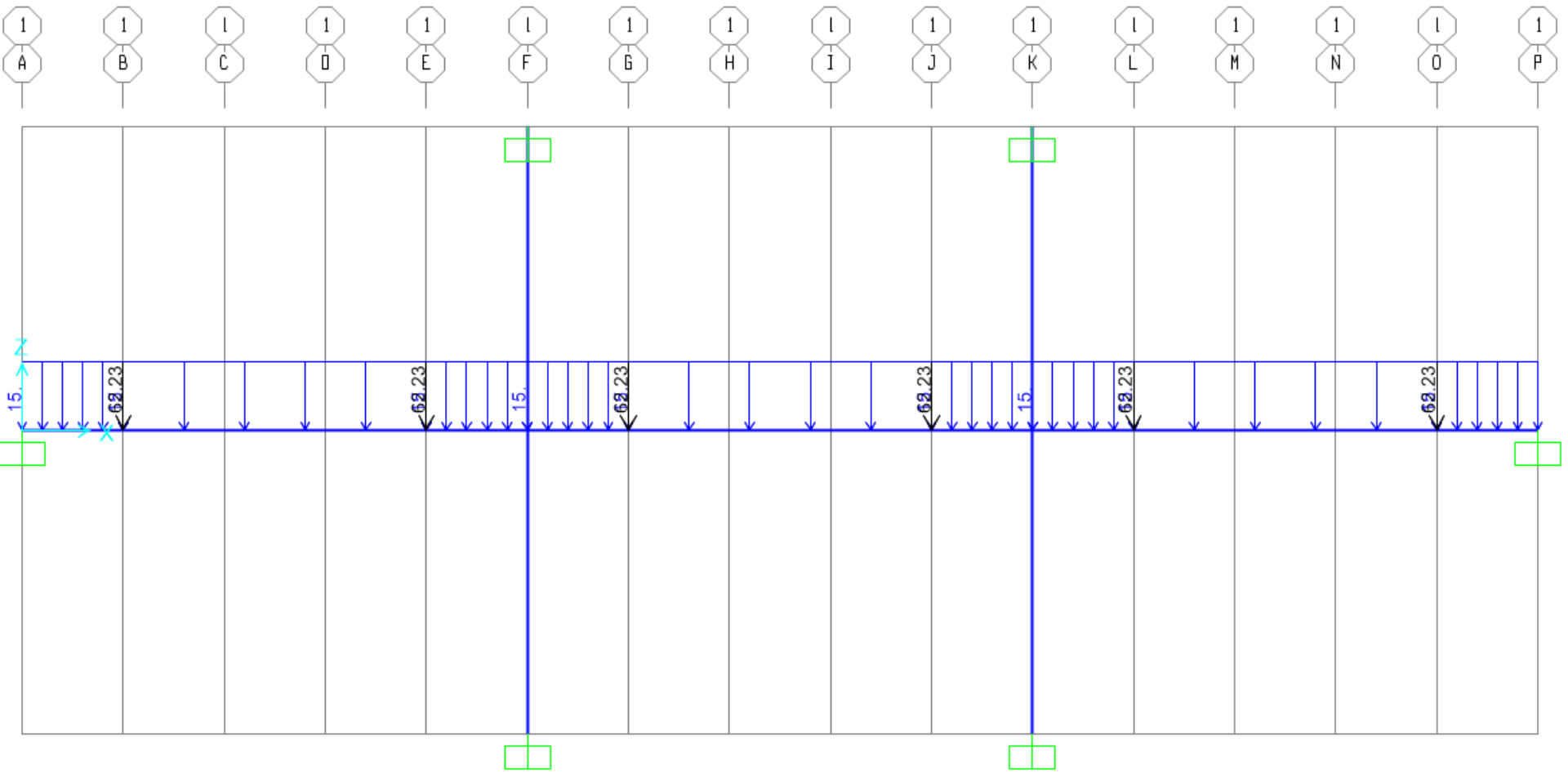
SOL UÇ K105 KİRİŞİ BURULMA ÇATLAMA MOMENTİ(T_{cr}=15.4 kNm)



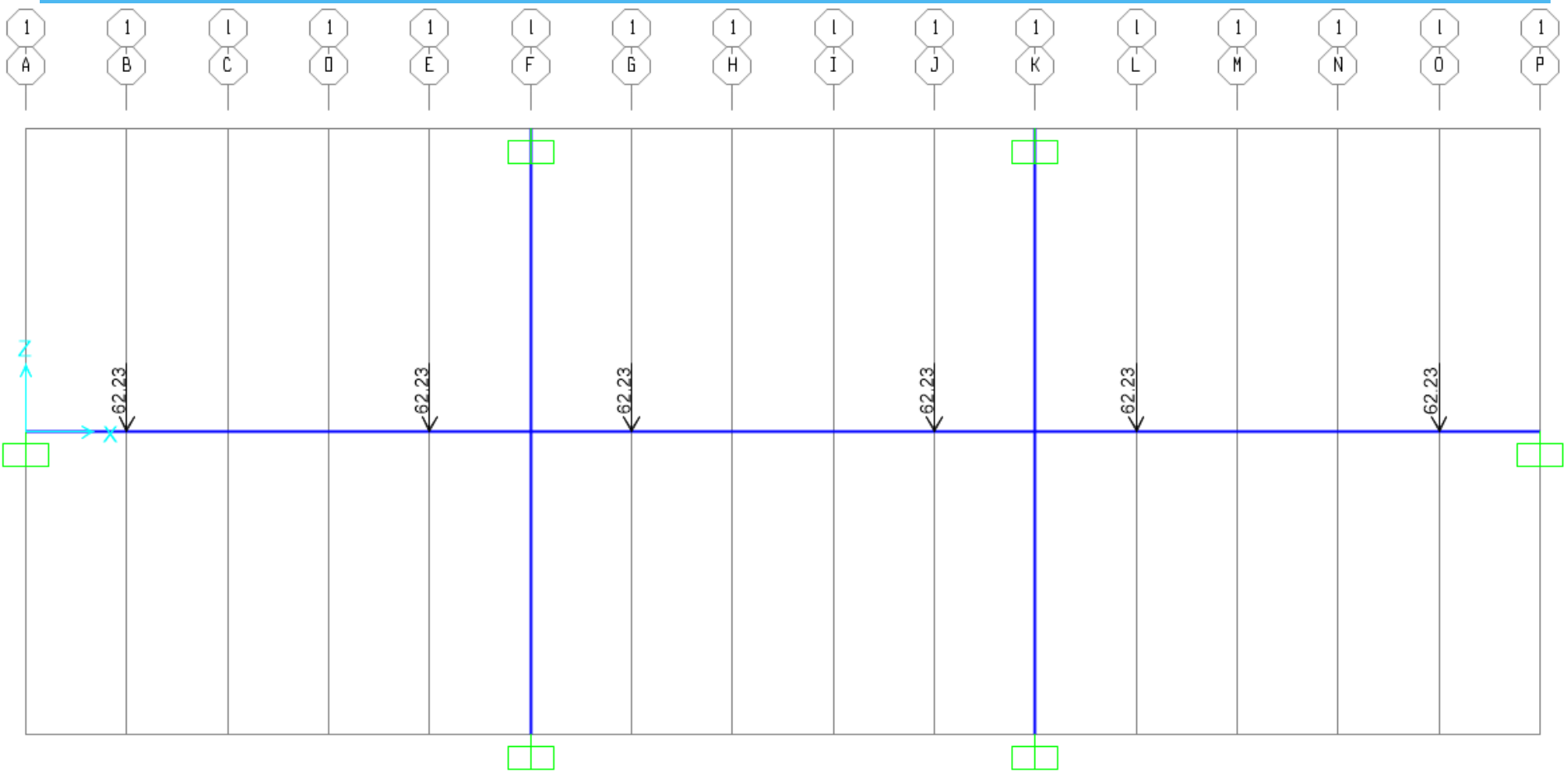
SOL UÇ K105 KİRİŞİ BURULMA ÇATLAMA MOMENTİ(T_{cr}=15.4 kNm)



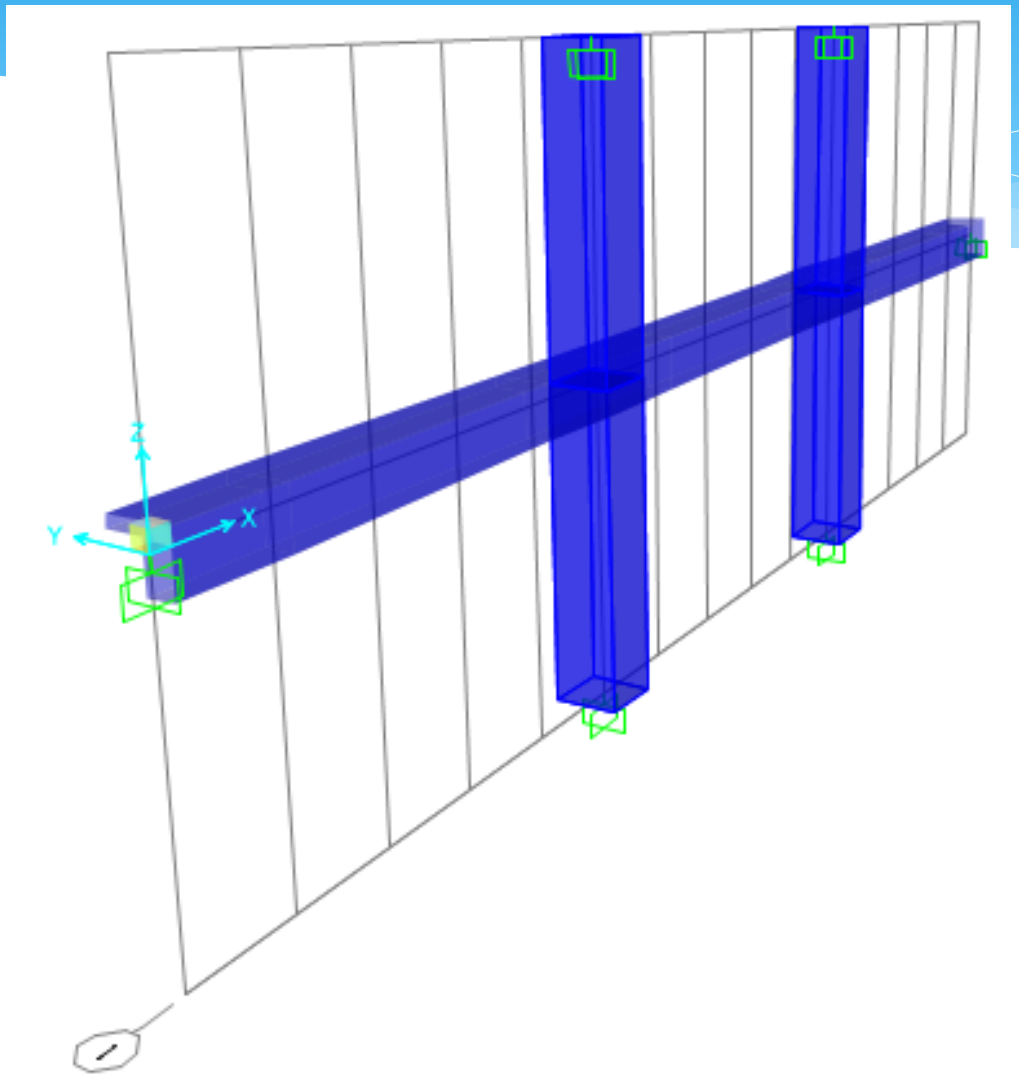
K105 KİRİŞİ KAT ÇERÇEVESİ MODELİ
K105 YÜKLEME DURUMU
(K101 REAKSİYON KUVVETLERİ VE 15 kN/m)



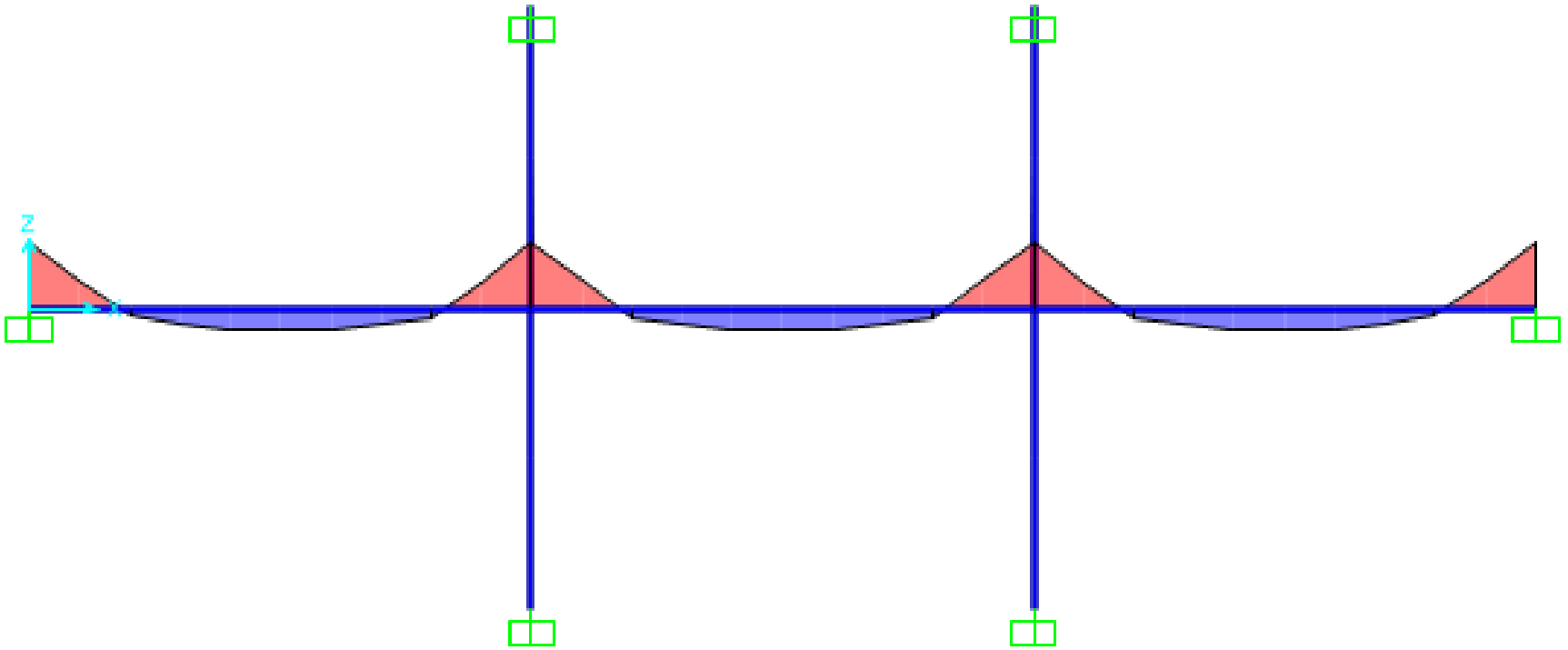
K105 KİRİŞİ KAT ÇERÇEVESİ MODELİ
K105 YÜKLEME DURUMU
(K101 REAKSİYON KUVVETLERİ VE 15 kN/m)



