

YILDIZ TEKNİK ÜNİVERSİTESİ * FEN BİLİMLERİ ENSTİTÜSÜ

**Tek Açıklıklı Kirişli Köprülerde
Yük Dağılımı**

Hasan Parlak

Yüksek Lisans Tezi

YILDIZ ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ

**TEK AÇIKLIKLI KİRİŞLİ KÖPRÜLERDE YÜK DAĞILIMININ
BURULMA TEORİSİ YARDIMI İLE BULUNMASI ve SONUÇLARIN
COURBON YÖNTEMİ İLE KIYASLANMASI.**

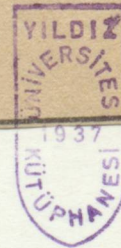
(YÜKSEK LİSANS TEZİ)

**HASAN PARLAR
İnş. Müh.**

İstanbul - 1986

YILDIZ UNİVERSİTESİ
GENEL KİTAPLIĞI

Kot : R 150
Alındığı Yer : Fen Bil. Ens. 77
Tarih : 8.12.1986
Fatura : -
Fiatı : 1.500 TL
Ayniyat No : 1/32
Kayıt No : 44631
UDC :
Ek :



Comp

YILDIZ ÜNİVERSİTESİ

D.B. No. 42449

YILDIZ ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ

TEK AÇIKLIKLI KİRİŞLİ KÖPRÜLERDE YÜK DAĞILIMININ
BURULMA TEORİSİ YARDIMI İLE BULUNMASI VE
SONUÇLARIN COURBON YÖNTEMİ İLE KIYASLANMASI.

(YÜKSEK LİSANS TEZİ)

TEZİ YÖNETEN : Doç. Naci YÜCEFER

TEZİ HAZIRLAYAN : İnş.Müh.Hasan PARLAR

İSTANBUL 1986

Bu çalışmanın ortaya çıkmasında değerli ilgi ve desteğini gördüğüm hocam Doç.Naci YÜCEFER'e teşekkürlerimi sunarım.

	I
	II
İÇİNDEKİLER	
ÖZET	II
SUMMARY	III
I. GİRİŞ	I
I.1.St.Venant burulması	I
I.2.Zorlama burulması	I
I.3.Bimoment	2
I.4.Kayma Merkezi	2
I.5.Burulma diferansiyel Denklemi	3
I.6.Çarpılma Gerilmeleri	3
2. COURBON YÖNTEMİ	4
3. SAYISAL ÖRNEKLER	5
3.1.Genel açıklamalar	5
3.2.Dört ana kirişli ve tek açıklıklı köprülerde yük dağılımının burulma teorisi yardımı ile bulunması ve sonuçların Courbon yöntemi ile kıyaslanması.	6
3.3.Beş ana kirişli ve tek açıklıklı köprüde yük dağılımının bulunması	37
3.4.Altı ana kirişli ve tek açıklıklı köprülerde yük dağılımının bulunması	79
4. SONUÇ	128
KAYNAKLAR	138
ÖZ GEÇMİŞ	139

ÖZET

Tek açıklıklı ve kirişli köprülerde yük dağılımını burulma teorisi ile bulmak uzun bir yöntemdir. Aynı iş Courbon yöntemi ile çabuk ve basit şekilde bulunabilir.

Bu çalışmada tek açıklıklı ve dört ,beş, altıana kirişli köprülerde açıklık ortasındaki yük dağılımı burulma teorisi yöntemi ile bulunup, Courbon yöntemi ile kıyaslanmıştır. Bu iki yöntemin sonuçlarının birbirine son derece yakın çıktığı görülmüştür.

III

Kaliteli çeliklerin taşıyıcı sistemlerde kullanılmasıyla birlikte malzeme kalitelerinin de azalmıştır. Bu nedenle bu taşıyıcı sistemlerde burulma kavramı önem kazanmıştır. Burulma teorisiyle ilgili kavramlar aşağıda açıklanmıştır. İki cins burulma vardır.

1.1-St. VENANT BURULMASI. (Fiziksel burulma)

İki uçundan birbirine ait yönde burulma etkileri olan bir çubukta, bu yönden oluşan boylama deplasmanlar herhangi bir sebeple, herhangi bir noktada keskin yönde engellenirse, bu durumda oluşan burulma türüne "St. Venant burulması" denir. Bu tür burulma durumunda boylama yönündeki tüm kesit-

SUMMARY

To find the load distribution for a single span girder bridge using the torsion theory approach is long and tedious work. However, using the Courbon method one can do the same work simply and quickly.

This study has been a comparison of the torsion theory with the Courbon method for finding the middle load distribution of single span four, five, and six main girder bridges, it has been seen that the results using both methods come extremely close to one another.

I - GİRİŞ

Kaliteli çeliklerin taşıyıcı sistemlerde kullanılmasıyla birlikte malzeme kalınlıkları da azalmıştır. İnce cidarlı bu taşıyıcı elamanlarda burulma kavramı önem kazanmıştır. Burulma teorisiyle ilgili kavramlar aşağıda özetlenmiştir. İki cins burulma vardır.

I.1-St.VENANT BURULMASI.(Primer burulma: M_t)

İki ucundan birbirine zıt yönde burulma etkileri olan bir çubukta ,bu yüzden oluşan boylama deplasmanlar herhangi bir sebeple,örneğin mesnetlenme durumu yüzünden engellenmezse söz konusu olan burulma türüne "St.Venant burulması" denir.Bu tür burulma durumunda boylama yönündeki tüm kesitler boyuna yönde aynı deplasmanı yaparlar.Bunun sonucu olarak da normal gerilme oluşmaz.Bir diğer deyişle de Kesitlerde normal gerilme yaratmayan burulma cinsine veya kısmına St.Venant burulması denir.

$$M_T: G.J_t.\varphi'$$

G:Kayma modülü.

J_t :Dril mukavemeti.

φ' :Dönme açısı 1.türevi.

$$J_t:I/3 \sum s_j.t_j^3 \quad (I=0,630 t_j/s_j)$$

s_j : Çok kollu kesitlerde j kolunun boyu

t_j : j kolunun cidar kalınlığı.

Hazır profiller için k değeri çelik kitaplarından alınmak üzere şu formül kullanılabilir.

$$J_t:k .I/3 \sum s_j.t_j^3$$

I.2- ZORLAMA BURULMASI (Sekunder burulma: M_z)

Çubuk kesitindeki toplam burulma momentinin normal gerilme vermeyen kısmına "St.Venant burulması" olarak adlandırılmıştık. Ancak çubuğun özelliğine bağlı olarak, mesnetlenme, yükleme durumu, kesit geometrisinden oluşan normal gerilmelerle birlikte denge şartlarından yukarıda belirtilen kayma gerilmeleri oluşmaktadır. Bu kayma gerilmelerinin bileşke burulma momentine 'zorlama veya çarpılma burulması' adı verilir.

Ağırlık merkezi asal eksenlerden geçirmek ve kayma merkezini (M) noktası almakla aşağıdaki formül elde edilir.

$$M_z : -E \cdot J_{ww} \cdot \varphi'''(x)$$

I.3- BİMOMENT: M_w (Çarpılma burulması momenti integrali)

$$M_w : \int M_z \cdot dx \quad \text{veya} \quad M_w : -E \cdot J_{ww} \cdot \varphi''(x)$$

I.4- KAYMA MERKEZİ: (M)

Zorlama burulması (Sekunder) kayma gerilmelerinin bileşkesi olduğuna göre, bu bileşke kayma merkezinden geçen bir kuvvet şeklinde olduğunda (veya kesme kuvveti kayma merkezinden geçtiğinde) kesitte burulma meydana gelmez.

Bu noktanın bir özelliğide, bu nokta merkez olarak bulunan çarpılma koordinatları (w_m) ile hesaplanan sektör atalet momentinin ($J_{w_m w_m}$) minimum oluşudur. Bu itibarla kayma merkezinden geçen eksen aynı zamanda çubuğun "Tabii dönme eksenidir".

(M) noktasının yeri şu şekilde belirlenir.

$$y_m: \frac{J_y \cdot w_s}{J_{yy}} \quad , \quad z_m: \frac{-J_{yz} w_s}{J_{zz}}$$

Bu şekilde bulunmuş olan noktaya 'Kayma merkezi' denir.

I.5-BURULMA DİFERANSİYEL DENKLEMİ

Bu denklemi elde etmek için toplam burulma momentini yazalım.

$$M_{T\Sigma} = M_t + M_z$$

Buradaki değeri φ cinsinden yazarsak gerekli denklem elde edilir.

$$M_{T\Sigma} = -E \cdot J_{ww} \varphi''' + G \cdot J_t \cdot \varphi'$$

$$k = \sqrt{\frac{G_s J_t}{E \cdot J_{ww}}}$$

Dönme açısı

$$\varphi = M_{T\Sigma} / (G \cdot J_t) \left(x/2 - \frac{\text{sh}(kl/2)}{k \cdot \text{sh}(kl)} \cdot \text{sh}(kx) \right) \quad (0 \leq x \leq l/2)$$

Dönme açısının gerekli türevleri.

$$\varphi' = M_{T\Sigma} / (G \cdot J_t) \cdot (1/2 - \text{sh}(kl/2) / \text{sh} kl) \cdot \text{ch} kx$$

$$\varphi'' = -M_{T\Sigma} / (G \cdot J_t) \cdot \text{sh}(kl/2) \cdot k \cdot \text{sh} kx / \text{sh} kl$$

$$\varphi''' = -M_{T\Sigma} / (G \cdot J_t) \cdot \text{sh}(kl/2) \cdot k^2 \cdot \text{ch} kx / \text{sh} kl$$

I.6- ÇARPILMA GERİLMELERİ (G_x , τ_x)