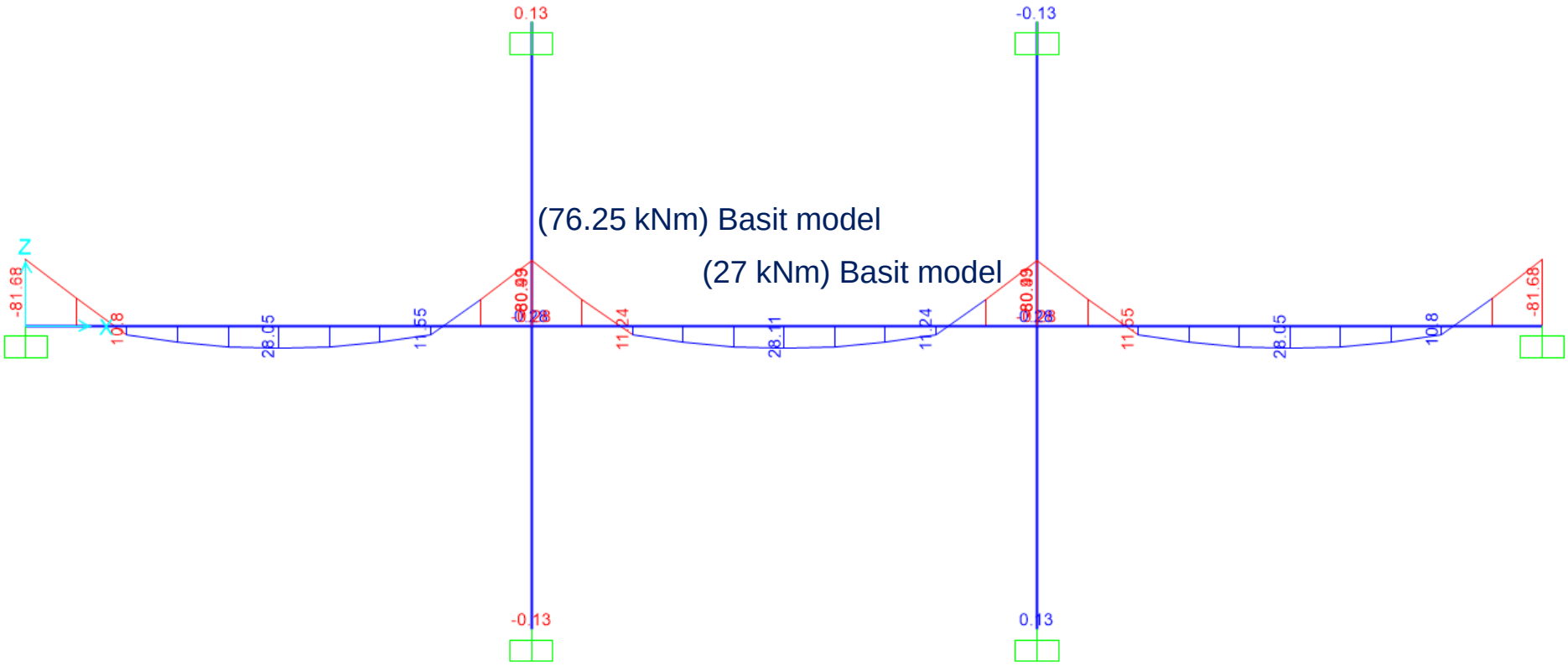
3 BOYUTLU K105 KESİT GÖRÜNÜŞÜ



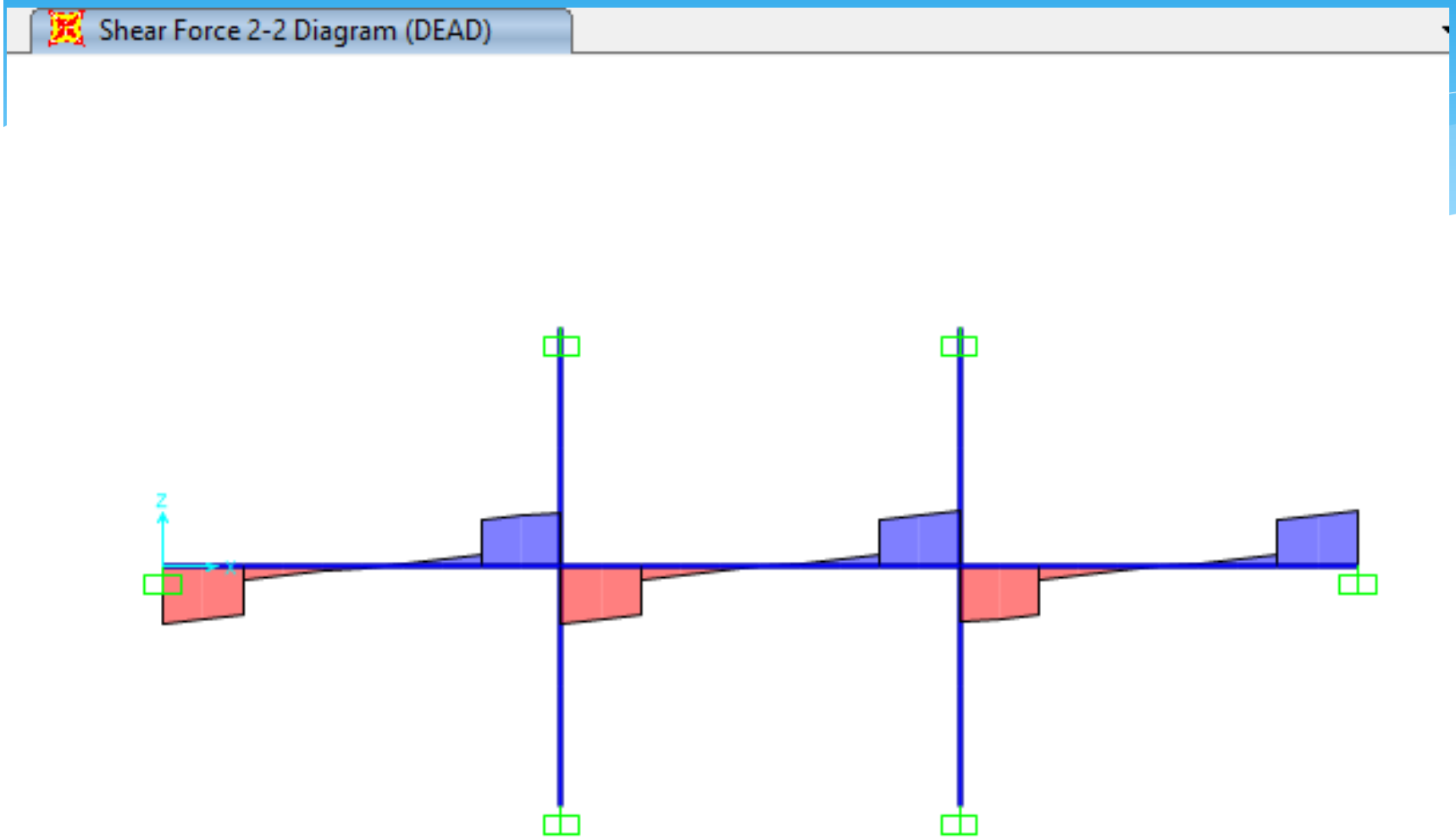
K105 MOMENT DİYAGRAMI



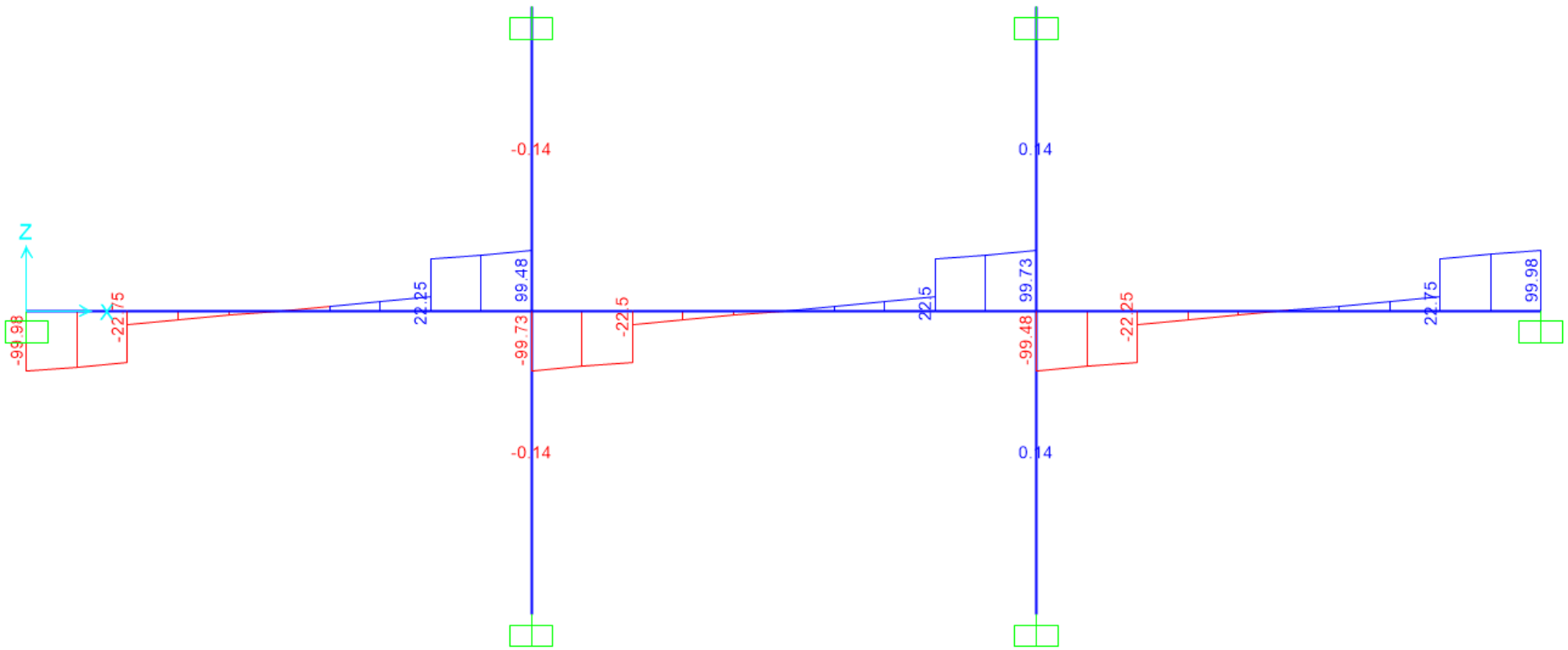
K105 MOMENT DİYAGRAMI



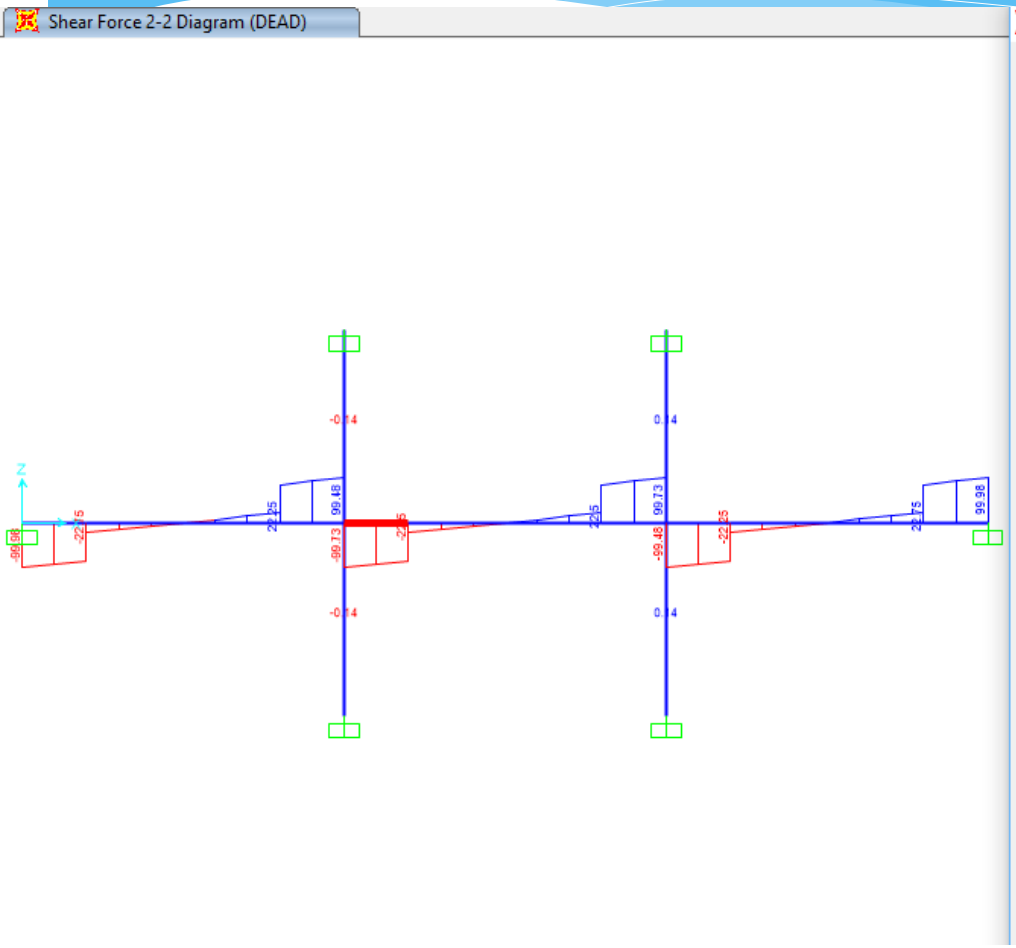
KESME KUVVETİ DİYAGRAMI

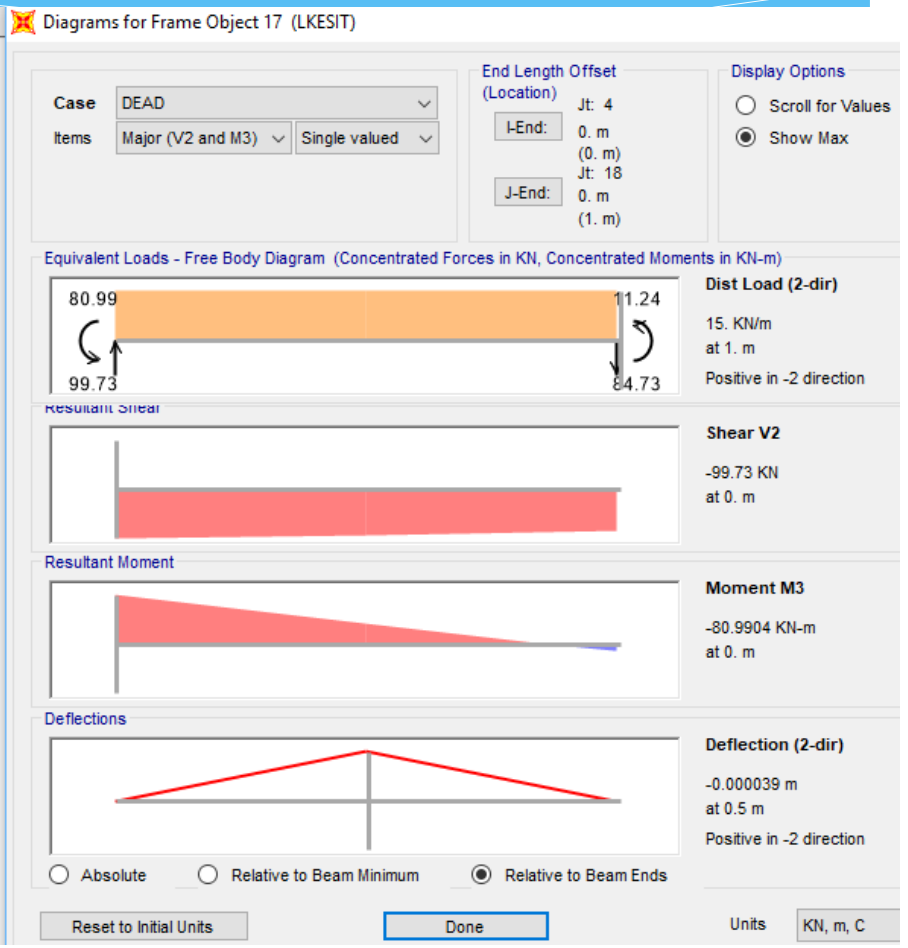


KESME KUVVETİ DİYAGRAMI

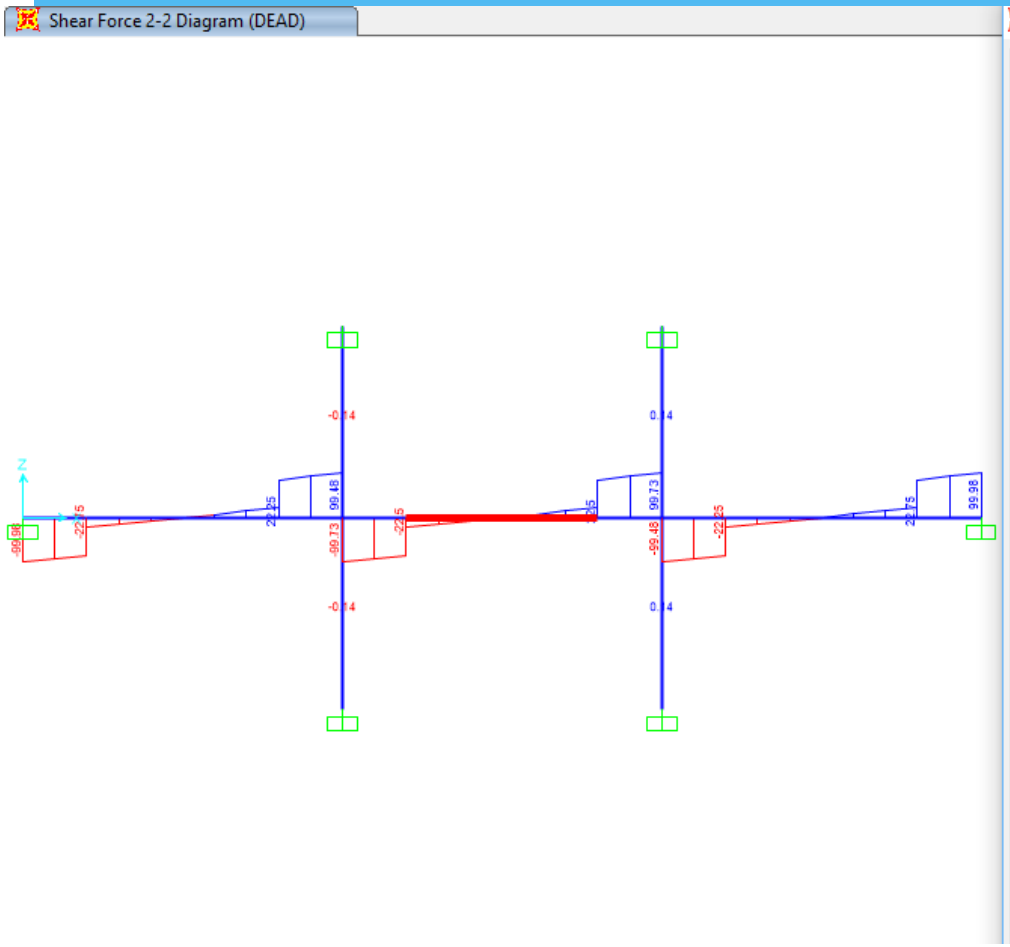


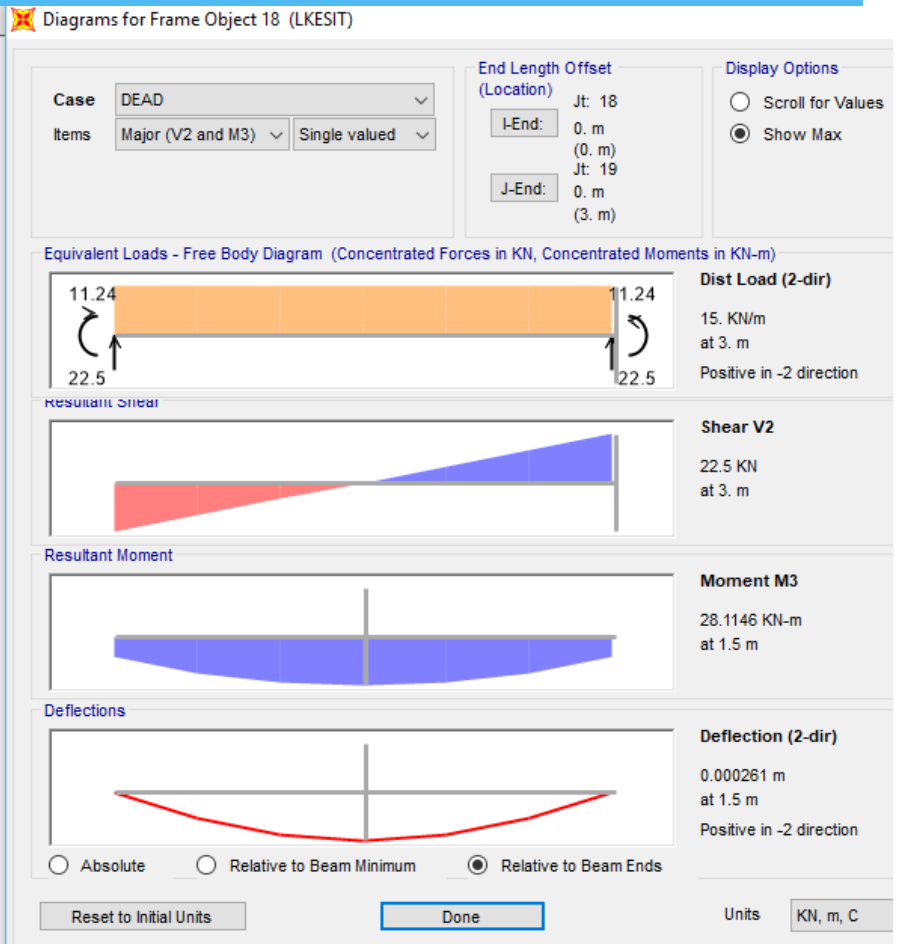
K105 MESNET İLE K101 ARASI



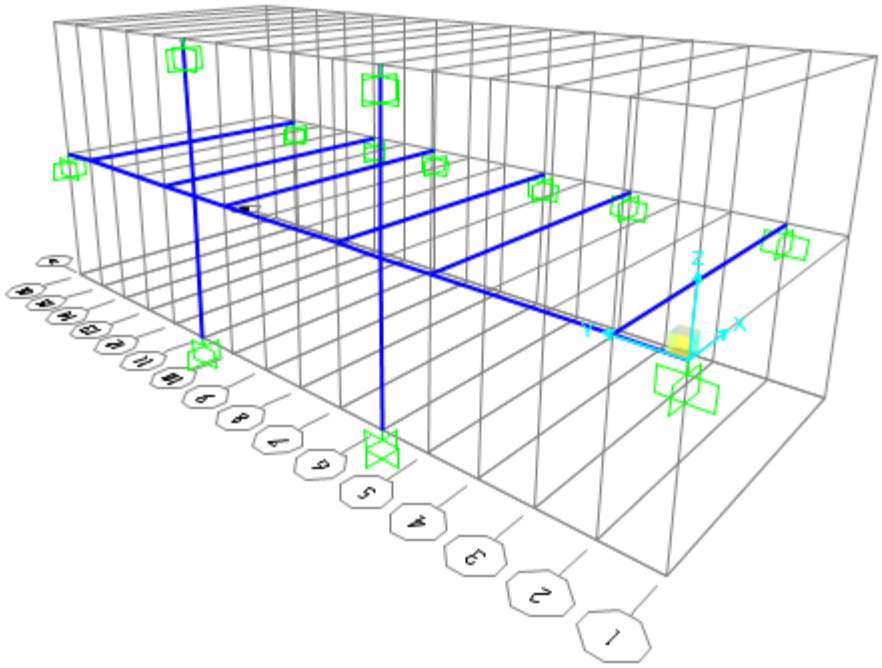


K101 İLE K101 ARASI

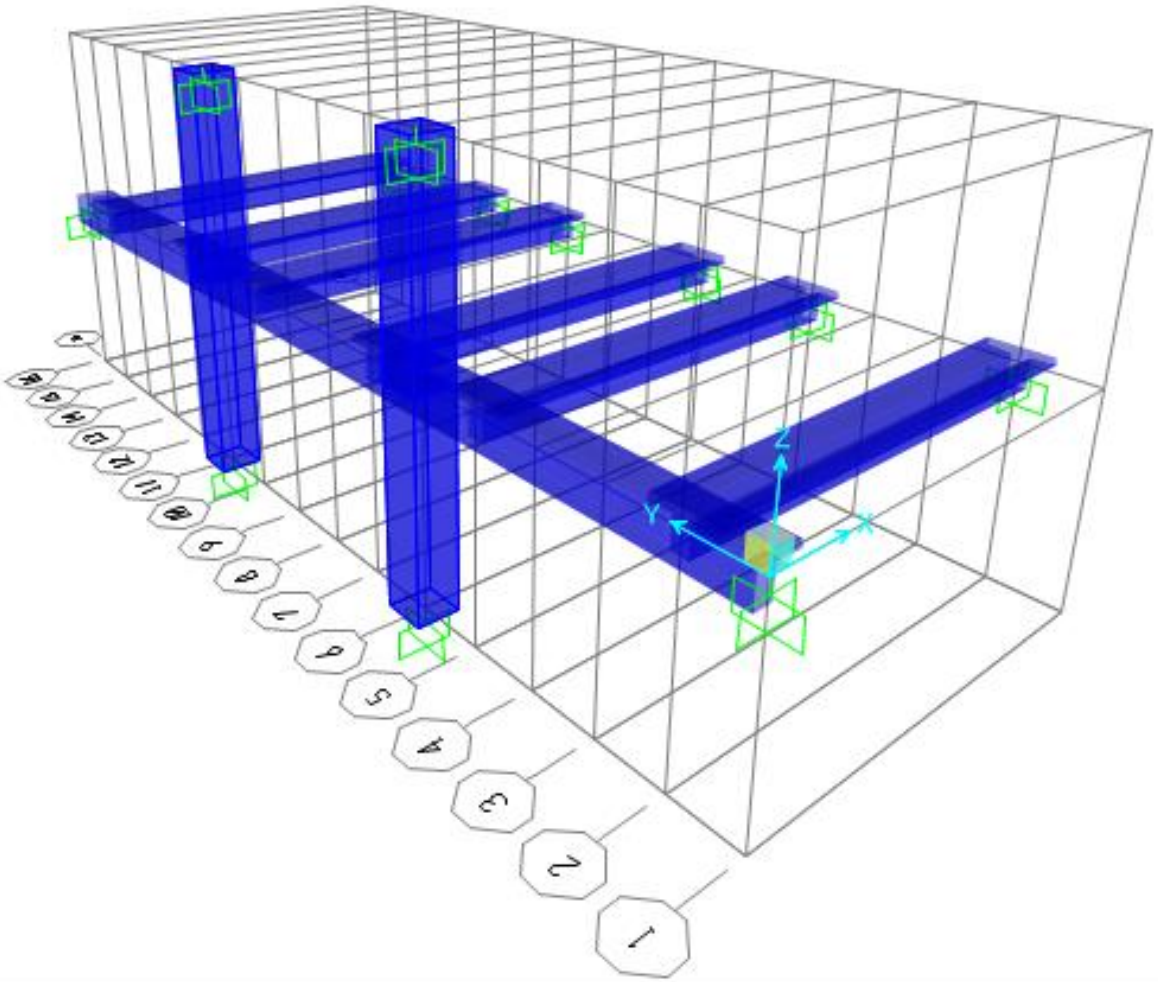




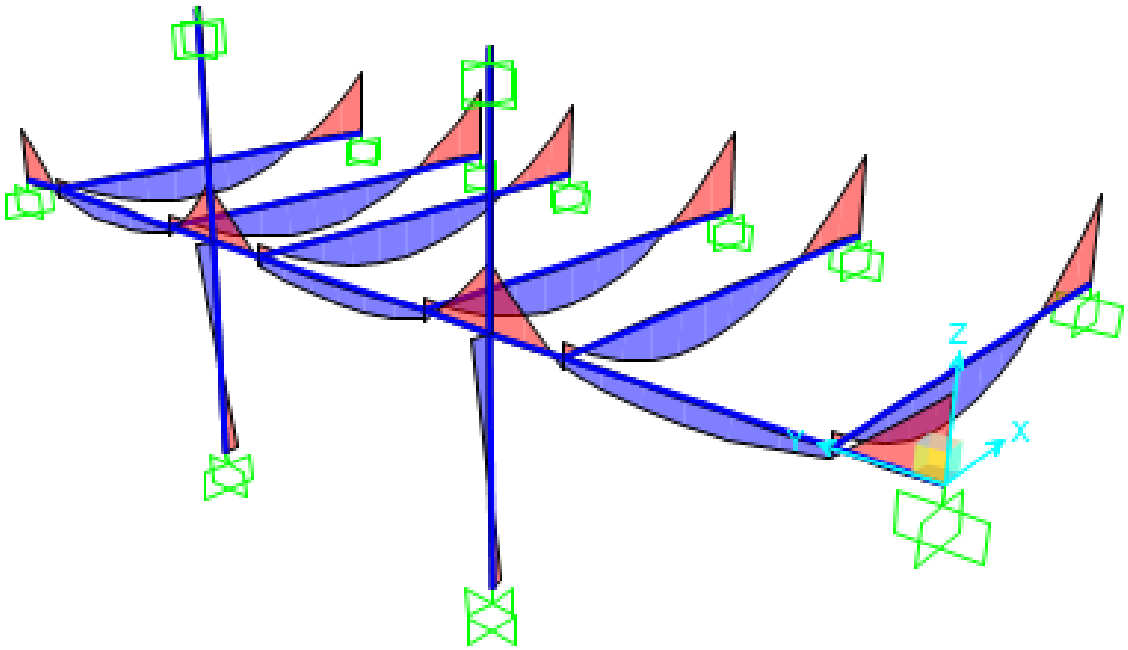
K105 VE K101 3 BOYUTLU KAT ÇERÇEVE MODELİ