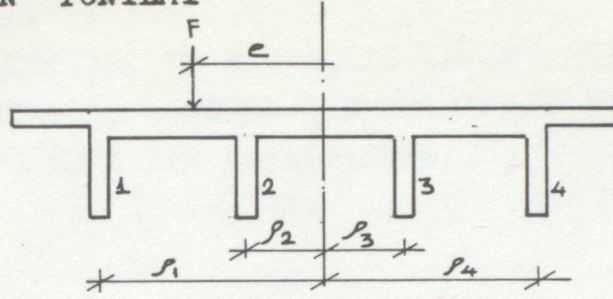
$$G_x = \frac{N}{F} + \frac{M_y}{J_{yy}} \cdot z - \frac{M_z}{J_{zz}} \cdot y + \frac{M_w}{J_{ww}} \cdot w_m$$

$$G_{xw} = \frac{M_w}{J_{ww}} \cdot w_m$$

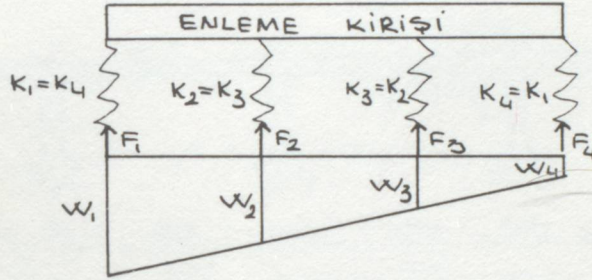
kayma gerilmesi

$$\Delta \tau_w = \tau_w = - \frac{M}{J_{ww}} \cdot \frac{S_{ww}(s)}{t(s)}$$

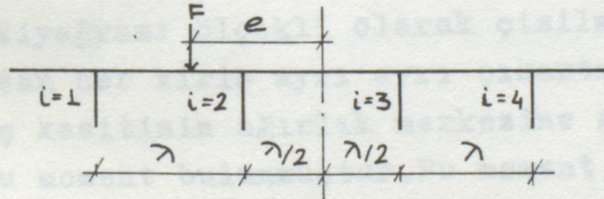
2- COURBON YÖNTEMİ



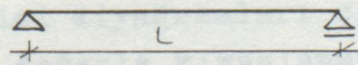
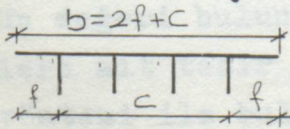
$$\begin{aligned} n &= 4 \\ f_1 &= -f_4 \\ f_2 &= -f_3 \end{aligned}$$



courbon yönteminde kirişlere nazaran enlemeler çok rijid ($J_e: \infty$) olduğu kabul edilir. Böylelikle enlemelerin sehim eğrisi doğrusaldır. Basit mesnetli çok kirişli bir köprüde, kirişlerin açıklıkları (köprü boyu), genişliğinin iki katından büyük olduğu zaman bu yöntem uygun sonuç verir.



-Courbon formülünün atalet momentleri eşit ve kiriş açıklıkları eşit sistemler için özel şekli.



$$L > 2b$$

$$\Delta_i: I + 6 \frac{n+I-2i}{+n^2-I} \frac{e}{\lambda}$$

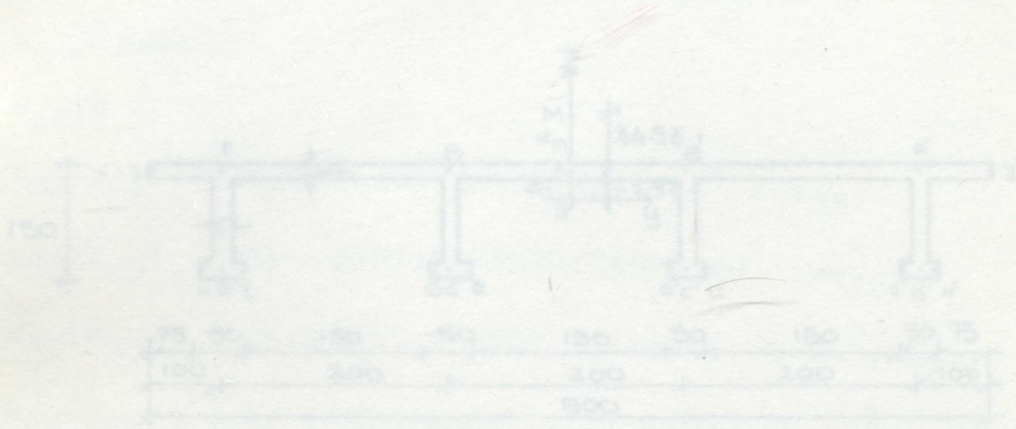
$$F_i: \frac{I}{n} F \cdot \Delta_i$$

n: Ana kiriş sayısı

not: Kiriş noları eksantrik taraftan başlar.

3.2- ÖRNEK 1

DÜRT ANA KIRIŞLI VE TEK AÇIKLIKLI KÖPRÜDE YÜK DAĞILIMININ BURULMA TEORİSİ YARDIMI İLE BULUNMASI VE SONUÇLARIN COURBON YÖNTEMİ İLE KIYASLANMASI.



3 - SAYISAL ÖRNEKLER

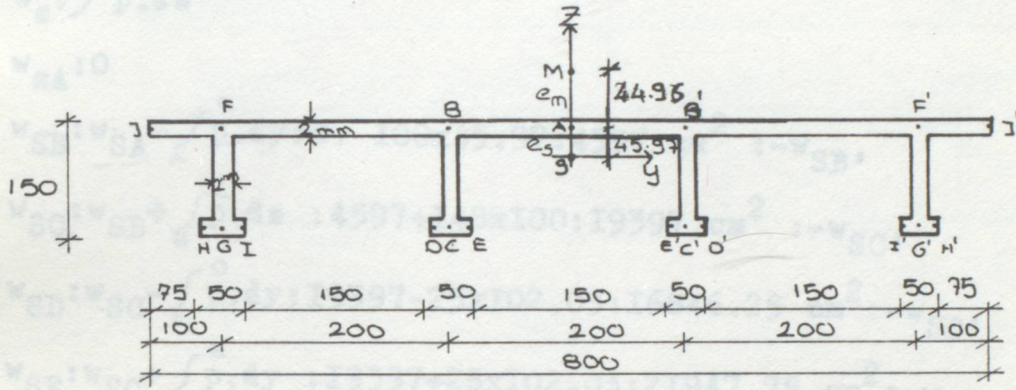
3.1- GENEL AÇIKLAMALAR

Bu bölümde tek açıklıklı kirişli köprülerde yük dağılımını sadece açıklık ortası için incelenmiştir. Köprünün açıklık ortası enkesiti bir metrelik parçalara bölünmüştür. Bir tonluk birim gezici kuvvetin her metredeki pozisyonu için yük dağılımı kirişler için tek tek incelenmiştir.

Burulma teorisine göre bulunan açıklık ortası normal gerilme diyagramı ölçekli olarak çizilmiştir. Bu ölçekli diyagramdan her kiriş ayrı ayrı çıkartılarak incelenmiştir, Kiriş kesitinin ağırlık merkezine göre kuvvetlerin doğurduğu moment bulunmuştur. Bu moment değerinden o kirişe düşen yük bulunup, bir tonluk kuvvetin ana kiriş sayısına bölünmesiyle bulunan değerle toplanıp o kirişe düşen yükün değeri bulunur. Bulunan bu değerler yardımı ile kirişlere ait tesir çizgisi diyagramları çizilmiştir. Courbon yöntemi ile bulunan değerle kıyaslanmıştır.

not: Tüm sayısal örneklerde cidar kalınlığı ($t:2\text{cm}$), $l=20\text{m}$, Köprü yüksekliği ($h:15\text{m}$), Kiriş aralıkları ($\lambda:2\text{m}$) alınmıştır.

3.2- ÖRNEK I
DÖRT ANA KIRIŞLI VE TEK AÇIKLIKLI KÖPRÜDE YÜK DAĞILIMININ
BURULMA TEORİSİ YARDIMI İLE BULUNMASI VE SONUÇLARIN
COURBON YÖNTEMİ İLE KIYASLANMASI.



3.2.I- AĞIRLIK MERKEZİ VE BURULMA ATALET MOMENTİNİN
BULUNUŞU.

$$E_s = \frac{2 \times 800 \times I_{49} + 2 \times I_{46} \times 75 \times 4 + 2 \times 50 \times 4}{2 \times 800 + 2 \times I_{46} \times 4 + 2 \times 50 \times 4} : 103.03 \text{ cm.}$$

$$e_s : 150 - 103.03 - 1 : 45.97 \text{ cm.}$$

$$J_t : I/3 \sum s_j \cdot t_j^3 : I/3 (2^3 \times 800 + 2^3 \times I_{46} \times 4 + 2^3 \times 50 \times 4) : 4224 \text{ cm}^4.$$

3.2.2-Z-Z ATALET MOMENTİNİN BULUNUŞU

$$J_{zz} : \int y^2 \cdot dA : 800^2 \times 2 / I_2 + 2 \times (I_{46} \times 2^3 / I_2 + I_{46} \times 2 \times I_{00}^2) \\ + 2 \times (I_{46} \times 2^3 / I_2 + I_{46} \times 2 \times 300^2) + 2 \times (50^3 \times 2 / I_2 + 50 \times 2 \times I_{00}^2) \\ + 2 \times (50^3 \times 2 / I_2 + 50 \times 2 \times 300^2) : 163817056 \text{ cm}^4.$$

3.2-3 - AĞIRLIK MERKEZİNE GÖRE BİRİM ÇARPILMA

KOORDİNATLARI (w_g):