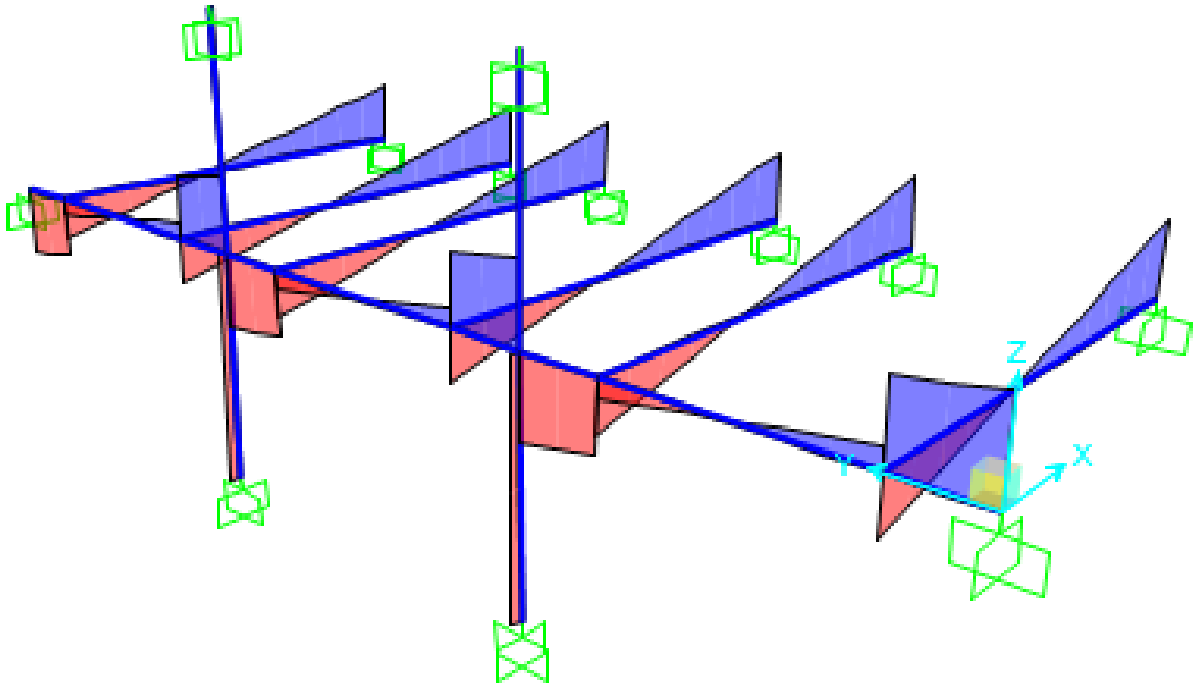
3 BOYUTLU ÇERÇEVE VE KESİTLER



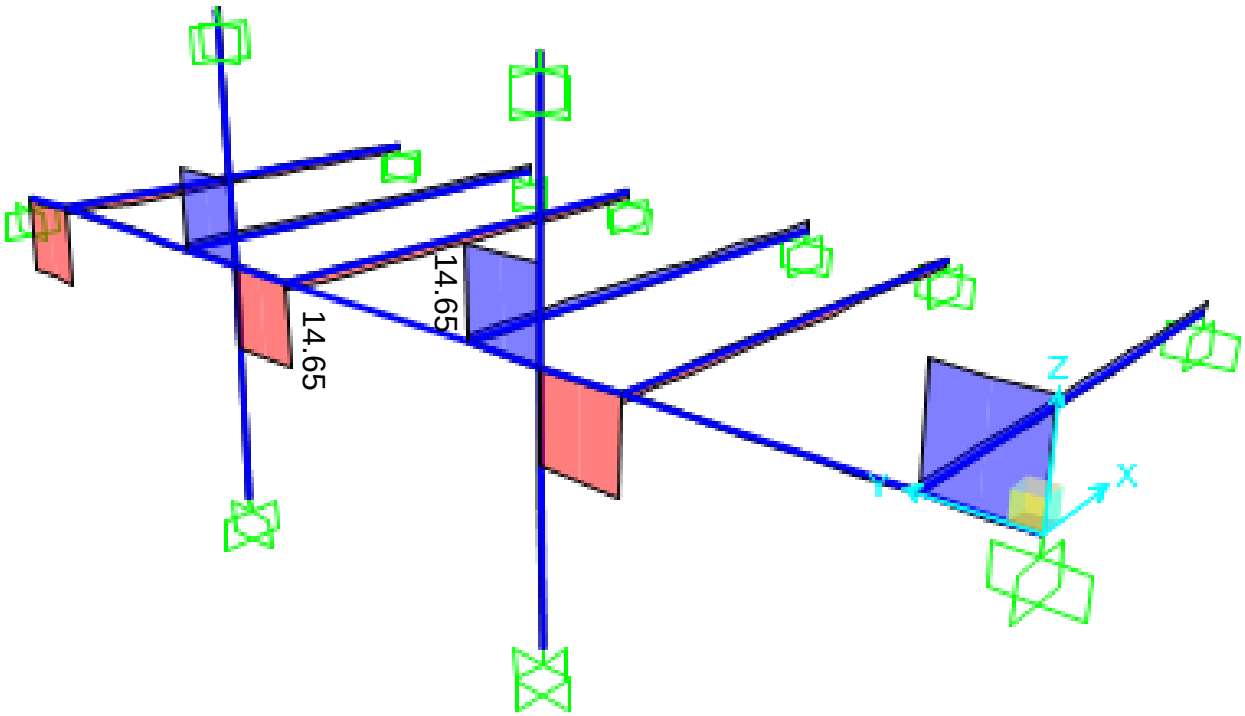
EĞİLME MOMENTİ



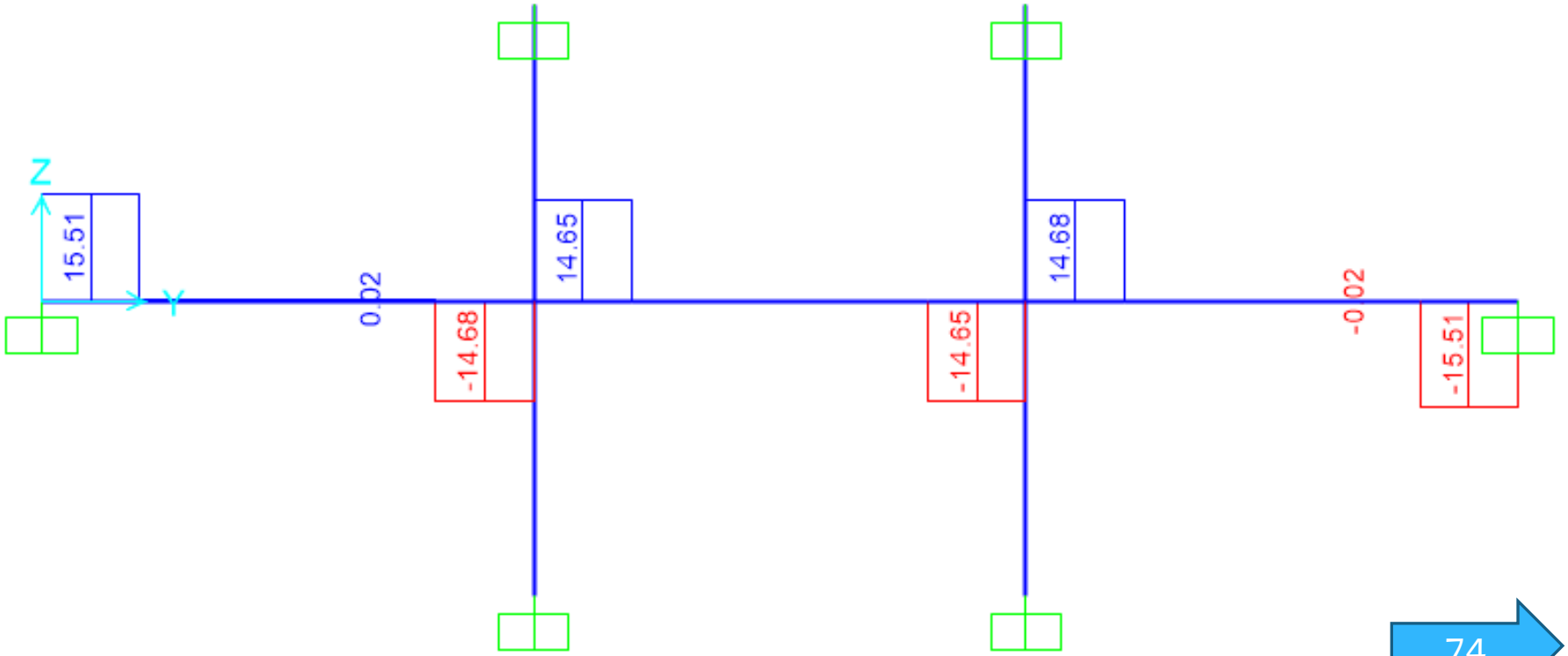
KESME KUVVETİ



BURULMA MOMENTİ (K105 ve K101)



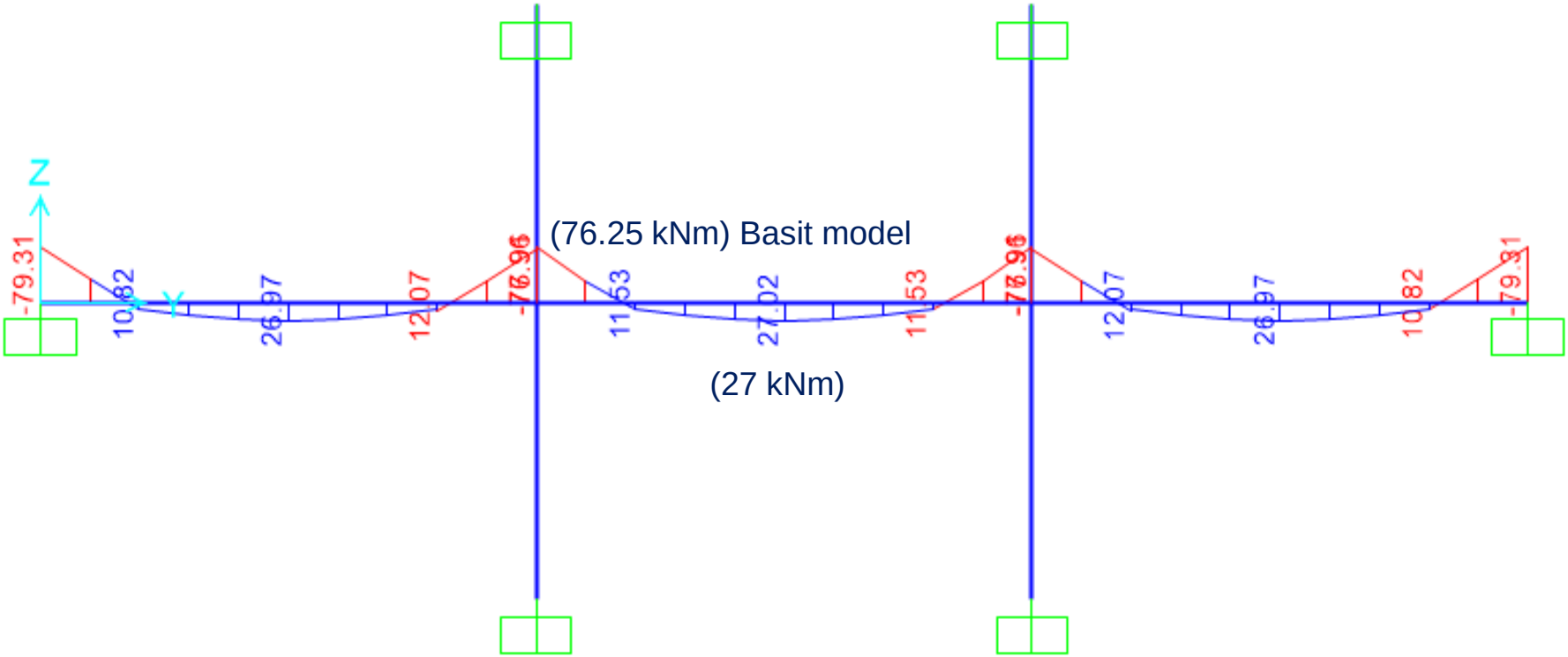
BURULMA MOMENTİ(K105)