Kesitin simetri özelliğinden yararlanarak w_g değerlerinin bulunuşuna simetrik eksen (z) üzerindeki A noktasından başlayalım. (saatin tersi yönünde pozitif)

$$w_g = \int p \cdot ds$$

$$w_{SA} = 0$$

$$w_{SB} = w_{SA} + \int_A^B p \cdot dy = 0 + 100 \times 45.97 = 4597 \text{ cm}^2 = -w_{SB}$$

$$w_{SC} = w_{SB} + \int_B^C p \cdot dz = 4597 + 148 \times 100 = 19397 \text{ cm}^2 = -w_{SC}$$

$$w_{SD} = w_{SC} - \int_C^D p \cdot dy = 19397 - 25 \times 102.03 = 16846.25 \text{ cm}^2 = -w_{SD}$$

$$w_{SE} = w_{SD} + \int_D^E p \cdot dy = 16846.25 + 25 \times 102.03 = 21947.75 \text{ cm}^2 = -w_{SE}$$

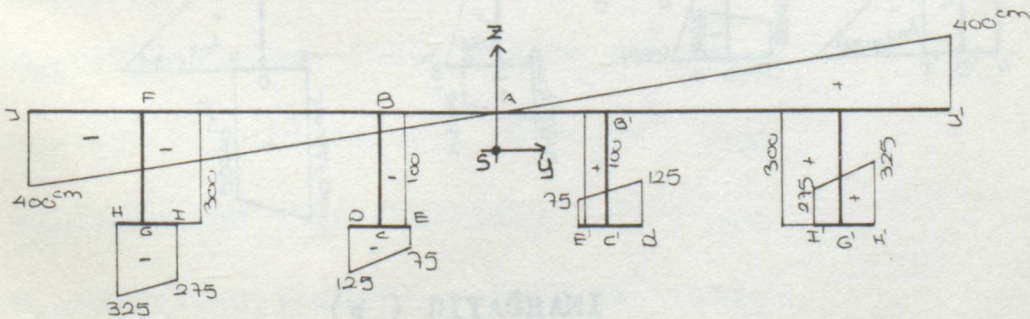
$$w_{SF} = w_{SE} + \int_E^F p \cdot dy = 21947.75 + 200 \times 45.97 = 33141.75 \text{ cm}^2 = -w_{SF}$$

$$w_{SG} = w_{SF} + \int_F^G p \cdot dz = 33141.75 + 148 \times 300 = 77681.75 \text{ cm}^2 = -w_{SG}$$

$$w_{SH} = w_{SG} - \int_G^H p \cdot dy = 77681.75 - 25 \times 102.03 = 75166.75 \text{ cm}^2 = -w_{SH}$$

$$w_{SI} = w_{SH} + \int_H^I p \cdot dy = 75166.75 + 25 \times 102.03 = 75668.75 \text{ cm}^2 = -w_{SI}$$

$$w_{SJ} = w_{SI} + \int_I^J p \cdot dy = 75668.75 + 400 \times 45.97 = 93755.75 \text{ cm}^2 = -w_{SJ}$$



(Y) DİYAĞRAMI

3.2-3 BİMETRİK DİSTRİBÜYON MOMENTİ (J_{xy})

Kaynak merkezinin bulunduğu için gerekli olan bu değer

$$J_{xy} = \int y \cdot x \cdot dA$$

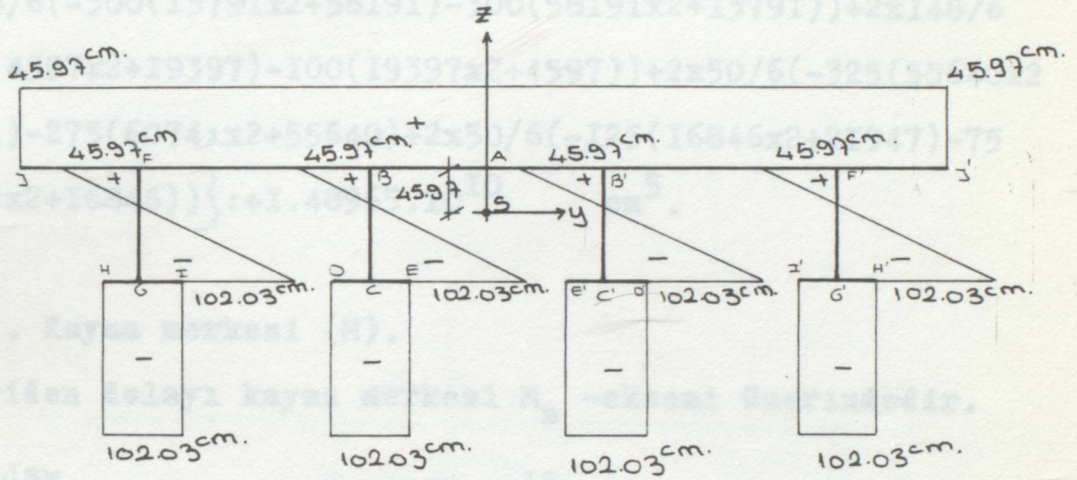
$$J_{xy} = 2 \times \left\{ 800/6 \cdot (-400 (18388 \times 2 - 18388) + 400 (-18388 \times 2 + 18388)) \right.$$

$$+ 2 \times 148/6 \cdot (-300 (13791 \times 2 + 58191) - 100 (58191 \times 2 + 13791)) + 2 \times 148/6$$

$$\cdot (-100 (100 (-19397) - 100 (19397 \times 2 + 4597)) + 2 \times 50/6 \cdot (-324 (58191 \times 2 + 13791))$$

$$+ 60741 \cdot (-100 (100 (-19397) - 100 (19397 \times 2 + 4597)) + 2 \times 50/6 \cdot (-324 (13791 \times 2 + 58191))) \cdot 75$$

$$(21947 \times 2 + 100 (100 (-19397) - 100 (19397 \times 2 + 4597))) \cdot 75$$

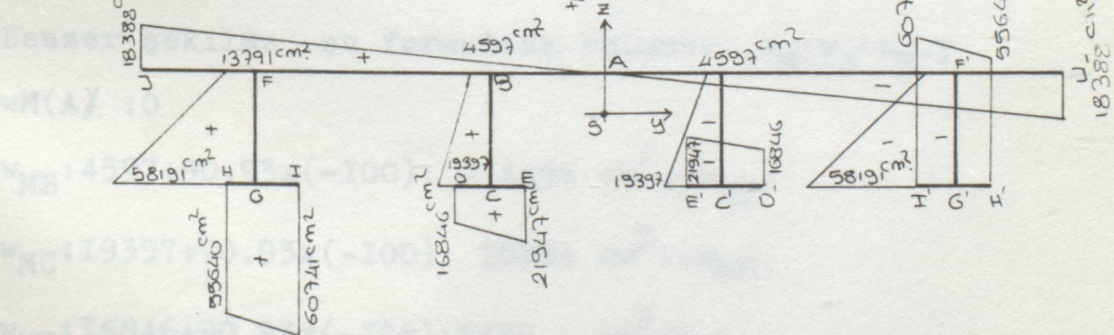


(Z) DİYAĞRAMI

$$J_{xy} = -1.48965 \cdot 10^8 \text{ cm}^4$$

3.2-5. KAYNAK MERKEZİNİN ÖZEL DİSTRİBÜYON MOMENTİNİN DİSTRİBÜYONU

(J_{yy})



(J_{yy}) DİYAĞRAMI

3.2-3 SEKTOR DEVIASYON MOMENTİ (J_{zw_s})

Kayma merkezinin bulunması için gerekli olan bu değer

$$J_{zw_s} : \int y \cdot w_s \cdot dA$$

$$J_{zw_s} : 2 \times \left\{ 800/6 (-400 (I_{8388x2} - I_{8388}) + 400(-I_{8388x2} + I_{8388})) \right. \\ + 2 \times I_{48/6} (-300(I_{379Ix2} + 58I_{9I}) - 300(58I_{9Ix2} + I_{379I})) + 2 \times I_{48/6} \\ (-100(4597x2 + I_{9397}) - 100(I_{9397x2} + 4597)) + 2 \times 50/6 (-325(55640x2 \\ + 60741) - 275(60741x2 + 55640)) + 2 \times 50/6 (-I_{25}(I_{6846x2} + 2I_{947}) - 75 \\ \left. (2I_{947x2} + I_{6846})) \right\} : +1.48965 \cdot 10^{10} \text{ cm}^5.$$

3.2-4.. Kayma merkezi (M).

Simetriden dolayı kayma merkezi M_z -ekseni üzerindedir.

$$z_M : - \frac{J_{zw_s}}{J_{zz}} : - \frac{-1.48965 \cdot 10^{10}}{163817056} : 90.93 \text{ cm.}$$

$$e_M : z_M - e_s : 90.93 - 45.97 : 44.96 \text{ cm.}$$

3.2-5.. KAYMA MERKEZİNE GÖRE BULUNAN ÇARPILMA KOORDİNATLARI (w_M).