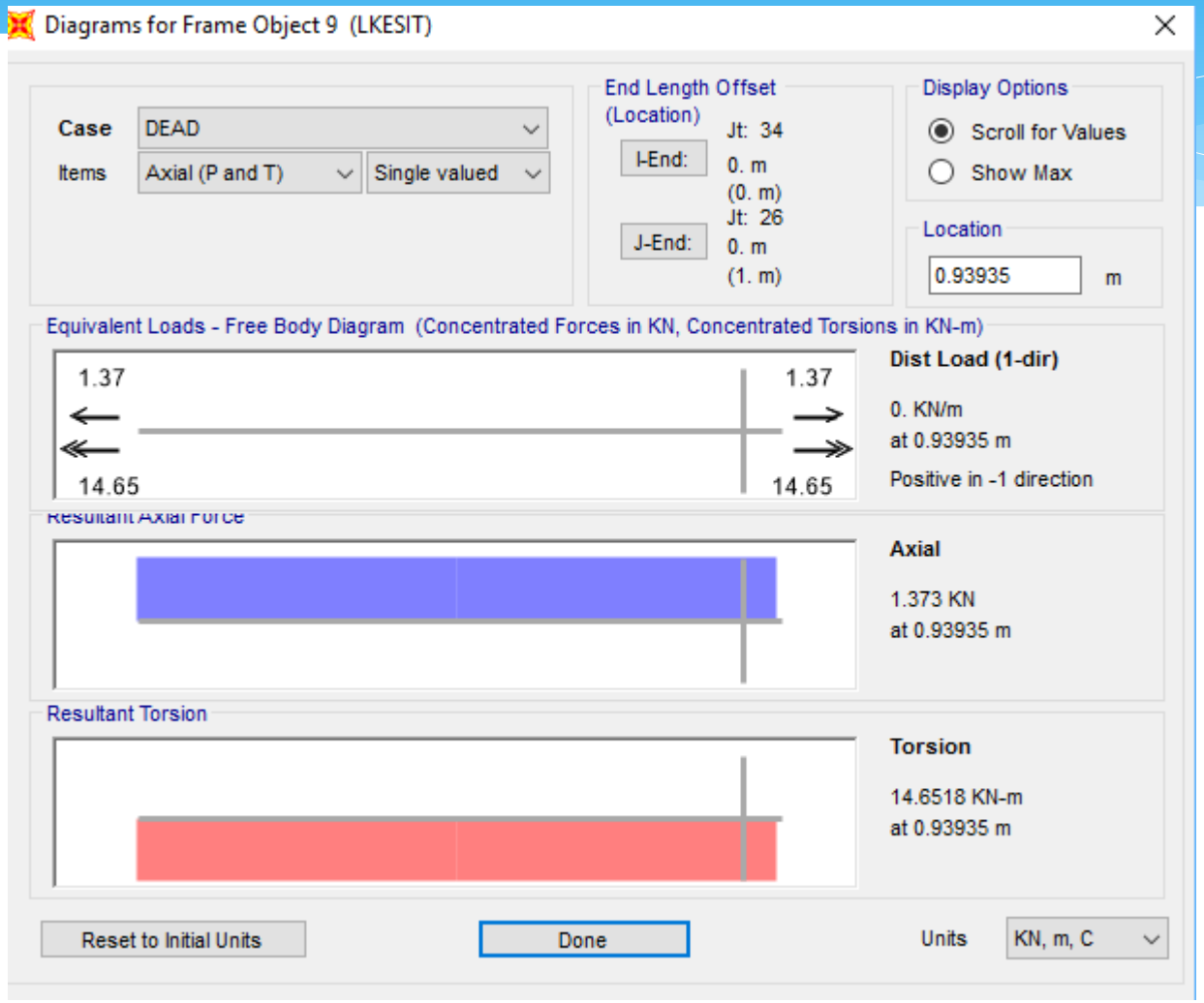
74

81

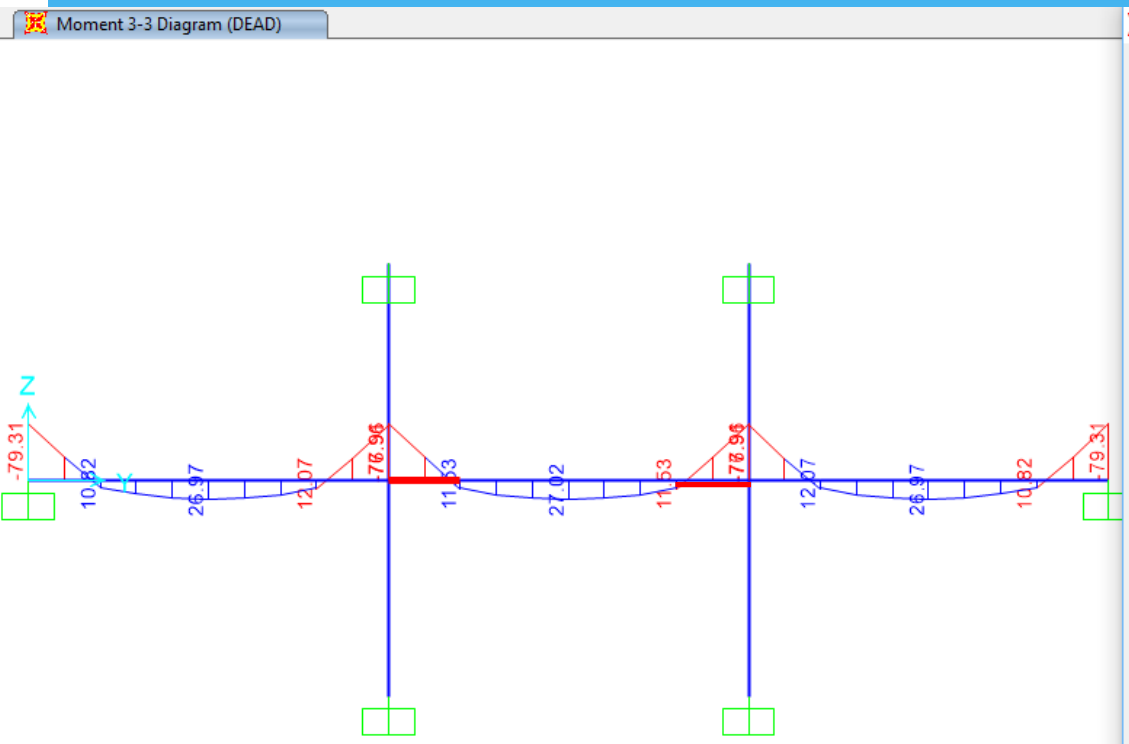
EĞİLME MOMENTİ

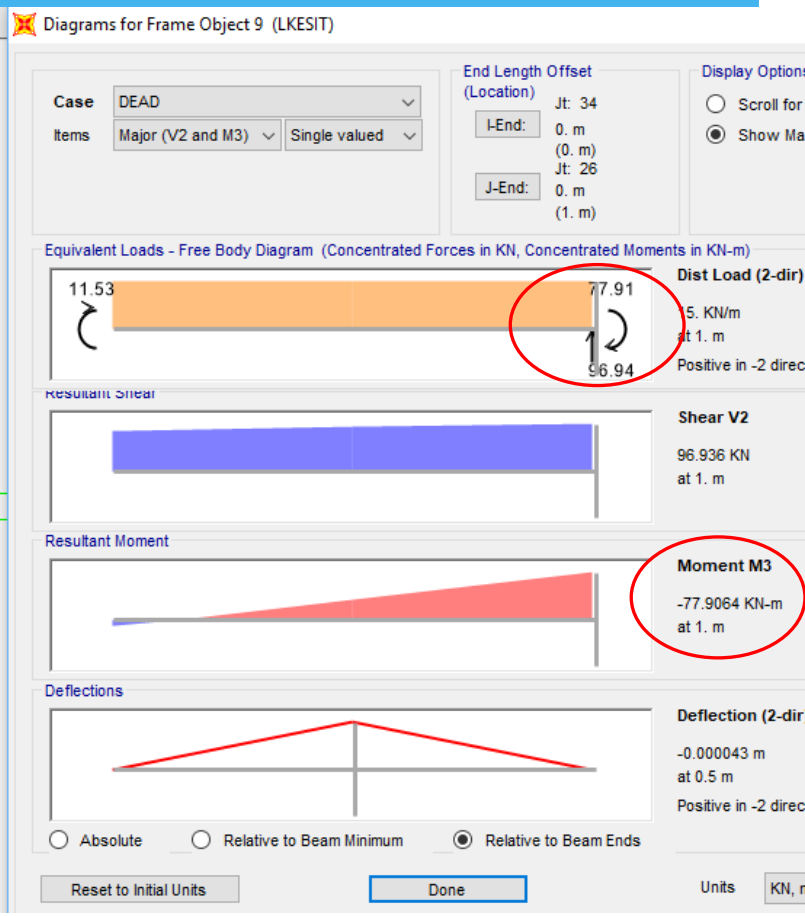


K105 MESNET İLE K101 ARASI

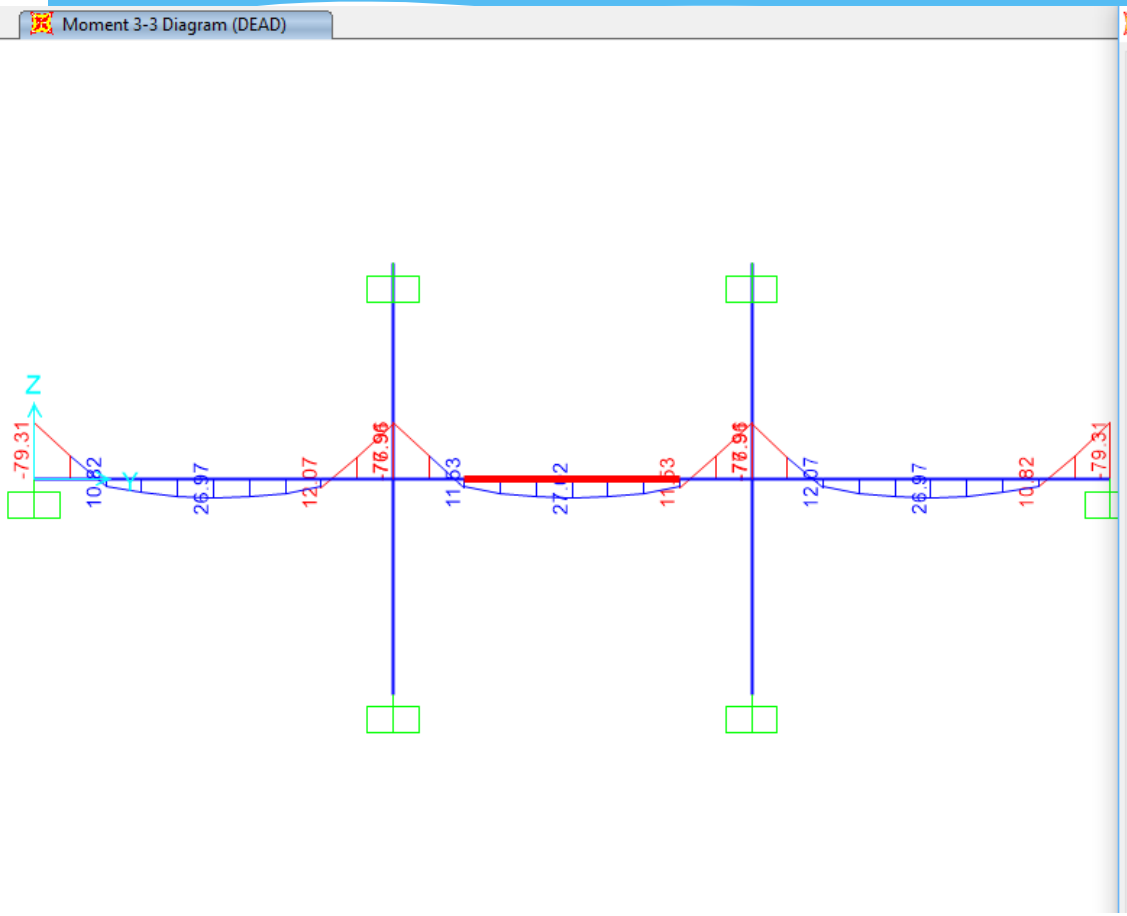


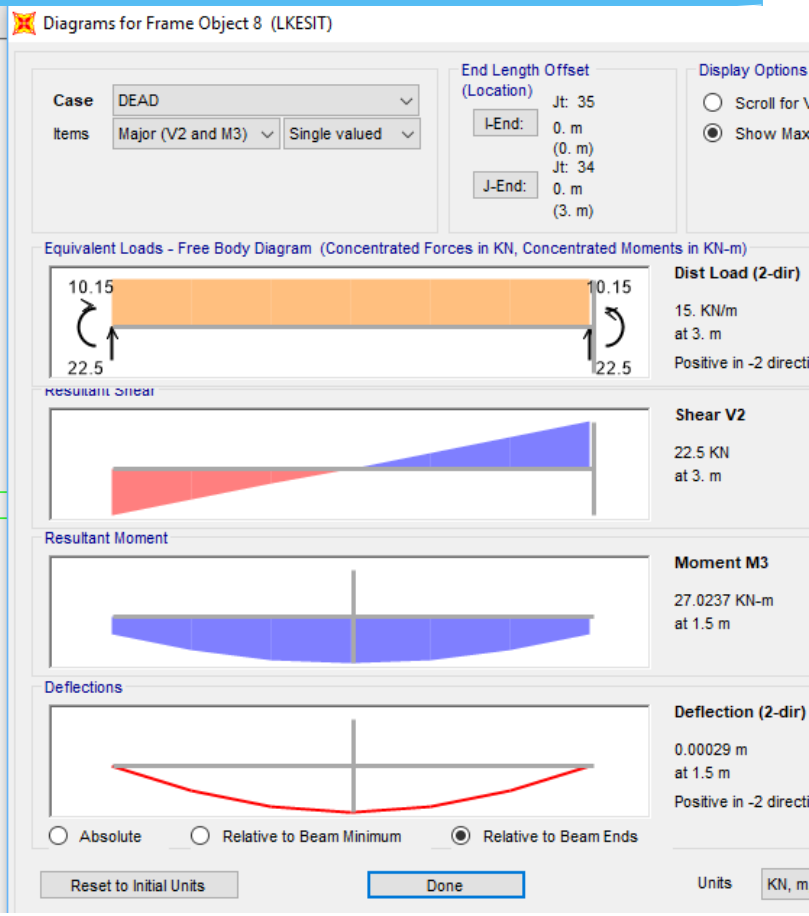
K105 MESNET İLE K101 ARASI



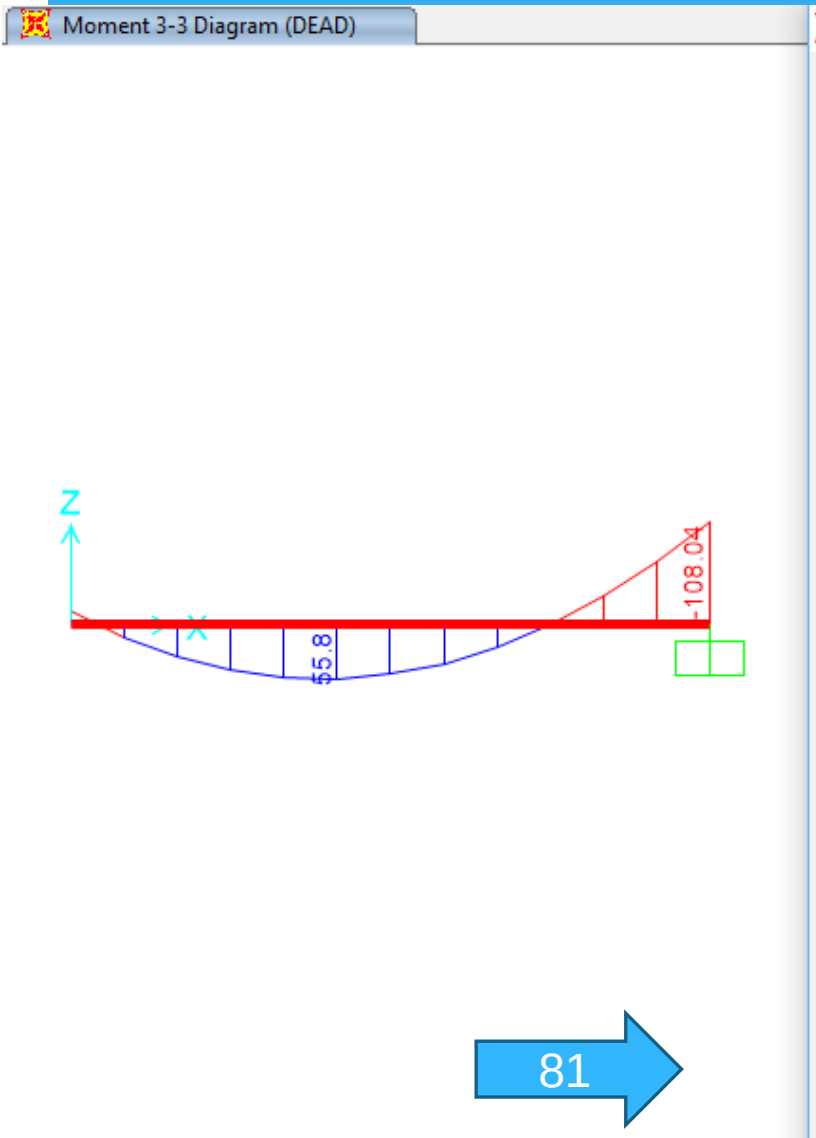


K101 İLE K101 ARASI

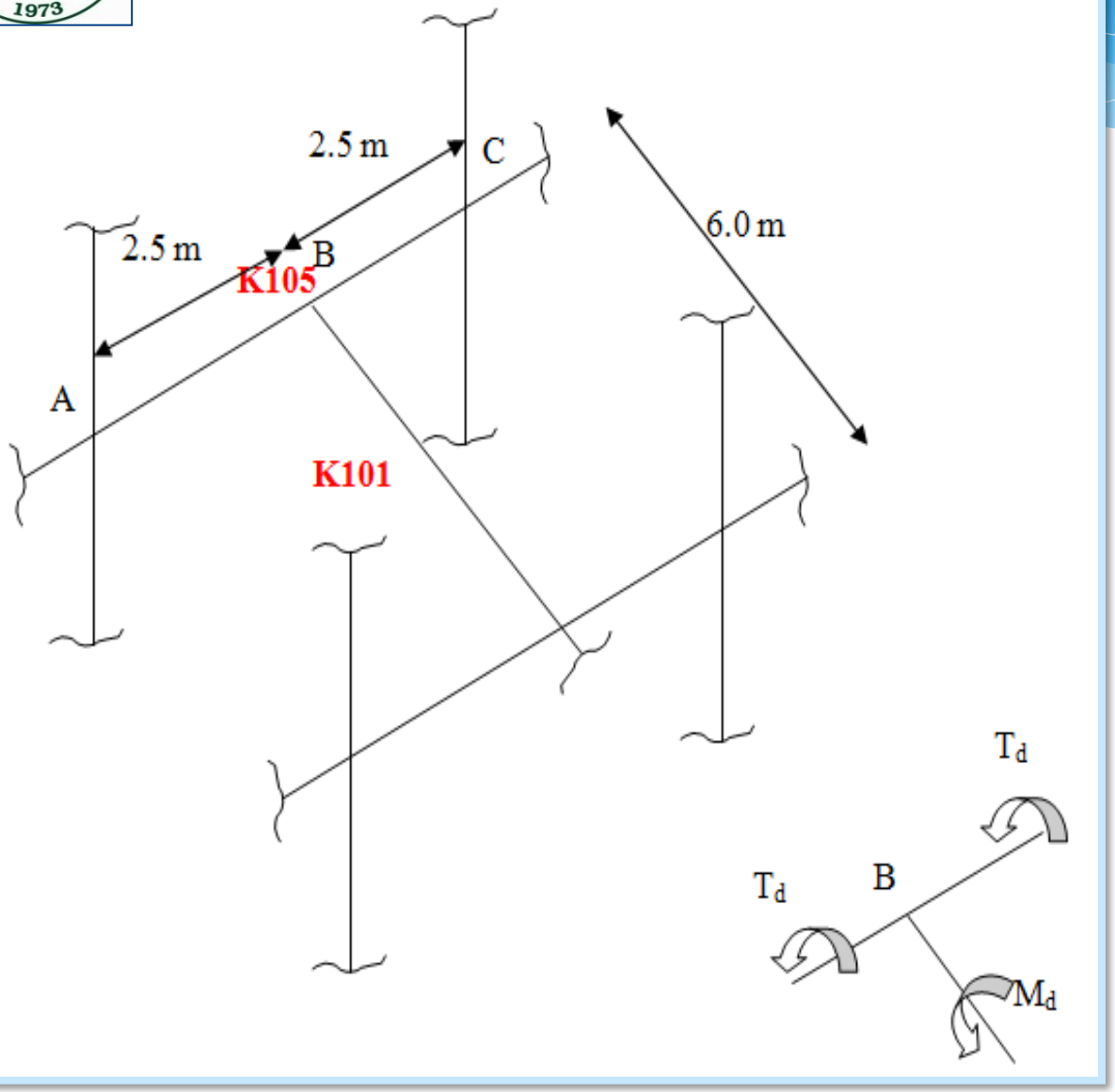




K101 KİRİŞİ


Moment 3-3 Diagram (DEAD)
Z
X
-108.04
55.8
Diagrams for Frame Object 45 (TKESIT)
Case
DEAD
Items
Major (V2 and M3)
Single valued
End Length Offset (Location)
I-End:
Jt: 34
0. m
(0. m)
J-End:
Jt: 59
0. m
(6. m)
Display Options
Scroll for Values
Show Max
Equivalent Loads - Free Body Diagram (Concentrated Forces in KN, Concentrated Moments in KN-m)
14.65
108.04
59.44
90.56
Dist Load (2-dir)
25. KN/m
at 4.5 m
Positive in -2 direction
Resultant Shear
Shear V2
90.564 KN
at 6. m
Resultant Moment
Moment M3
-108.0372 KN-m
at 6. m
Deflections
Deflection (2-dir)
0.0014 m
at 2.5 m
Positive in -2 direction
Absolute
Relative to Beam Minimum
Relative to Beam Ends
Reset to Initial Units
Done
Units
KN, m, C

PROBLEMİN İRDELENMESİ



Kat planında K105 kirişine açıklık ortasında yalnız bir kiriş saplansaydı; K101 kirişindeki negatif moment $\mathbf{2T_{cr}}$ olacaktı. Eğer K105 kirişinin kesit boyutları 500x700 mm ve tabla kalınlığı h_f= 200 mm olsaydı; burulma çatlama ($\mathbf{T_{cr}}$) momenti oldukça büyük olurdu.

32

$$1.35\,S = \frac{1.35}{3}[(500^2)(700) + (200^2)(3)(200)] = 89.5 * 10^6\ mm^3$$

$$T_{cr} = f_{ctd}\ 1.35\,S = 1.0 * 89.5 * 10^6 * 10^{-6} = 89.5\ kNm$$

Bu durumda K101 (250*500) kirişinin kenar mesnedindeki moment $2T_{cr}$

$-M_d = 2 * 89.5 = 179\ kNm$

Bu moment oldukça büyüktür. Limit analize dayanan şu yaklaşım daha uygun olacaktır.

Plastik mafsal K101 kirişinin kenar mesnedinde oluştuğu varsayılarak mevcut donatıya göre kapasite momenti hesaplanır.

$M_p \approx 1.4\,M_r = 1.4\,A_s\,f_{yd}(d - d')$

K101 üst donatı (mesnette) **2ϕ18(510 mm^2)+2ϕ12(226)=736 mm^2**

$M_p = 1.4 * 736 * 0.365 * 430 * 10^{-3} =$ **161.2 *kNm***

Bu moment temel alınarak K105 kiriş uçlarına giden burulma momenti hesaplanır.

K105 $T_d = \frac{161.2}{2} =$ **80.6 *kNm*** $T_{cr} = 89.5\ kNm > T_d$

Bu durumda plastik mafsalın K101'in ucunda oluştuğu varsayımı doğrudur. K105 çatlamada burulma momentine erişmez. Minimum burulma donatısı konulacaktır.

Eğer K101 kirişinin mesnedindeki üst donatı

$4\phi 18 + 2\phi 12$ ($-A_s$= **1246 mm²**) olsaydı. Hesap burulma momenti;

$$M_p = 1.4 * \ 1246 * \ 0.365 * 430 * 10^{-3} = \mathbf{273.4\ kNm}$$

K105 kirişi mesnetlerindeki burulma momenti;

$$T_d = \frac{M_p}{2} = \ \mathbf{136.9\ kNm} \ > T_{cr}$$

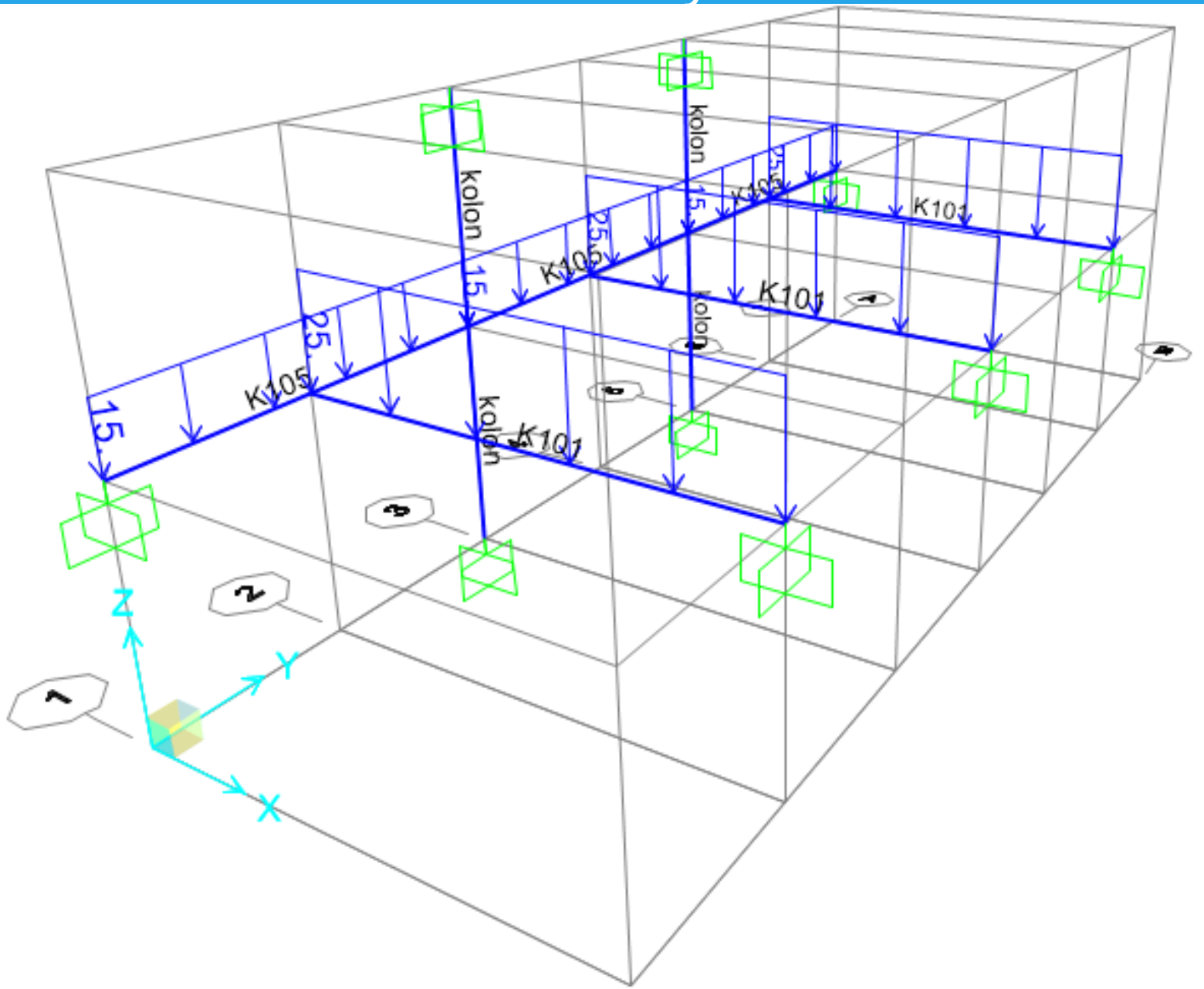
Bu durumda mafsalın K101 kirişinde oluşması olanaksızdır. Plastik mafsallar K105 kirişinin 2 ucunda burulma çatlamasından oluşacaktır.

$$T_d = T_{cr} = 89.5\ kNm$$

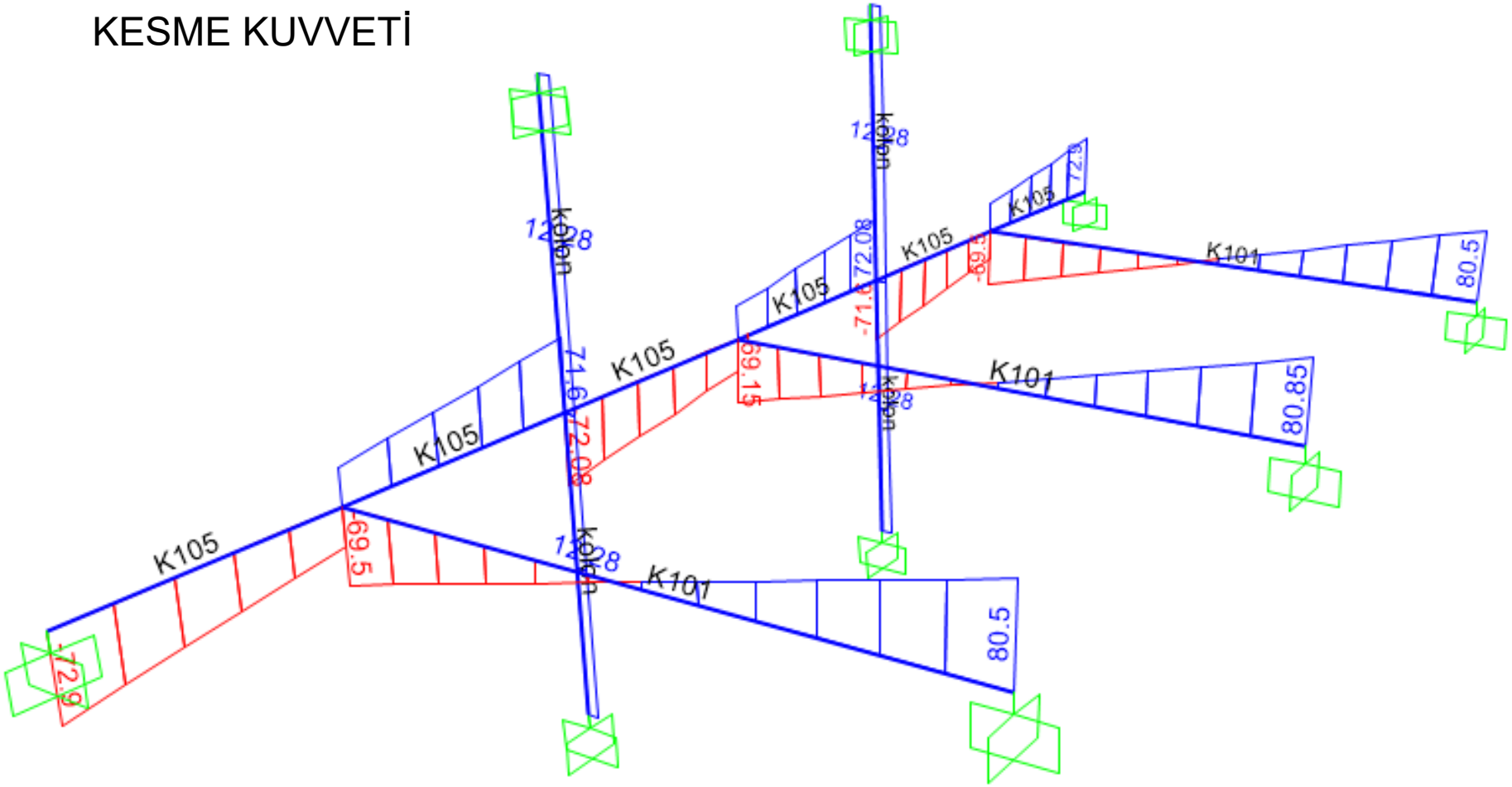
K101'in kenar mesnedinde moment $M_d = 2 \times T_{cr}$ olacaktır.

$$M_d = 2 * 89.5 = 179\ kNm$$

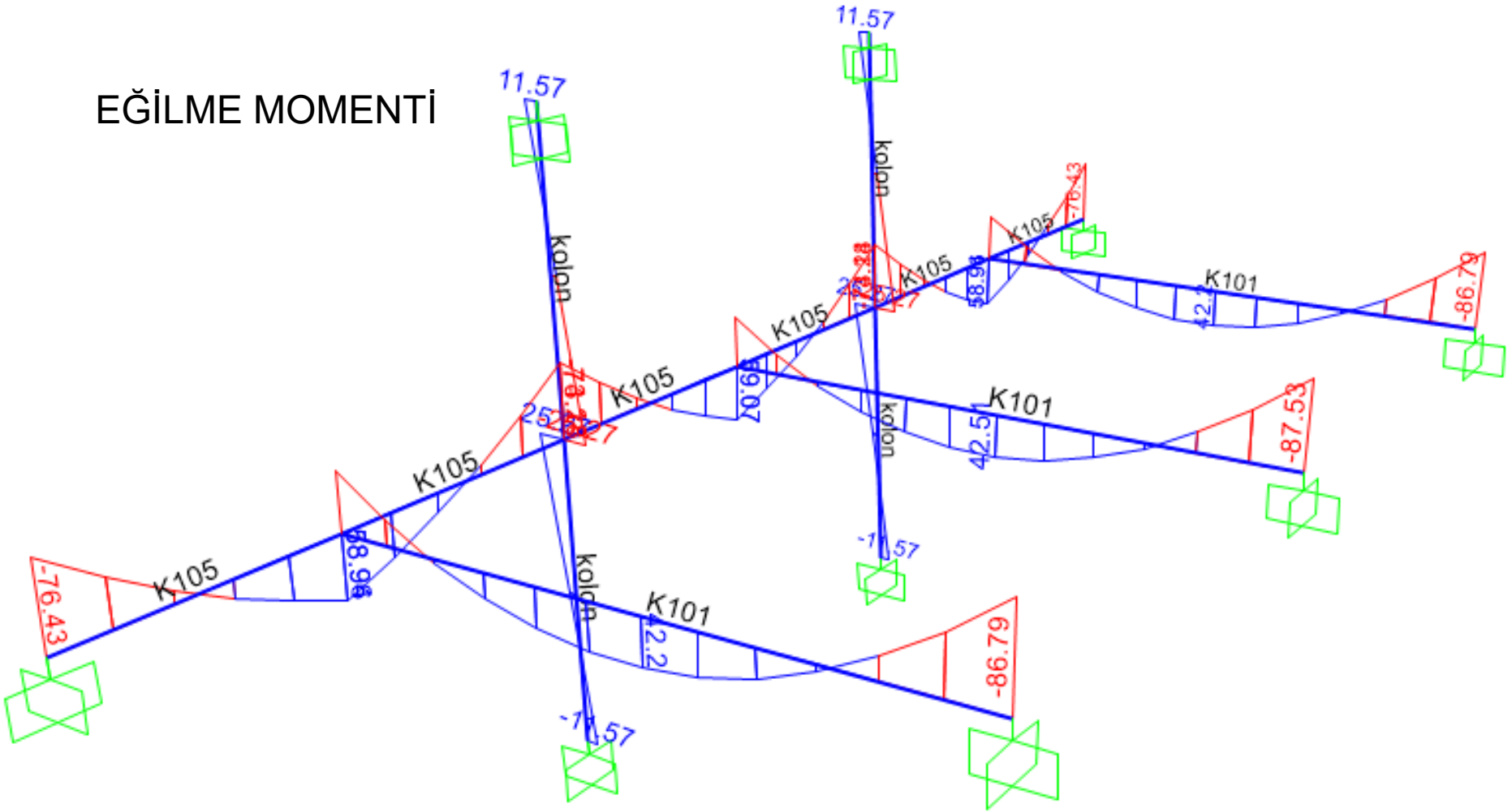
SAP2000 ile 3 Boyutlu



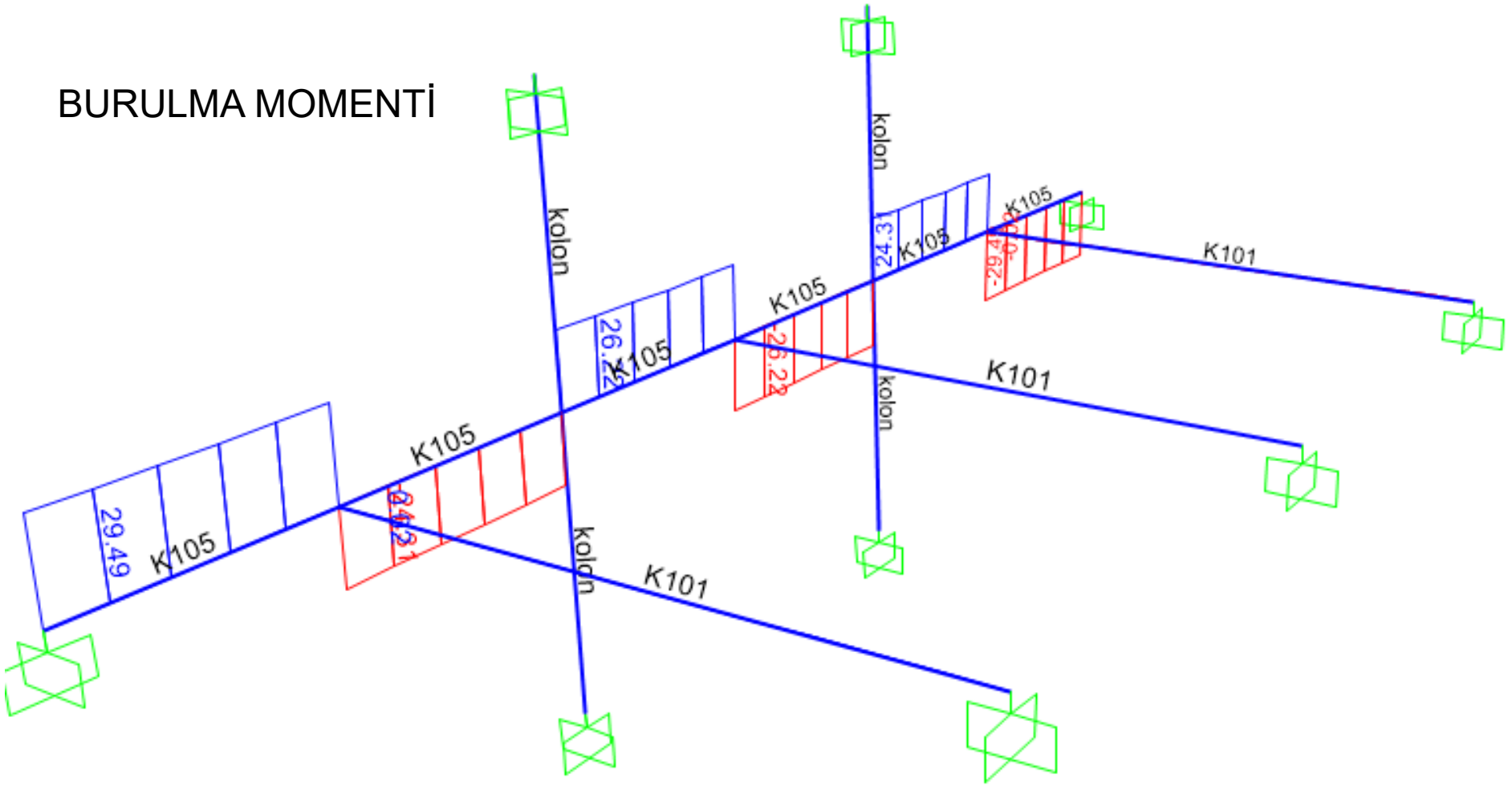
KESME KUVVETİ



EĞİLME MOMENTİ



BURULMA MOMENTİ



Diagrams for Frame Object 2 (K105)