Benzer şekilde şu formülden bulunur. $w_M : w_S + z_M \cdot y$

$$w_M(A) : 0$$

$$w_{MB} : 4597 + 90.93x(-100) : - 4496 \text{ cm}^2 : -w_{MB}$$

$$w_{MC} : I_{9397} + 90.93x(-100) : 10304 \text{ cm}^2 : -w_{MC}$$

$$w_{MD} : I_{6846} + 90.93x(-I_{25}) : 5479 \text{ cm}^2 : +w_{MD}$$

$$w_{ME} : 2I_{947} + 90.93x(-75) : 15128 \text{ cm}^2 : -w_{ME}$$

$$w_{MF} = I379I + 90.93x(-300) : -I3488 \text{ cm}^2. \quad :-w_{MF}$$

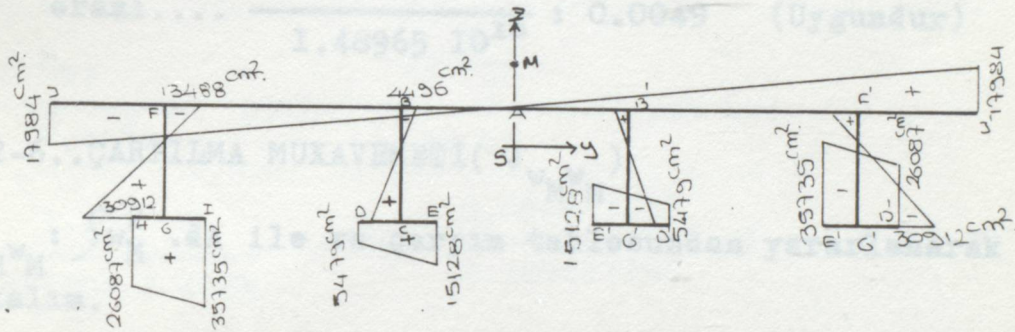
$$w_{MG} = 58I9I + 90.93 x(-300) : 309I2 \text{ cm}^2 \quad :-w_{MG}$$

$$w_{MH} = 55640 + 90.93x(-325) : 26087 \text{ cm}^2 \quad :-w_{MH}$$

$$w_{MI} = 6074I + 90.93x(-275) : 35735 \text{ cm}^2 \quad :-w_{MI}$$

$$w_{MJ} = I8388 + 90.93x(-400) : -I7984 \text{ cm}^2 \quad :-w_{MJ}$$

$-I7984) + 2xI48/6 (-300(-I3488x2+309I2) - 300(309I2x2-I3488))$
 $+ 2xI48/6 (-I00(-4496x2+I0304) - I00(I0304x2-4496)) + 2x50/6$
 $(-325(26087x2+35735) - 275(35735x2+26087)) + 2x50/6 (-I25$
 $(5479x2+I5I28) - 75(I5I28x2+5479)) \} : 72735I28 \text{ cm}^3$



(w_m) DİYAĞRAMI

$2x \{ 800/6 (-I7984(-I7984x2+I7984) - I7984(I7984x2$
 $-I7984)) + 2xI48/6 (-I3488(-I3488x2+309I2) + 309I2 (309I2x2$
 $-I3488)) + 2xI48/6 (-4496(-4496x2+I0304) + I0304(I0304x2$
 $-4496)) + 2x50/6 (26087(26087x2+35735) + 35735(2x35735+$
 $26087)) \} : 5.46I \cdot 10^{11} \text{ cm}^6$

3.2-7..Burulma Diferansiyel denklemleri ve çözümü.

$$E I \phi''(x) = M(x)$$

$$\text{Denklemleri } \kappa = \sqrt{\frac{G I_p}{E I}} = \sqrt{\frac{810000 \cdot 4224}{2100000 \cdot 15.46 \cdot 10^{11}}} = 5.46 \cdot 10^{-5} \text{ cm}^{-2}$$

$$\kappa = 5.46 \cdot 10^{-5} \text{ cm}^{-2}$$

KONTROL DENKLEMLERİ

$$\int z \cdot w_M \cdot dA : 0 \quad (\text{Simetri ve antimetriiden dolayı})$$

$$\int y \cdot w_M \cdot dA \approx 0$$

$$\int y \cdot w_M \cdot dA: 2 \times \left\{ 800/6 (-400(-17984x^2+17984)+400(17984x^2-17984))+ 2 \times I48/6 (-300(-13488x^2+30912)-300(30912x^2-13488)) + 2 \times I48/6 (-100(-4496x^2+10304)-100(10304x^2-4496))+ 2 \times 50/6 (-325(26087x^2+35735)-275(35735x^2+26087))+ 2 \times 50/6 (-125(5479x^2+15128)-75(15128x^2+5479)) \right\} : 72735128 \text{ cm}^5.$$

Kıyaslama

$$\text{oranı} \dots \frac{72735128}{1.48965 \cdot 10^{10}} : 0.0049 \quad (\text{Uygundur})$$

3.2-6..ÇARPILMA MUKAVEMETİ($J_{w_M w_M}$)

$J_{w_M w_M} : \int w_M^2 \cdot dA$ ile ve çarpım tablosundan yararlanarak bulalım.

$$J_{w_M w_M} : 2 \times \left\{ 800/6 (-17984(-17984x^2+17984)+17984(17984x^2-17984))+ 2 \times I48/6 (-13488(-13488x^2+30912)+ 30912 (30912x^2-13488))+ 2 \times I48/6 (-4496(-4496x^2+10304)+10304(10304x^2-4496))+ 2 \times 50/6 (26087(26087x^2+35735)+35735(2 \times 35735+26087)) \right\} : 5.461 \cdot 10^{11} \text{ cm}^6.$$

3.2-7..Burulma Diferansiyel denklemi ve çözümü.