Case: DEAD

Items: Major (V2 and M3) | Single valued

End Length Offset (Location)

I-End: Jt: 2, 0. m, (0. m)

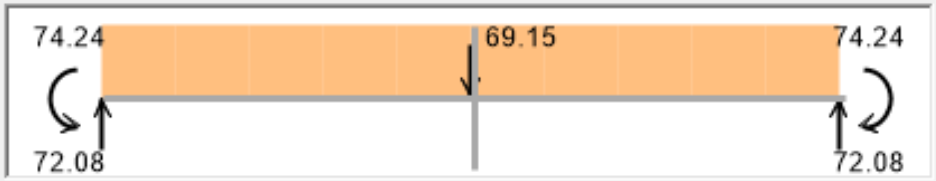
J-End: Jt: 3, 0. m, (5. m)

Display Options

- (•) Scroll for Values
- ( ) Show Max

Location: 2.5 m

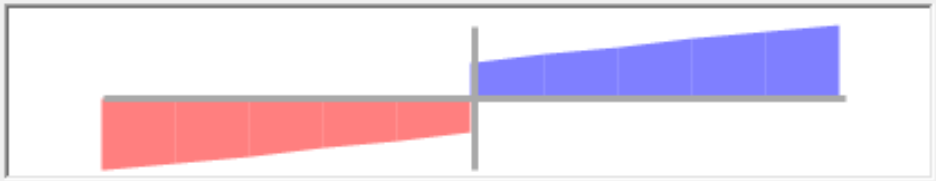
Equivalent Loads - Free Body Diagram (Concentrated Forces in KN, Concentrated Moments in KN-m)



Dist Load (2-dir)

15. KN/m
at 2.5 m
Positive in -2 direction

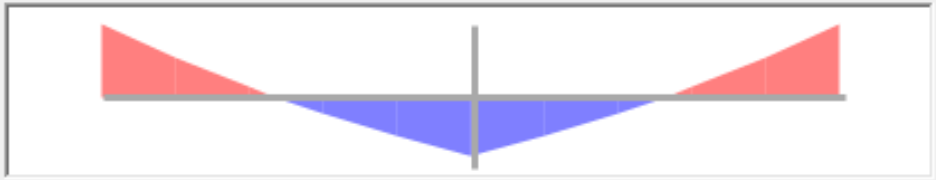
Resultant Shear



Shear V2

-34.576 KN
at 2.5 m

Resultant Moment



Moment M3

59.0741 KN-m
at 2.5 m

Deflections

Deflection (2-dir)

0.000242 m
at 2.5 m
Positive in -2 direction

( ) Absolute ( ) Relative to Beam Minimum (•) Relative to Beam Ends

Reset to Initial Units | Done | Units: KN, m, C

Diagrams for Frame Object 2 (K105)

Case: DEAD

Items: Axial (P and T) | Single valued

End Length Offset (Location)

I-End: Jt: 2, 0. m, (0. m)

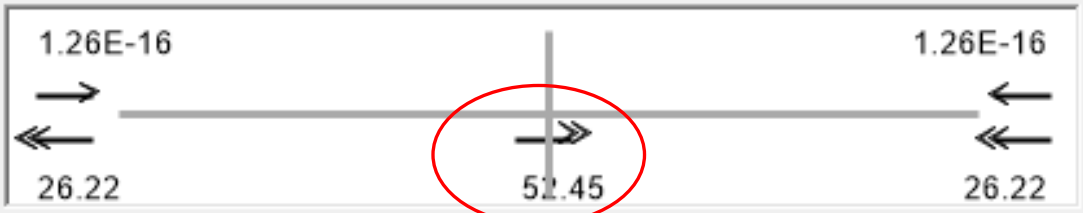
J-End: Jt: 3, 0. m, (5. m)

Display Options

- (•) Scroll for Values
- ( ) Show Max

Location: 2.5 m

Equivalent Loads - Free Body Diagram (Concentrated Forces in KN, Concentrated Torsions in KN-m)



Dist Load (1-dir)

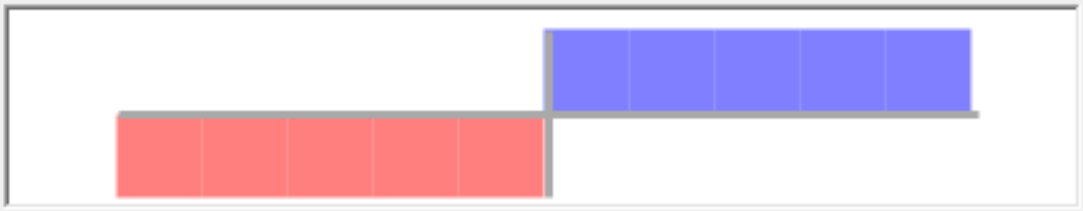
0. KN/m
at 2.5 m
Positive in -1 direction

Resultant Axial Force

Axial

-1.261E-16 KN
at 2.5 m

Resultant Torsion



Torsion

26.2249 KN-m
at 2.5 m

Reset to Initial Units | Done | Units: KN, m, C

Diagrams for Frame Object 5 (K101)

Case: DEAD

Items: Major (V2 and M3) | Single valued

End Length Offset (Location)

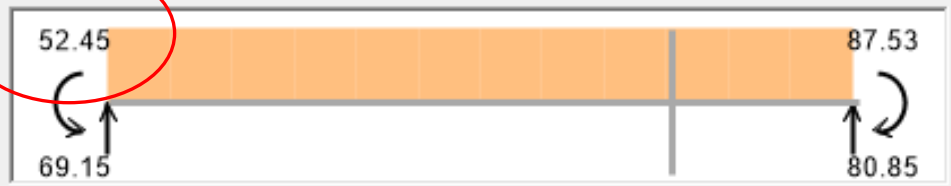
I-End: Jt: 7, 0. m, (0. m)

J-End: Jt: 8, 0. m, (6. m)

Display Options

- Scroll for Values
- Show Max

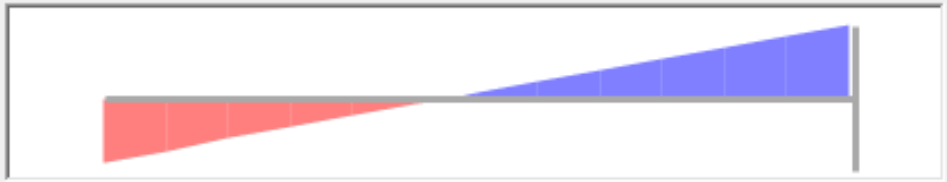
Equivalent Loads - Free Body Diagram (Concentrated Forces in KN, Concentrated Moments in KN-m)



Dist Load (2-dir)

25. KN/m
at 4.5 m
Positive in -2 direction

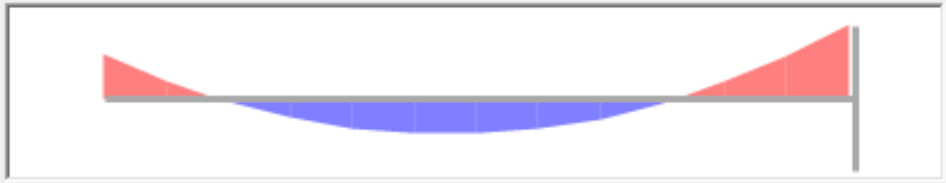
Resultant Shear



Shear V2

80.847 KN
at 6. m

Resultant Moment



Moment M3

-87.5328 KN-m
at 6. m

Deflections

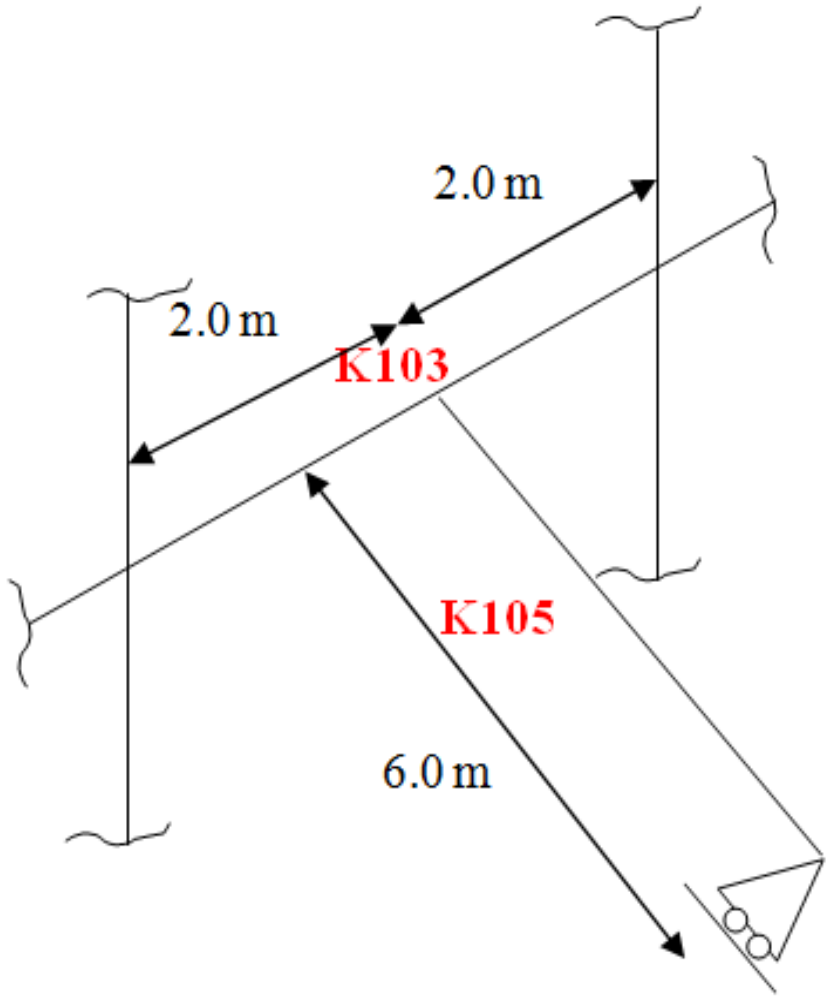
Deflection (2-dir)

0.001616 m
at 3. m
Positive in -2 direction

- Absolute
- Relative to Beam Minimum
- Relative to Beam Ends

Reset to Initial Units | Done | Units: KN, m, C

ÖRNEK 8.3.



Şekil 8.3

Şekil 8.3'te gösterilen K103 kirişinin donatısını hesaplayınız. (M, V, T altında) Malzeme: C20, S420.

Kolonlar: (1000*1000) mm

(Kolon boyu üstte ve altta 3.0 m)

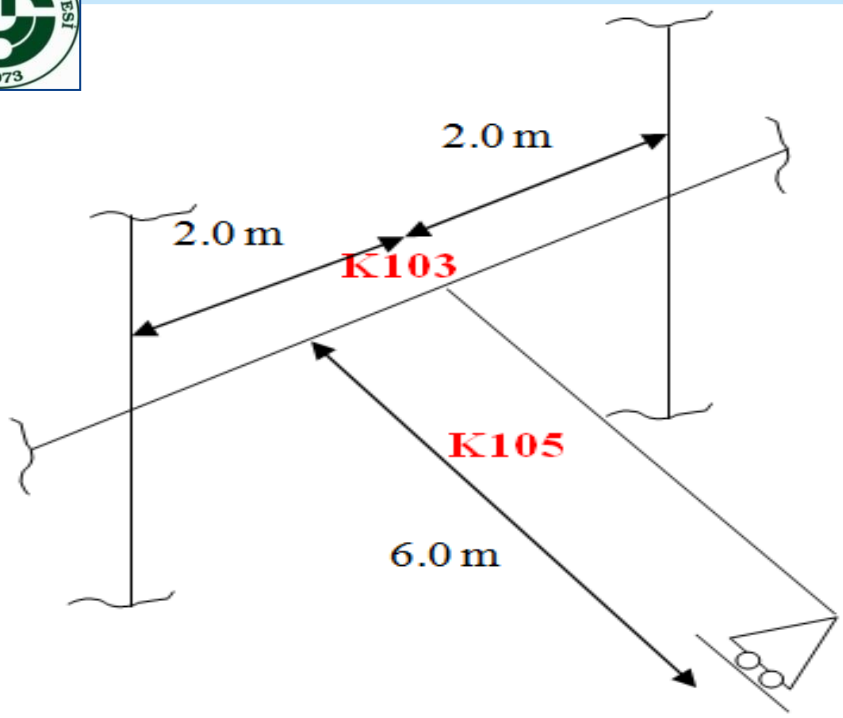
Kirişler: (300*500) mm (d= 465 mm)

Düzgün yayılı kiriş yükleri:

K103 için;p_g=7.1 kN/m, p_q=9.0 kN/m

K105 için;p_g=16.0kN/m,p_q=5.0 kN/m

(kendi ağırlıkları dahil)



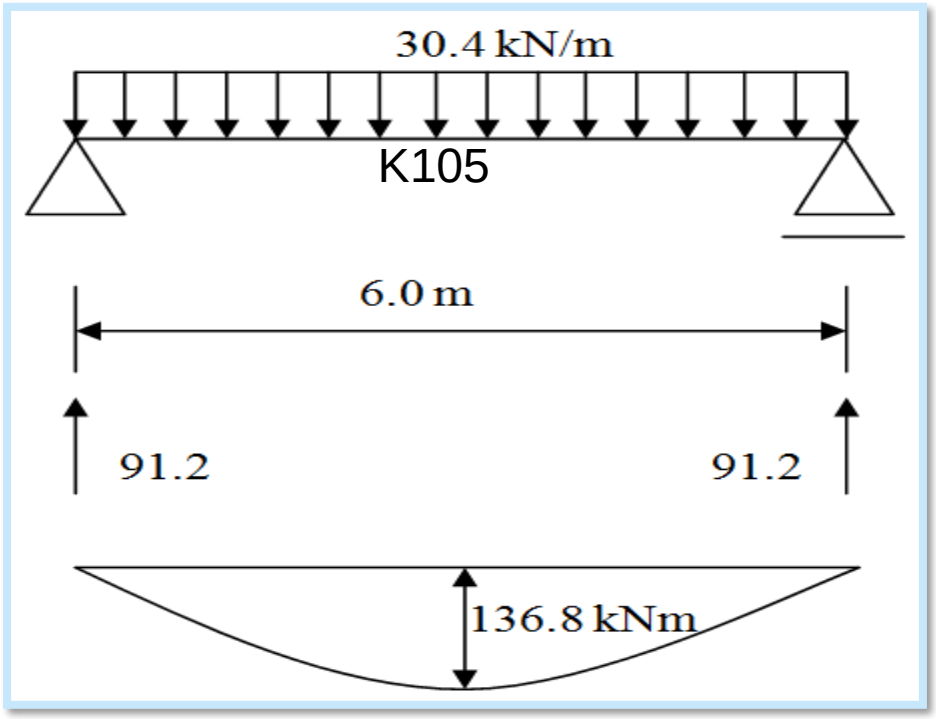
Şekil 8.3

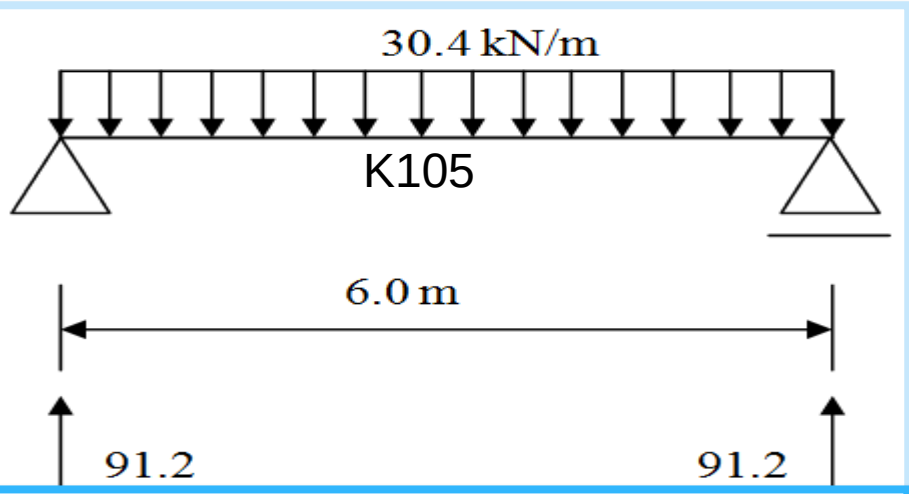
Yalnız 1.4G + 1.6Q yük birleşimi için hesap yapınız. K103 kirişinin arkasında döşeme bulunmamaktadır. Kiriş açıklıkları net açıklıktır.

ÇÖZÜM 8.3.

$$K105 \quad P_d = 1.4 * 16 + 1.6 * 5 = 30.4\ kN/m$$

$$K103 \quad P_d = 1.4 * 7.1 + 1.6 * 9 = 24.34\ kN/m$$


30.4 kN/m
K105
6.0 m
91.2
91.2
136.8 kNm



K105 kirişi eğilme ve kesme hesabı

$-M_d = 2\,T_{cr} = 1.35\,S\,f_{ctd}$ K105 kirişinin K103 kirişine saplandığı noktada ki uç momenti K103 kirişinin $\mathbf{T_{cr}}$ momentinin 2 katı olur

$$S = \frac{1}{3} * 300^2 * 500 = 15 * 10^6\ mm^3$$

$$T_{cr} = 1.35 * 15 * 10^6 * 1 * 10^{-6} = 20.25\ kNm$$ +M=136.8 kNm

$$+A_s = \frac{136.8 * 10^6}{365 * 0.86 * 465} = 937.2\ mm^2$$ $Seçilen: 4Ø18 = 1018\ mm^2$

$2 \times T_{cr}$

$$-A_s = \frac{2 * 20.25 * 10^6}{365 * 0.86 * 465} = 277.4\ mm^2$$ $Mevcut: 2Ø18$ √

$$V_d = 91.2\ kNm$$

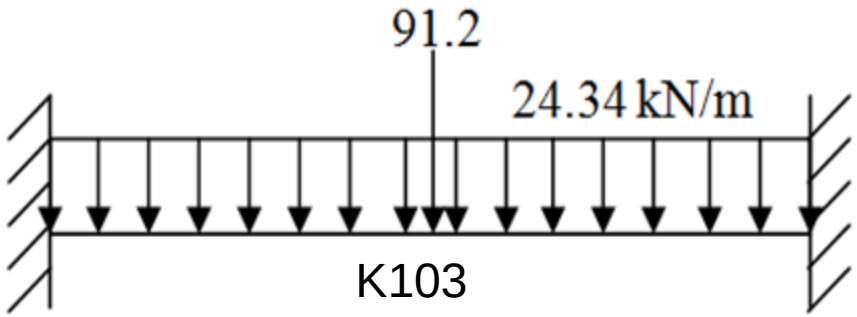
$$V_{cr} = 0.65 * 1 * 10^{-3} * 300 * 465 = 90.67\ kN$$

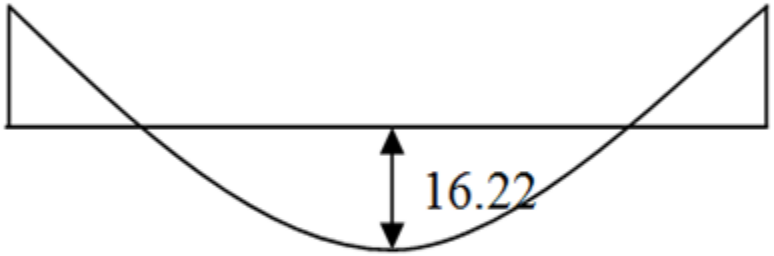
$V_d > V_{cr}$ $V_c = 72.54\ kN$

K105 kirişi etriye hesabı

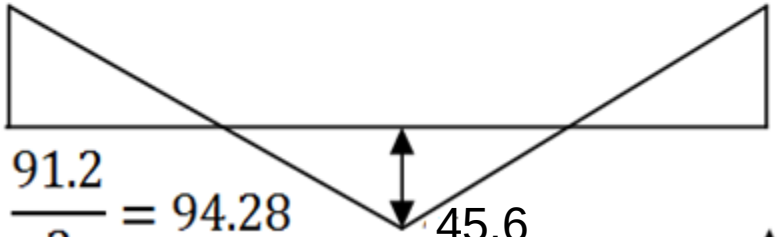
$$\frac{A_{os}}{s} = \frac{A_{sw}}{2s} = \frac{(91.2 - 0.5 * 72.54) * 10^3}{2 * 191 * 465} = 0.31\ mm^2/mm$$

$$Ø8 \implies A_0 = 50.26\ mm^2 \qquad \frac{50.26}{s} = 0.31 \qquad s = 161\ mm = 16\ cm \quad (Ø8/16\ )$$





$$\frac{P_d L^2}{12} = 32.45$$



$$\frac{P\,l}{8} = 45.6$$

$$+M_d = \mathbf{61.82}\ kNm$$

$$-M_d = 80.05\ kNm$$

$$48.68 + \frac{91.2}{2} = 94.28$$

94.28

K103 Eğilme Donatısı hesabı

$$+A_s = \frac{61.82 * 10^6}{365 * 0.86 * 465} = 423.5 mm^2$$

$$Seçilen: 4Ø12 = 2Ø12\ düz + 2Ø12\ pilye = 452\ mm^2$$

$$-A_s = \frac{80.05 * 10^6}{365 * 0.86 * 465} = 548.42\ mm^2$$

$$Mevcut: 2Ø12 + 2Ø12 + 1Ø12 = 565\ mm^2$$

K103 kirişi burulma donatısı hesabı
Burulma + kesme etriyesi ve burulma boyuna donatısı

$$\min\frac{A_0}{s} = 0.15 * \frac{1}{191} * \left(1 + 1.5 * \frac{20.25 * 10^3}{94.28 * 300}\right) 300 = 0.49\ mm^2/mm$$

$$\frac{T_d}{V_d\, b_w} = 0.71 < 1 \qquad \surd$$

$$\text{Ø}8 \implies A_0 = 50.26\ mm^2 \qquad \frac{50.26}{s} = 0.49 \qquad s = 102\ mm = 10\ cm \quad (\text{Ø}8/10\ )$$

$$b_k = 300 - 2 * 35 = 230\ mm$$

$$h_k = 500 - 2 * 35 = 430\ mm$$

$$U_l = 2(b_k + h_k) = 1320\ mm$$

$$A_e = (b_k * h_k) = 98900\ mm^2$$

$$\min A_{sl} = \frac{T_{cr} U_l}{2 f_{yd} A_e} = \frac{20.25 * 10^6 * 1320}{2 * 365 * 98900} = 370\ mm^2 \qquad \frac{A_{sl}}{2} = 185\ mm^2$$

K103 kirişi burulma birim dönme kontrolü

$$\theta_B = \frac{P_d L^3}{24EI}$$

K105 kirişinin her iki ucu da mafsallı kabul edilirse mesnetteki dönme açısı, $\theta_B = \frac{P_d L^3}{24EI}$

$I_{K105}=30*(50)^3/12= 3.125*10^5\ cm^4$ $E=2850\ kN/cm^2$

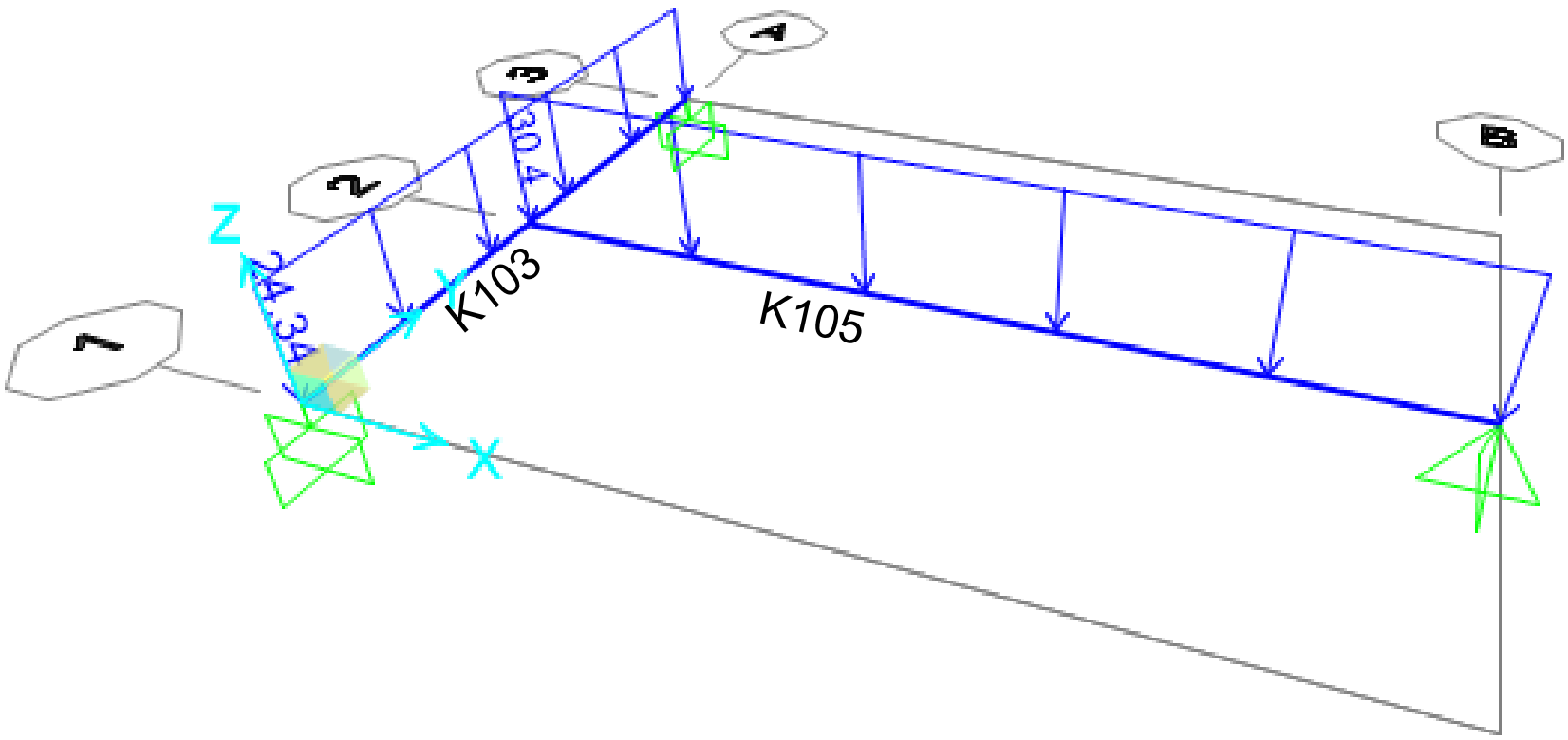
$EI=89.06*10^7\ kN\ cm^2$ olur.

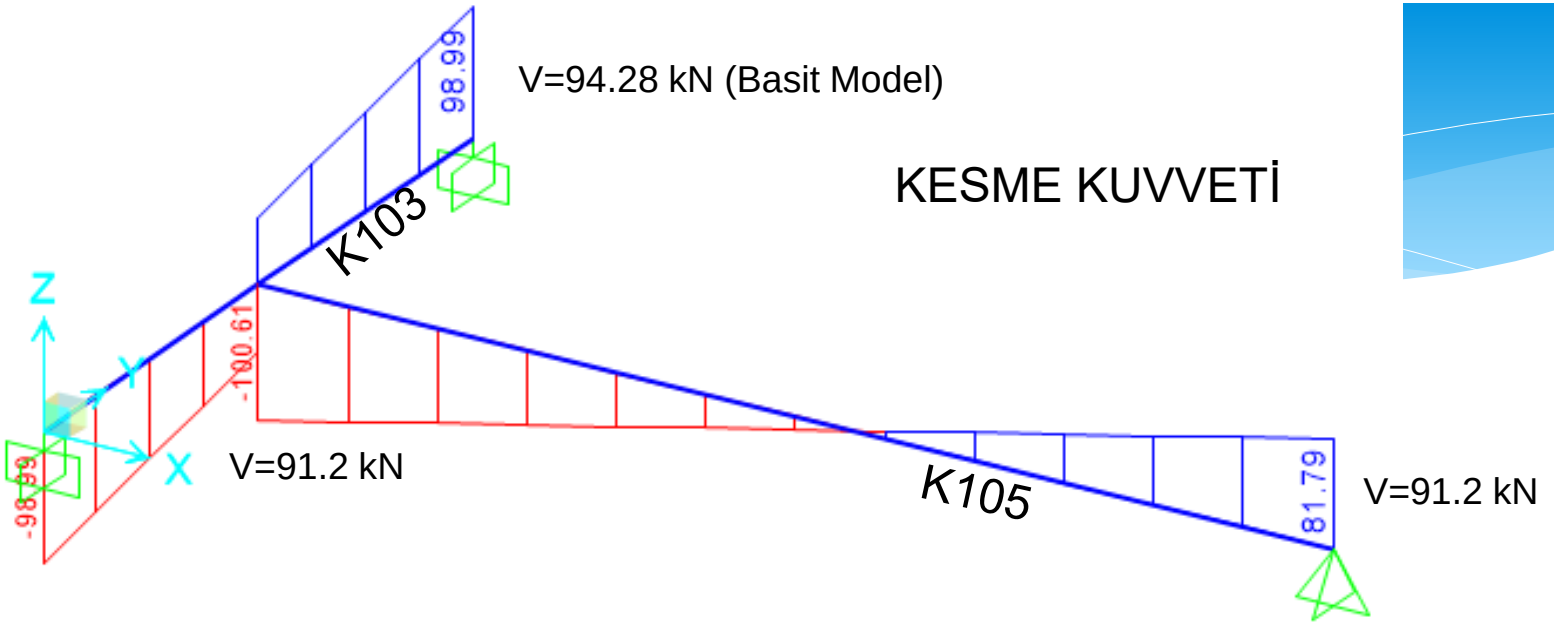
$$\theta_B=\frac{0.304*(600)^3}{24*\ 89.06*10^7} = 3.08*10^{-3}\ rad$$

a= 2.0 m burulma açıklığı

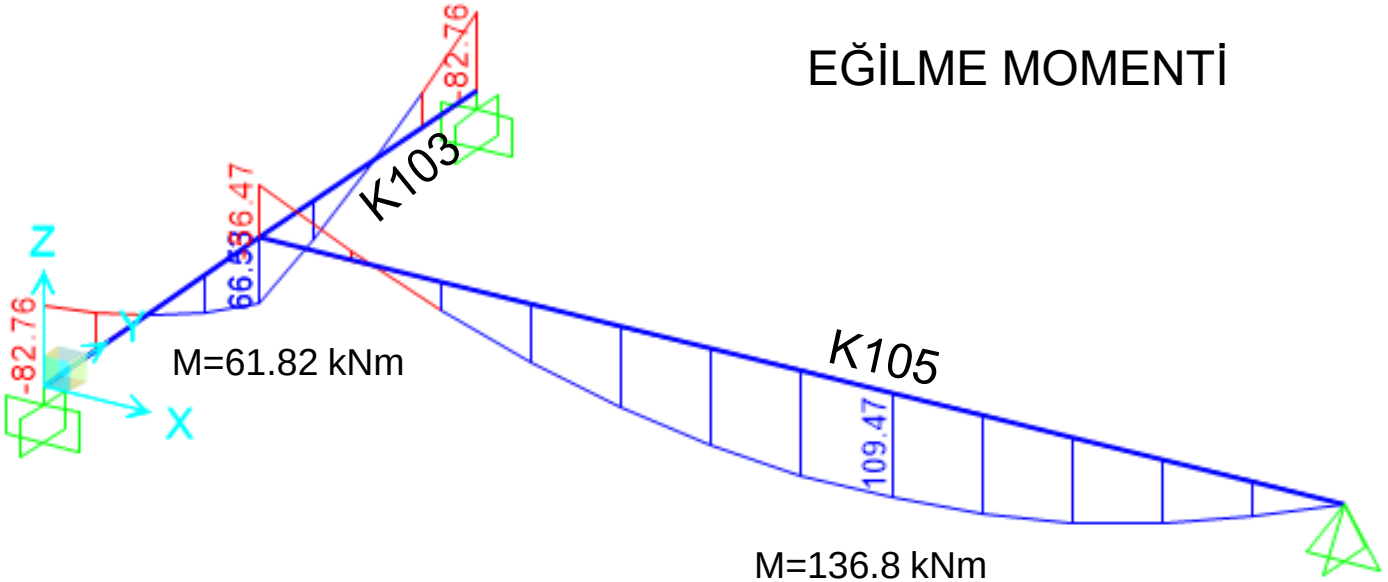
$\phi=\theta_B/2\ m=$ **$1.54*10^{-3}$ rad/m** $<10*10^{-3}\ rad/m$

SAP2000 ile 3 Boyutlu





M=80.05 kNm (Basit Model)



Diagrams for Frame Object 4 (K103)

Case: DEAD

Items: Major (V2 and M3) | Single valued

End Length Offset (Location)

I-End: Jt: 5, 0. m, (0. m)

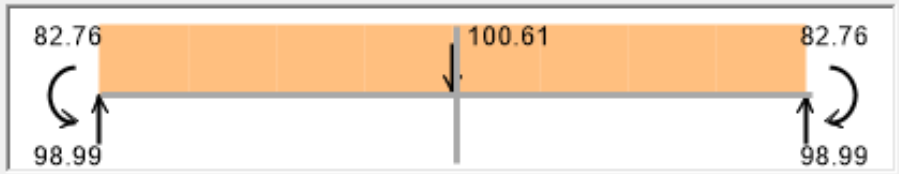
J-End: Jt: 6, 0. m, (4. m)

Display Options

- (•) Scroll for Values
- ( ) Show Max

Location: 2 m

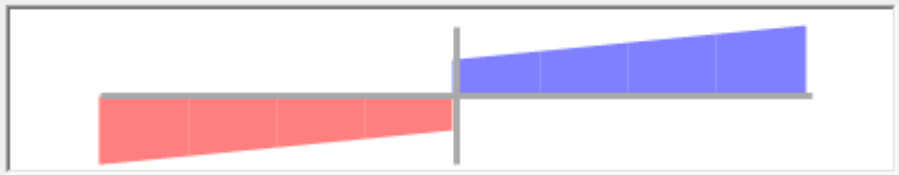
Equivalent Loads - Free Body Diagram (Concentrated Forces in KN, Concentrated Moments in KN-m)



Dist Load (2-dir)

24.34 KN/m
at 2. m
Positive in -2 direction

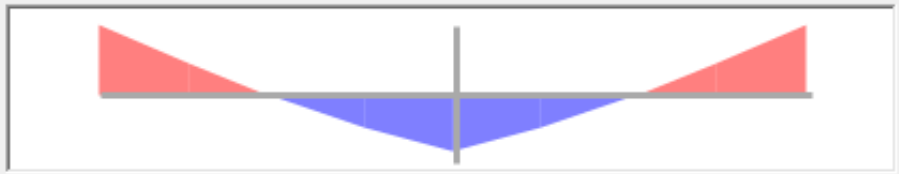
Resultant Shear



Shear V2

-50.306 KN
at 2. m

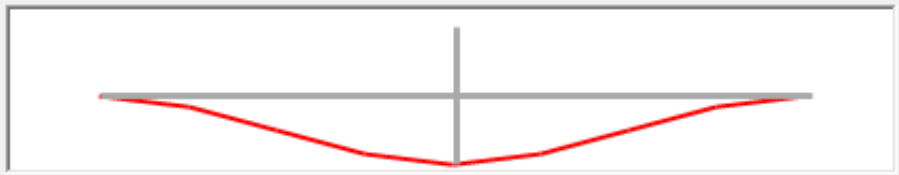
Resultant Moment



Moment M3

66.5322 KN-m
at 2. m

Deflections



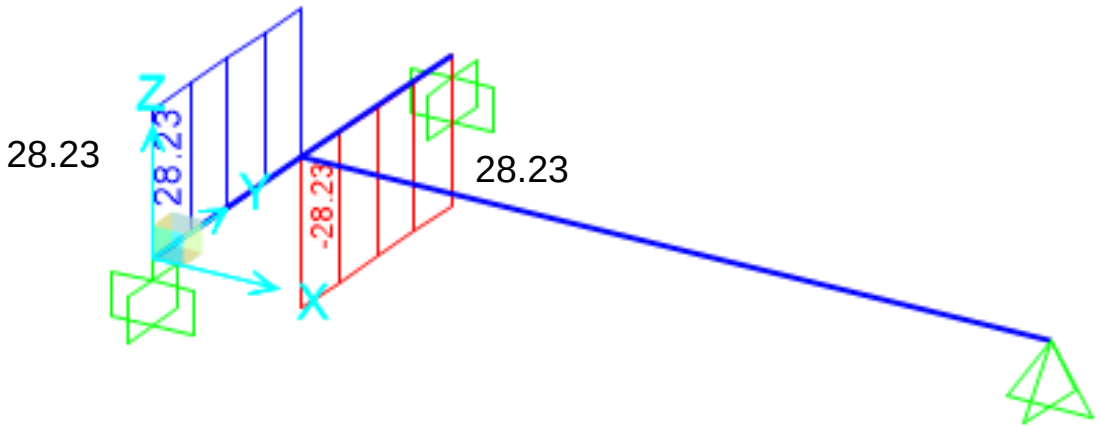
Deflection (2-dir)

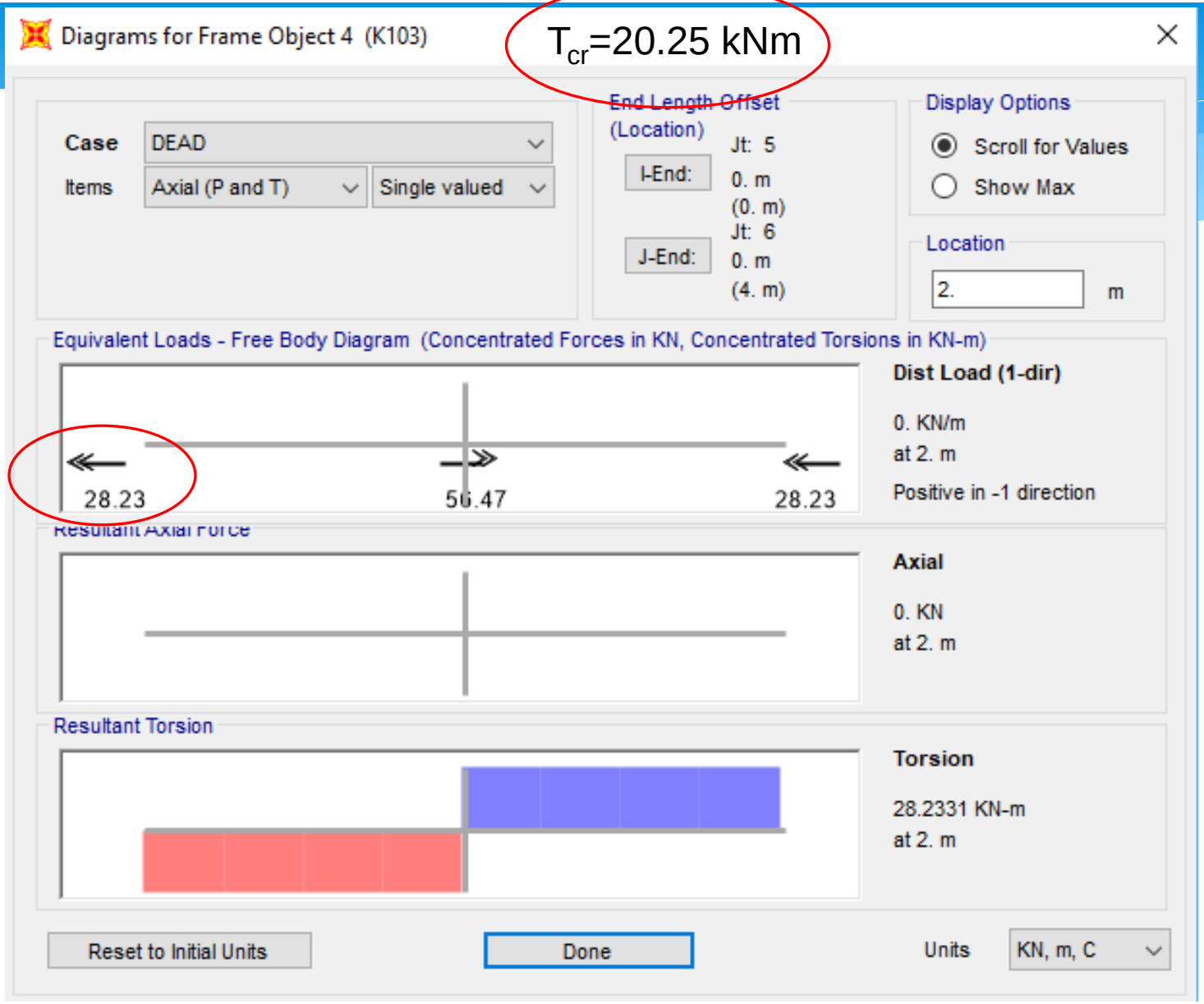
0.000756 m
at 2. m
Positive in -2 direction

( ) Absolute ( ) Relative to Beam Minimum (•) Relative to Beam Ends

Reset to Initial Units | Done | Units: KN, m, C

BURULMA MOMENTİ (T_{cr}=20.25 kNm)




Diagrams for Frame Object 4 (K103)
T_{cr}=20.25 kNm
Case
DEAD
Items
Axial (P and T)
Single valued
End Length Offset (Location)
I-End:
Jt: 5
0. m
(0. m)
J-End:
Jt: 6
0. m
(4. m)
Display Options
Scroll for Values
Show Max
Location
2.
m
Equivalent Loads - Free Body Diagram (Concentrated Forces in KN, Concentrated Torsions in KN-m)
28.23
56.47
28.23
Dist Load (1-dir)
0. KN/m
at 2. m
Positive in -1 direction
Resultant Axial Force
Axial
0. KN
at 2. m
Resultant Torsion
Torsion
28.2331 KN-m
at 2. m
Reset to Initial Units
Done
Units
KN, m, C

Diagrams for Frame Object 3 (K105)

Case: DEAD

Items: Major (V2 and M3) | Single valued

End Length Offset (Location)

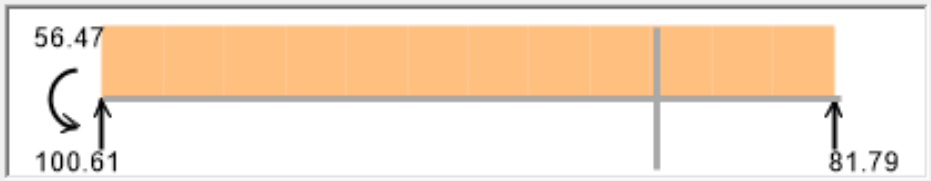
I-End: Jt: 2, 0. m, (0. m)

J-End: Jt: 4, 0. m, (6. m)

Display Options

- Scroll for Values
- Show Max

Equivalent Loads - Free Body Diagram (Concentrated Forces in KN, Concentrated Moments in KN-m)



Dist Load (2-dir)

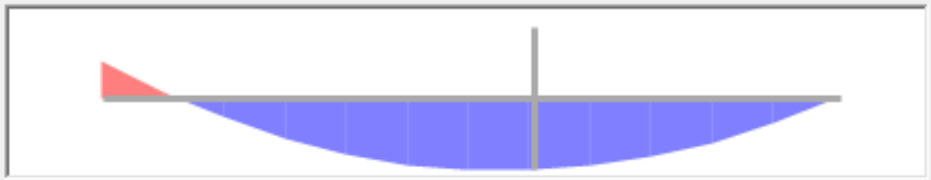
30.4 KN/m
at 4.5 m
Positive in -2 direction

Resultant Shear

Shear V2

-100.611 KN
at 0. m

Resultant Moment



Moment M3

109.4724 KN-m
at 3.5 m

Deflections

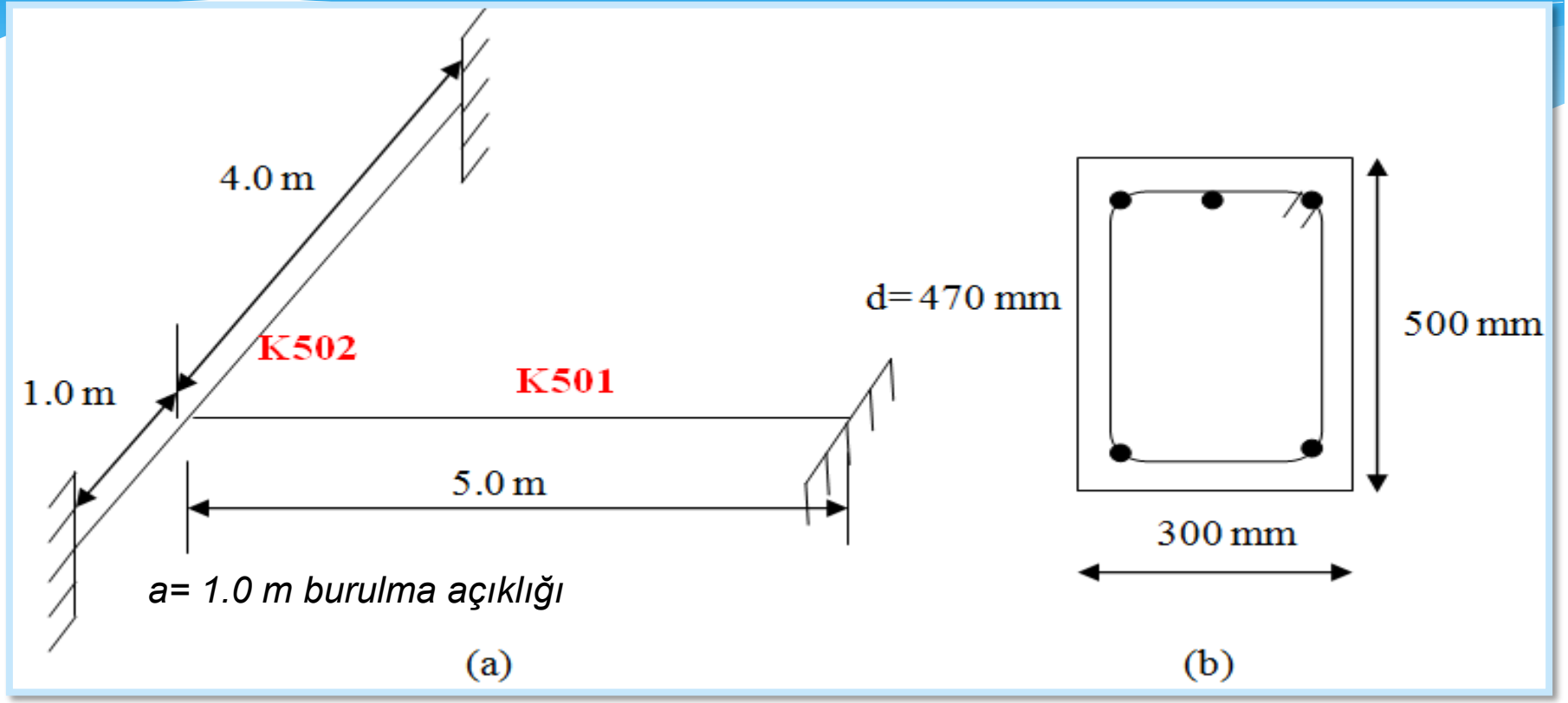
Deflection (2-dir)

0.004932 m
at 3. m
Positive in -2 direction

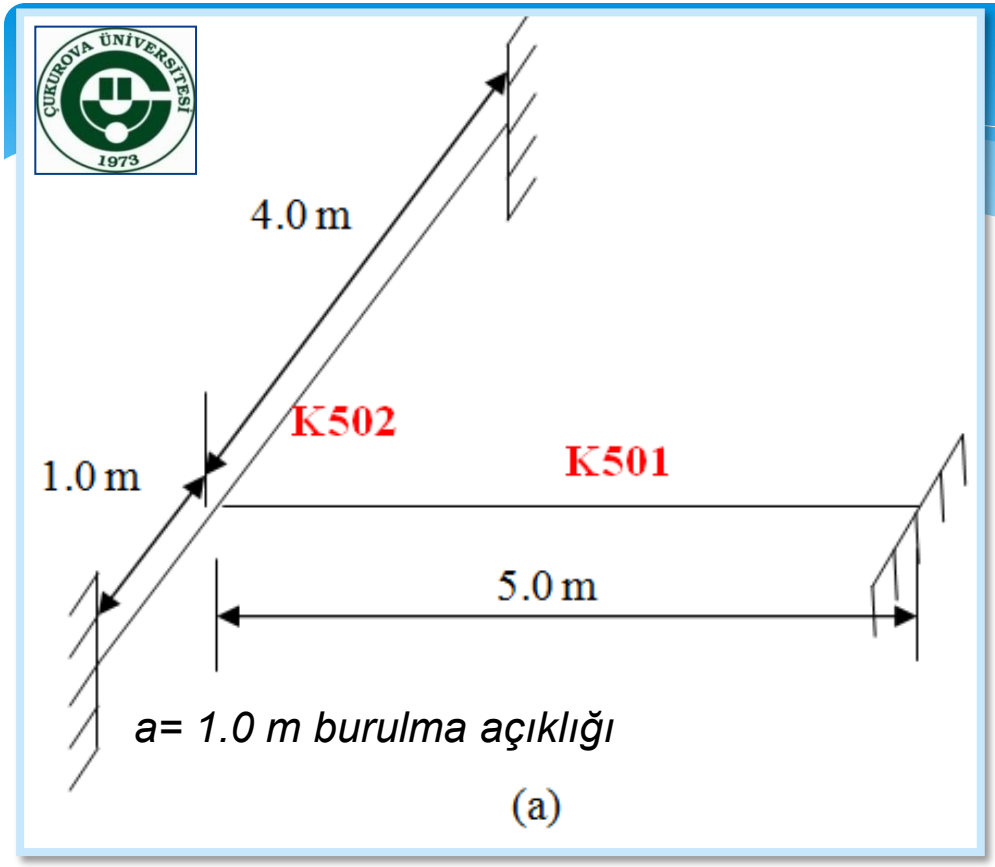
- Absolute
- Relative to Beam Minimum
- Relative to Beam Ends

Reset to Initial Units | Done | Units: KN, m, C

ÖRNEK 8.6



Şekil 8.6b'de görüldüğü gibi Şekil 8.6a'da ki yapı sistemine ait kiriş kesitleri dikdörtgendir ve net beton örtüsü (beton yüzünden etriyenin dışına), 15 mm'dir. Kirişler için gerekli boyuna donatıyı ve etriyeyi hesaplayınız. Donatıyı bir çizimle gösteriniz.



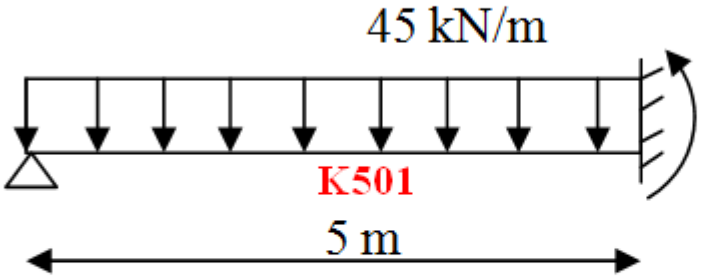
NOT: Şekil 8.6a'da kiriş uçlarındaki kolonların eğilme rijitlikleri çok yüksek olduğundan, bu noktalarda kirişler ankastre kabul edilmiştir. K502 kiriş açıklığı net açıklık, K501 kirişi sağ uç mesnet genişliği 30 cm. alınacaktır.

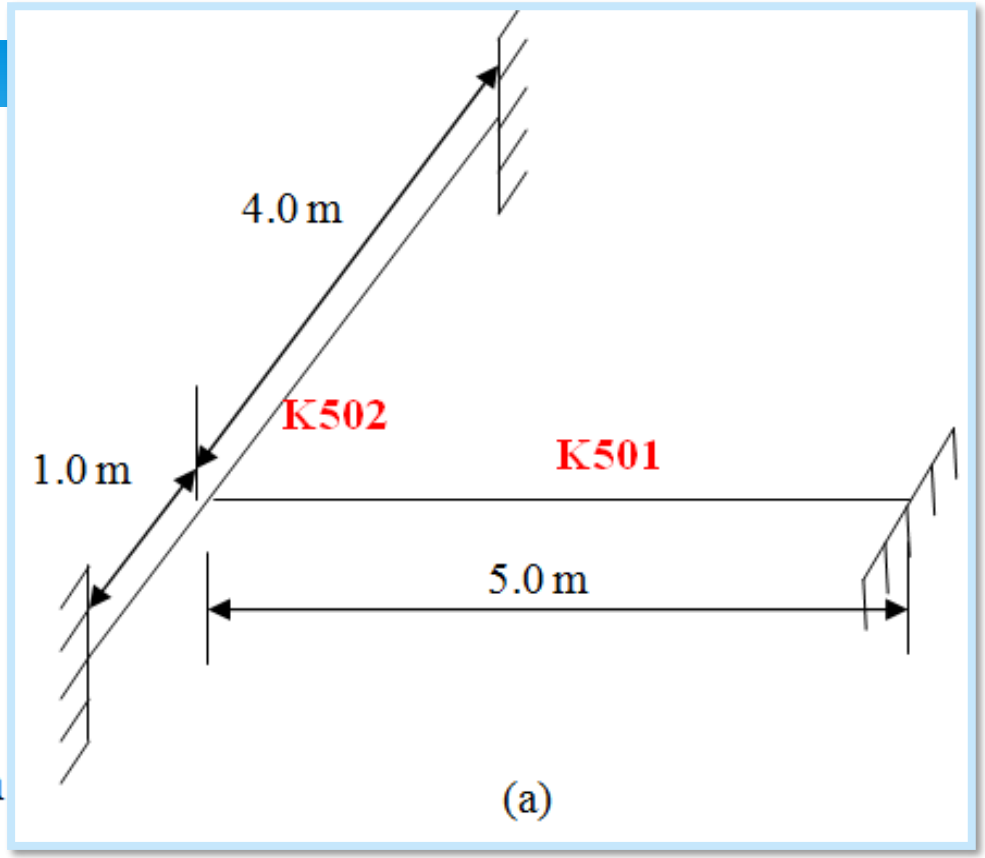
Malzeme: C20, S420

Hesap Yükleri:

K501, P_d= 45 kN/m; K502, P_d= 15 kN/m (Kendi ağırlıkları dahil)

- Burulma türü uygunluk burulmasıdır.





$$M = -\frac{P_d\, l^2}{8} = -\frac{45 * 5^2}{8} = 140.625 \text{ kNm}$$

$$\text{Mesnet yüzünde: } -M = 140.625 - \frac{140.625 * 0.30}{3} = 126.563 \text{ kNm}$$

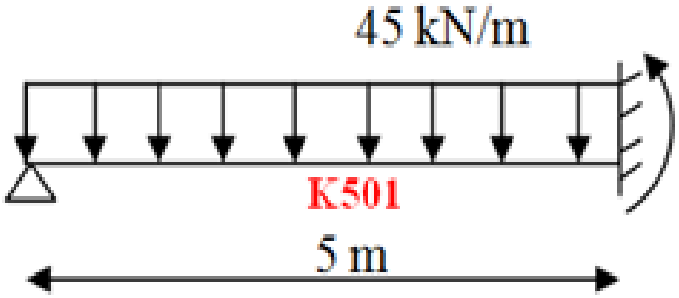
K501 kirişinin sağ mesnet genişliği 30 cm kabul edildi.

$$V_{sağ} = -\frac{45 * 5}{2} + \frac{-140.625}{5} = -140.625 \text{ kN}$$

$$V_{sol} = \frac{45 * 5}{2} + \frac{-112.5}{5} = 84.375 \text{ kN}$$

$+M = 79.15$ kNm ($x = 2.00$ m)

K501



M_d=79.15 kNm

$$A_{s1} = \frac{M_{d1}}{f_{yd} j\, d} = \frac{79.15 * 10^6}{365 * 0.86 * 470} = 536.5\, mm^2$$

Pas payı=30 cm

-M_d=126.653 kNm

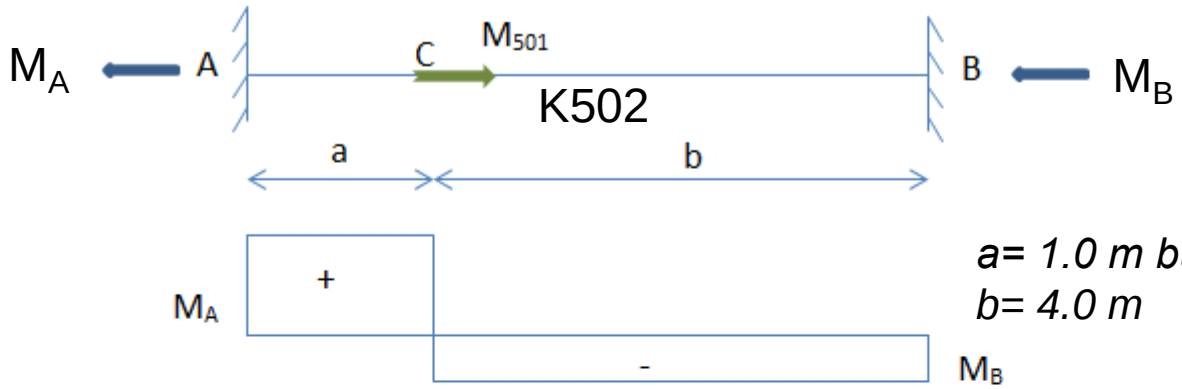
$$A_{s2} = \frac{M_{d2}}{f_{yd} j\, d} = \frac{126.653 * 10^6}{365 * 0.86 * 470} = 857.86\, mm^2$$

K502'ye saplandığı noktada;

$$M_A = M_{501}\frac{b}{a+b} \qquad M_B = M_{501}\frac{a}{a+b}$$

$$M_A = T_{cr} \qquad M_{501} = T_{cr}\frac{a+b}{b} = 20.25\frac{5}{4} = 25.31\ kNm$$

$$M_B = 20.25\frac{1}{5} = 5.06\ kNm$$



a= 1.0 m burulma açıklığı
b= 4.0 m

$$M_A = M_{501}\frac{b}{a+b} \qquad M_B = M_{501}\frac{a}{a+b}$$

$$M_A = T_{cr} \qquad M_{501} = T_{cr}\frac{a+b}{b} = 20.25\frac{5}{4} = \boxed{25.31\ kNm}$$

$$M_B = 20.25\frac{1}{5} = 5.06\ kNm$$

$$-A_s = \frac{\boxed{25.31x10^6}}{365x0.86x470} = 171.55\ mm^2$$

$$S = \frac{1}{3} b_w^2 h = \frac{1}{3} * 30^2 * 50 = 15000\ cm^3$$

$$T_{cr} = 1 * 1.35 * 15000 * 10^{-3} = 20.25\ kNm$$

$$-A_S = \frac{25.31x10^6}{365x0.86x470} = 171.55\ mm^2$$

$$M_{501} = T_{cr} \frac{a+b}{b} = 20.25 \frac{5}{4} = 25.31\ kNm$$

$$V_d = 140.625 - 45\left(0.470 + \frac{0.30}{2}\right) = 112.725\ kN$$

$$V_{cr} = 0.65\ f_{ctd}\ b_w\ d = 0.65 * 1 * 300 * 470 * 10^{-3} = 91.65\ kN$$

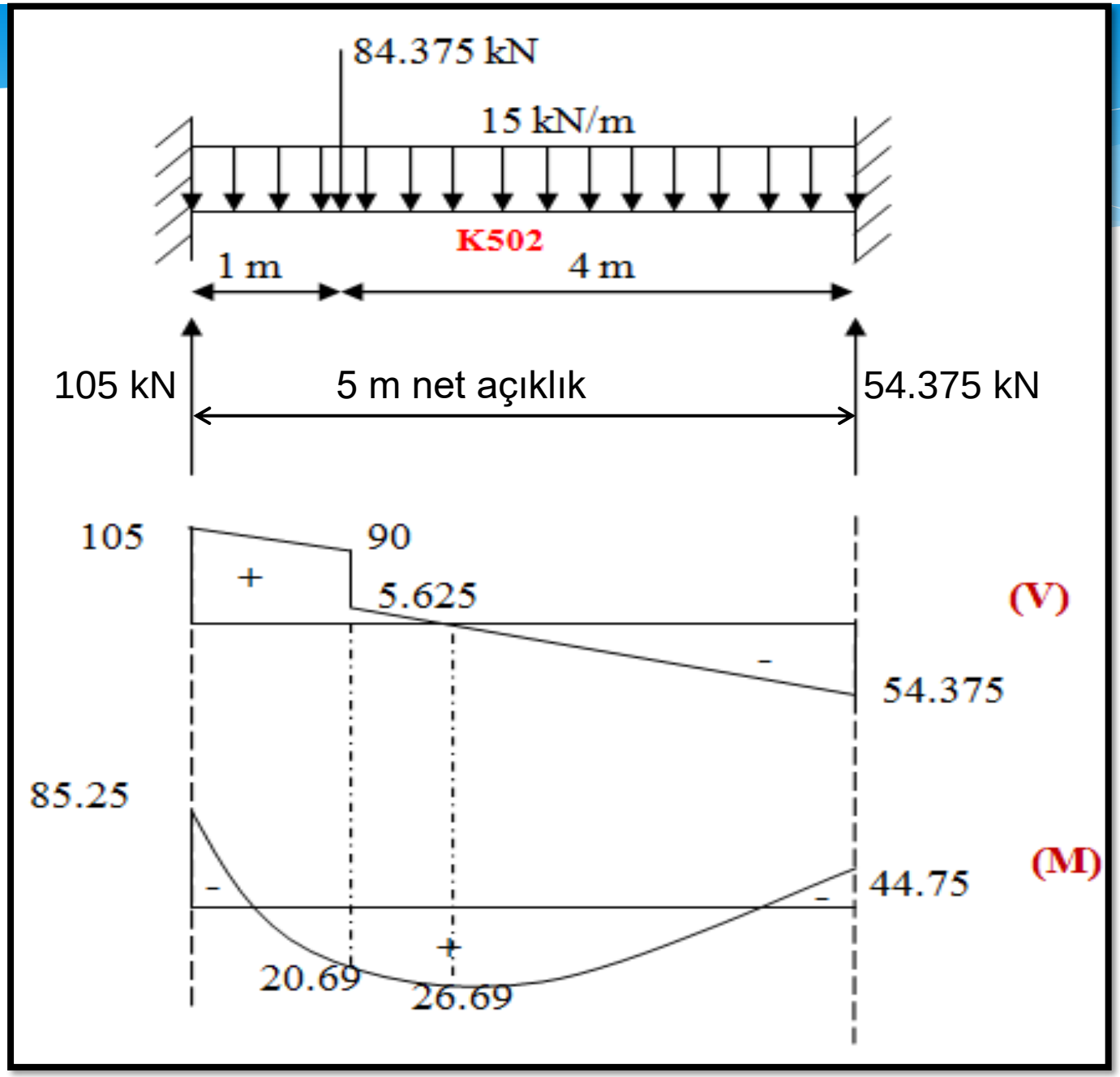
$$V_c = 0.8 * V_{cr} = 73.32\ kN$$

$$V_d > V_{cr}$$

$$min\frac{A_{sw}}{s} = 0.3\frac{f_{ctd}}{f_{ywd}}b_w = 0.47\ \frac{mm^2}{mm}$$

$$\frac{A_{sw}}{s} = \frac{V_d - V_c}{f_{ywd}\ d} = \frac{(112.725 - 73.32) * 10^3}{191 * 470} = 0.44\frac{mm^2}{mm} < 0.47\frac{mm^2}{mm}$$

Ø8 / 20 cm kullanılır.


84.375 kN
15 kN/m
K502
1 m
4 m
105 kN
5 m net açıklık
54.375 kN
105
90
+
5.625
(V)
-
54.375
85.25
(M)
44.75
-
-
+
20.69
26.69

K502

$+M_d = 26.69$ kNm

$$K_1 = \frac{4.95}{13 * 10^{-3}} = 380\,mm^2/kN \quad , \quad K = \frac{300 * 470^2}{26.69 * 10^6} = 2482 \ mm^2/kN \quad , \quad K > K_1$$

$$A_{s1} = \frac{M_{d1}}{f_{yd} j\, d} = 181\ mm^2$$

$-M_d = 85.25$ kNm Mesnet yüzünde (açıklık net olarak verildi.)

$$K_1 = \frac{4.95}{13 * 10^{-3}} = 380\,mm^2/kN \quad , \quad K = \frac{300 * 470^2}{85.25 * 10^6} = 777 \ mm^2/kN \quad , \quad K > K_1$$

$$A_{s2} = \frac{M_{d2}}{f_{yd} j\, d} = 578\ mm^2$$

V_d = *105 kN* Mesnet yüzünde (açıklık net olarak verildi.)
Mesnet yüzünden *d* uzaklıkta V_d=*105-15*0.470=97.95 kN*

$$V_{cr} = 0.65\, f_{ctd}\, b_w\, d = 0.65 * 1 * 300 * 470 * 10^{-3} = 91.65\ kN$$

$$V_c = 0.8 * V_{cr} = 73.32\ kN$$

$$T_d = T_{cr} = 20.25\ kNm$$

$$\min\frac{A_o}{s} = 0.15\frac{f_{ctd}}{f_{ywd}}(1+1.3\frac{T_{cr}}{V_d b_w})b_w$$

$$=0.15\frac{1}{191}(1+1.3\frac{20.25*10^3}{97.95*300})300 = 0.446$$

Yalnız kesme için gerekli etriye alanı;

$$\frac{A_{os}}{s} = \frac{A_{sw}}{2s} = \frac{V_d - V_c}{2\, f_{ywd}\, (d)} = \frac{(97.95-73.32)*10^3}{2*191*470} = 0.14 < 0.446\ mm$$

$$\min\frac{A_o}{s} = 0.446 \quad \phi 8/11\ cm$$

$$U_e = 2(440 + 240) = 1360\ mm$$

$$A_e = 440 * 240 = 105600\ mm^2$$

$$\min A_{sl} = \frac{T_d U_e}{2 f_{yd} A_e} = \frac{20.25 * 10^6 * 1360}{2 * 365 * 105600} = 357.25 mm^2$$

K501 kirişinin her iki ucu da mafsallı kabul edilirse mesnetteki dönme açısı, $\theta_B = \frac{P_d L^3}{24EI}$

$\theta_B = \frac{P_d L^3}{24EI}$

$I_{K501} = 30*(50)^3/12 = 3.125*10^5\ cm^4$ $\quad E = 2850\ kN/cm^2$

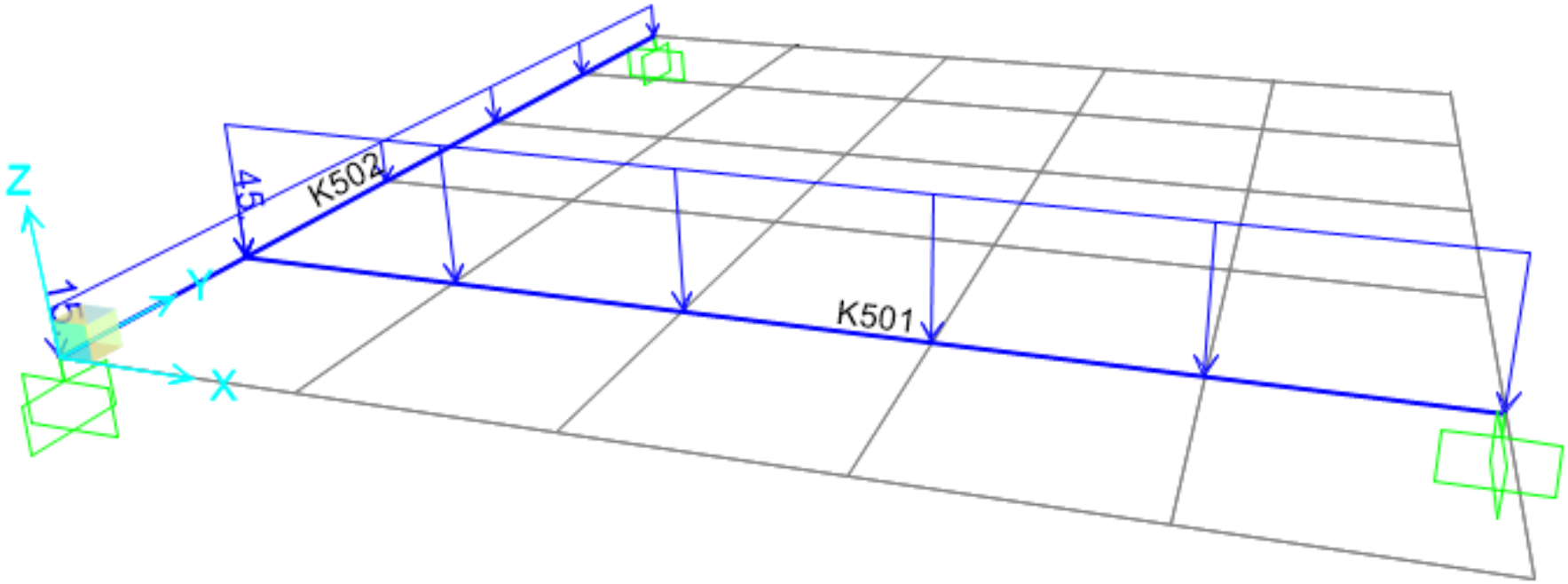
$EI = 89.06*10^7\ kN\ cm^2$ olur.

$$\theta_B = \frac{0.45*(500)^3}{24*89.06*10^7} = 2.632*10^{-3}\ rad$$

a= 1.0 m burulma açıklığı

$\phi = \theta_B / 1\ m = 2.632*10^{-3}\ rad/m < 10*10^{-3}\ rad/m$

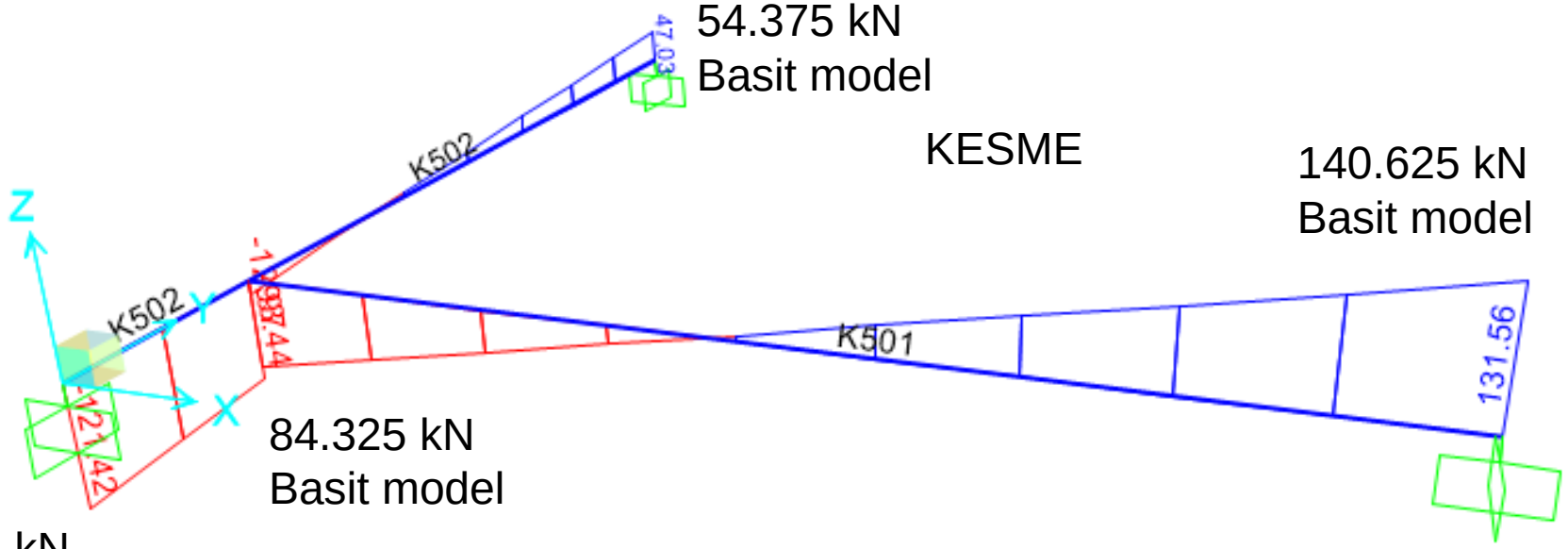
SAP2000 ile 3 Boyutlu



54.375 kN
Basit model

KESME

140.625 kN
Basit model



84.325 kN
Basit model

105 kN
Basit model

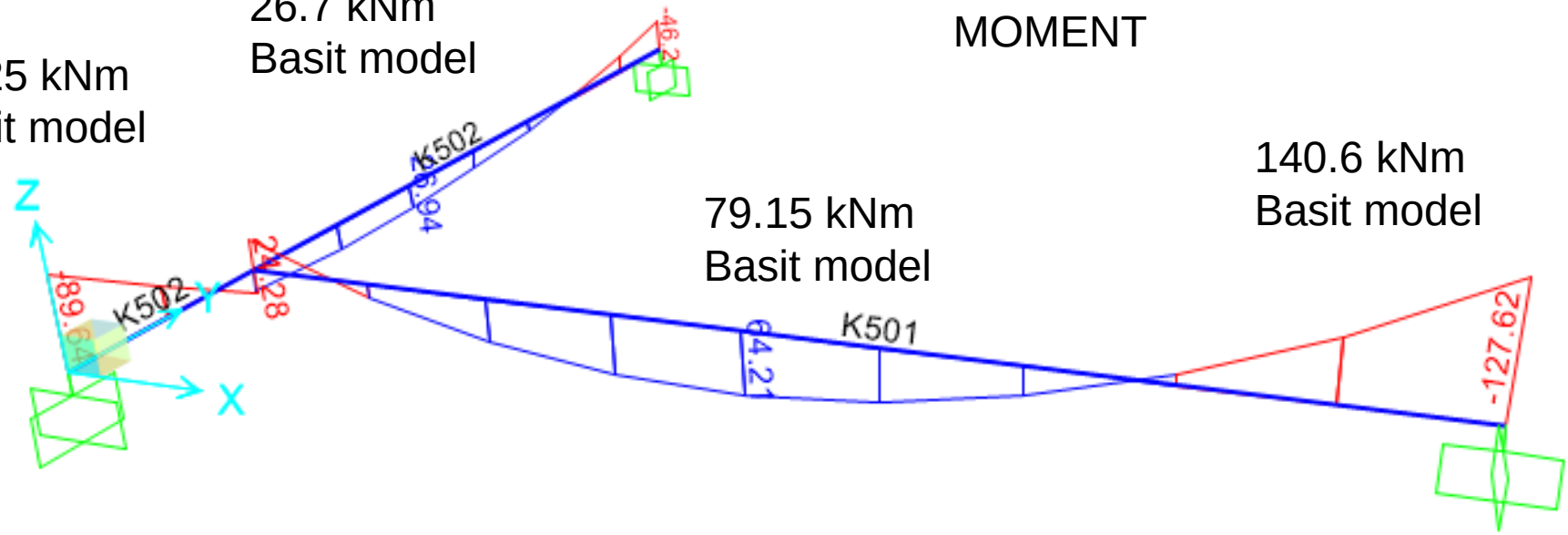
26.7 kNm
Basit model

MOMENT

85.25 kNm
Basit model

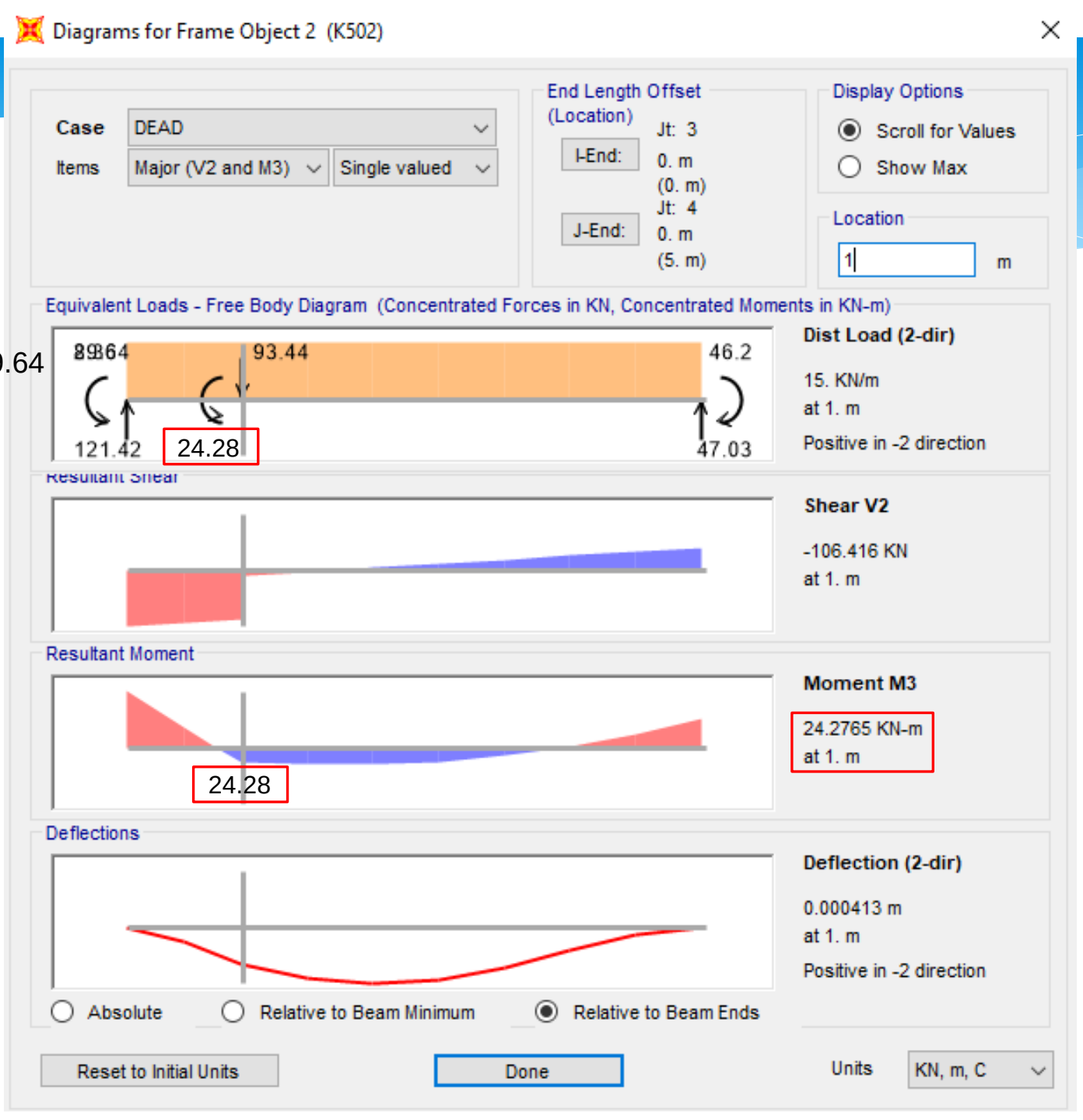
140.6 kNm
Basit model

79.15 kNm
Basit model

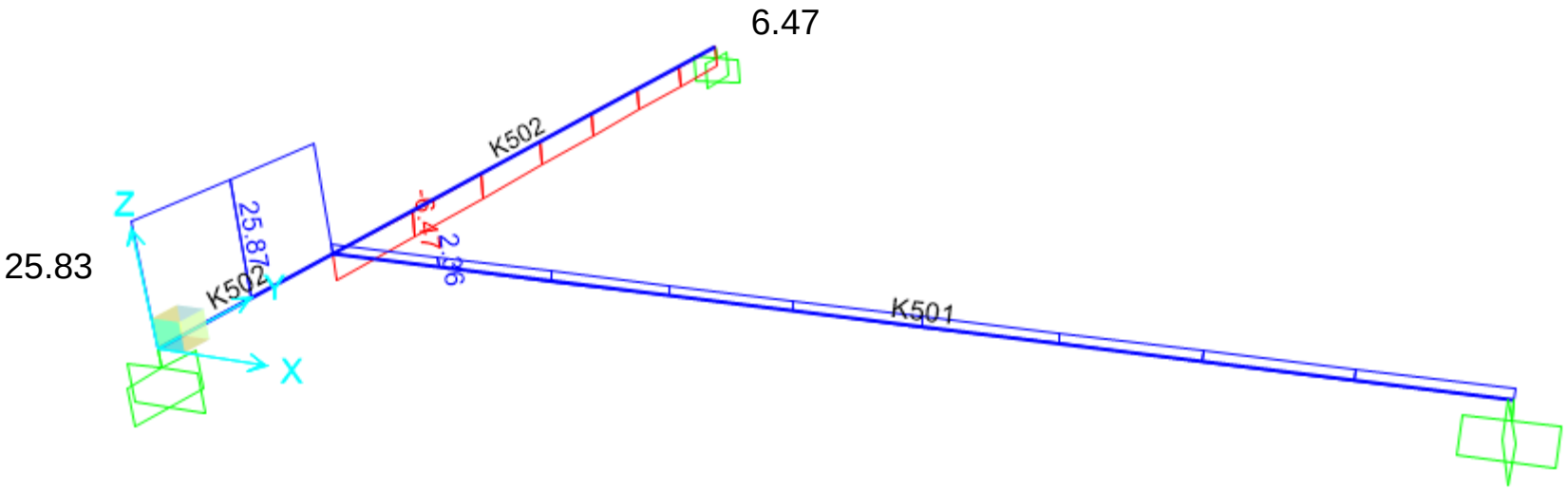


89.64

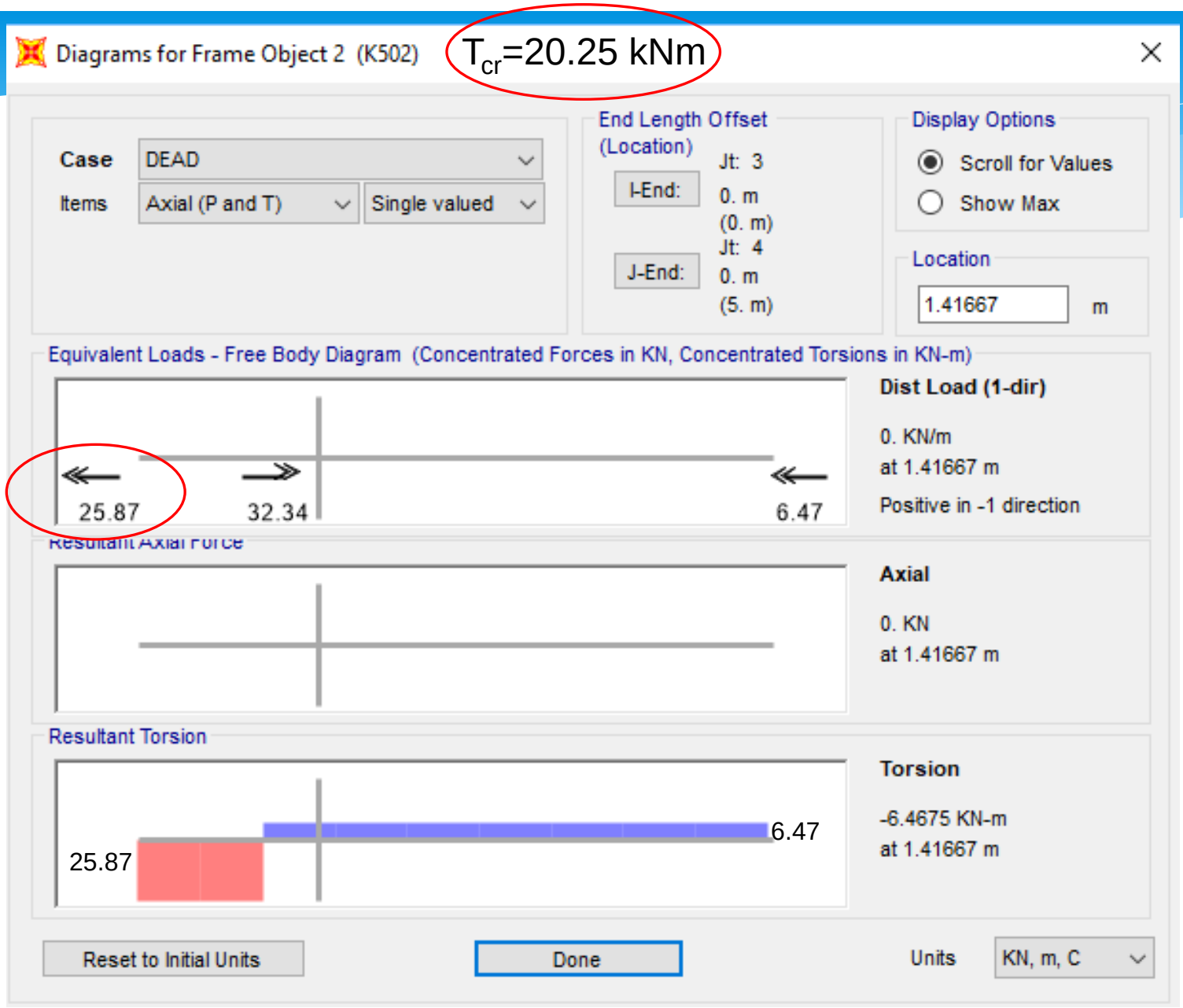
K502


Diagrams for Frame Object 2 (K502)
Case
DEAD
Items
Major (V2 and M3)
Single valued
End Length Offset (Location)
I-End:
Jt: 3
0. m
(0. m)
J-End:
Jt: 4
0. m
(5. m)
Display Options
Scroll for Values
Show Max
Location
1
m
Equivalent Loads - Free Body Diagram (Concentrated Forces in KN, Concentrated Moments in KN-m)
89.64
93.44
46.2
121.42
24.28
47.03
Dist Load (2-dir)
15. KN/m
at 1. m
Positive in -2 direction
Resultant Shear
Shear V2
-106.416 KN
at 1. m
Resultant Moment
24.28
Moment M3
24.2765 KN-m
at 1. m
Deflections
Deflection (2-dir)
0.000413 m
at 1. m
Positive in -2 direction
Absolute
Relative to Beam Minimum
Relative to Beam Ends
Reset to Initial Units
Done
Units
KN, m, C

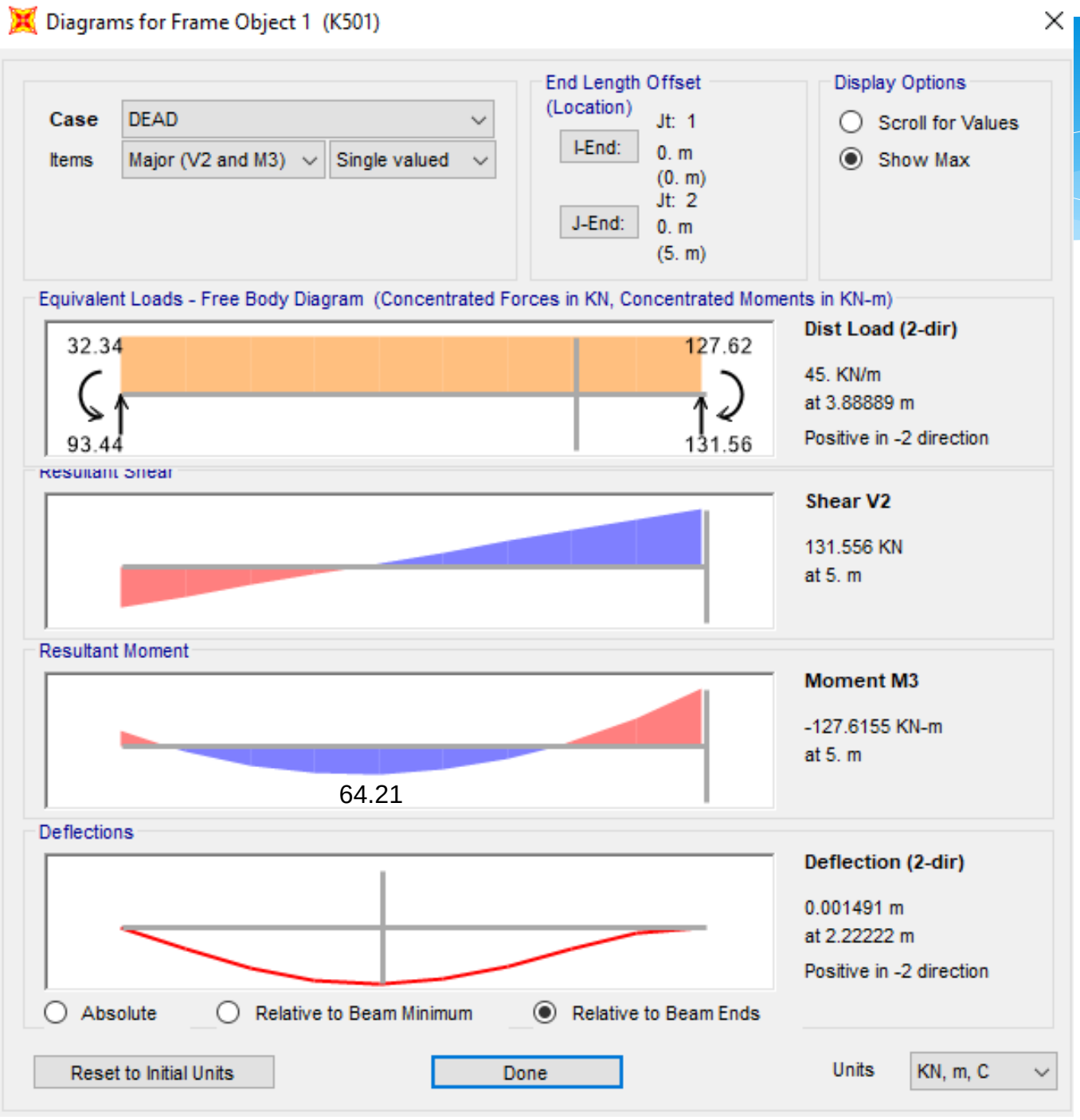
BURULMA MOMENTİ (T_{cr}=20.25 kNm)



K502


Diagrams for Frame Object 2 (K502)
T_{cr}=20.25 kNm
Case
DEAD
Items
Axial (P and T)
Single valued
End Length Offset (Location)
I-End:
Jt: 3
0. m
(0. m)
J-End:
Jt: 4
0. m
(5. m)
Display Options
Scroll for Values
Show Max
Location
1.41667
m
Equivalent Loads - Free Body Diagram (Concentrated Forces in KN, Concentrated Torsions in KN-m)
25.87
32.34
6.47
Dist Load (1-dir)
0. KN/m
at 1.41667 m
Positive in -1 direction
Resultant Axial Force
Axial
0. KN
at 1.41667 m
Resultant Torsion
25.87
6.47
Torsion
-6.4675 KN-m
at 1.41667 m
Reset to Initial Units
Done
Units
KN, m, C

K501



Sonraki Bölüm