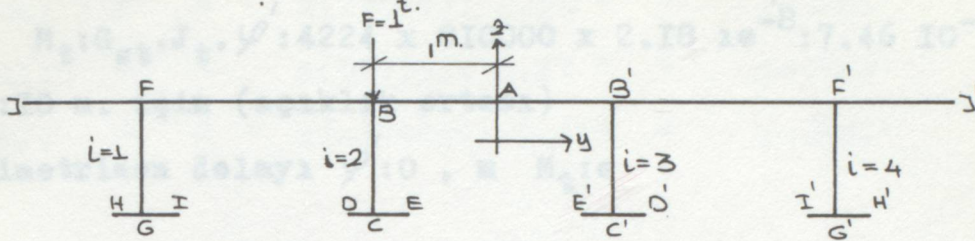
$$M_T \Sigma (x) : G_{st} \cdot J_t \cdot \varphi' - E_{st} \cdot J_{w_M w_M} \cdot \varphi''$$

$$\text{Denklemi } k : \sqrt{\frac{G_{st} \cdot J_t}{E_{st} \cdot J_{w_M w_M}}} : \sqrt{\frac{810000 \times 4224}{2100000 \times 5.46 \cdot 10^{11}}}$$

$$k : 5.46 \cdot 10^{-5} \text{ cm}^{-1}$$

3.2.a-... I. YÜKLEME

Dış burulma momenti $M_{T\Sigma} : Fx e : I x I : I \text{ tm.}$



Dönme açısının genel denklemi

$$\varphi : \frac{M_{T\Sigma}}{G_{st} \cdot J_t} \left(x/2 - \frac{\text{sh} \frac{k \cdot l}{2}}{\text{sh} k \cdot l} \text{sh} kx \right) \quad (0 < x < l/2)$$

$$\varphi' : \frac{M_{T\Sigma}}{G_{st} \cdot J_t} \left(l/2 - \frac{\text{sh} \frac{k \cdot l}{2}}{\text{sh} k \cdot l} \cdot \text{ch} kx \right)$$

$$\varphi' : \frac{1 \cdot 10^5}{810000 \cdot 4224} \left(0.50 - \frac{0.054627132}{0.109417157} \cdot 1.00 \right) : 2.18 \cdot 10^{-8} \text{ cm}^{-1}$$

$$\varphi'' : - \frac{1 \cdot 10^5}{810000 \cdot 4224} (5.46 \cdot 10^{-5}) \cdot 0.054627132 \cdot \frac{0.054627132}{0.109417157}$$

$$: -4.35 \cdot 10^{-11} \text{ cm}^{-2}$$

$$\varphi''' : - \frac{1 \cdot 10^5}{810000 \cdot 4224} \cdot \frac{0.054627132}{0.109417157} (5.46 \cdot 10^{-5})^2 \cdot 1.00 :$$

$$: -4.35 \cdot 10^{-14} \text{ cm}^{-3}$$

$$\text{sh} \frac{k \cdot l}{2} : \text{sh}(2000 \times 5.46 \cdot 10^{-5})/2 : 0.054627132$$

$$\text{sh} k \cdot l : \text{sh}(5.46 \cdot 10^{-5} \times 2000) : 0.109417157$$

- ..St.Venant burulma momenti (M_t) :

x:0 için.

$$M_t: G_{st} \cdot J_t \cdot \varphi' : 4224 \times 810000 \times 2.18 \cdot 10^{-8} : 7.46 \cdot 10^{-4} \text{ tm.}$$

x:10 m. için (açıklık ortası)

Simetriden dolayı $\varphi' : 0$, $M_t : 0$

- ..Çarpılma burulması (M_z)

x:0 için

$$M_z : E_{st} \cdot J_{w_M w_M} \cdot \varphi'' : 2100000 \times 5.46 \cdot 10^{11} \times (-4.35 \cdot 10^{-14}) : 0.499 \text{ tm.}$$

x:10 m. için Tüm kesit tesiri burulma momenti çarpılma

burulmasıdır. $M_z : 0.50 \text{ tm.}$

- ..Açıklık ortası normal gerilmeler (σ_x)

$$\sigma_x : \sigma_x \cdot w : \frac{M_w}{J_{w_M w_M}} \cdot w_M$$

$$M_w : -E_{st} \cdot J_{w_M w_M} \cdot \varphi'' : -2100000 \times 4.35 \cdot 10^{-11} \cdot J_{w_M w_M} : 9.135 \cdot 10^{-5} J_{w_M w_M}$$

$$\sigma_x : \frac{9.135 \cdot 10^{-5} J_{w_M w_M}}{J_{w_M w_M}} \cdot w_M : 9.135 \cdot 10^{-5} \times w_M$$

$$\sigma_{xA} : 0 \quad ?? (w_{MA} : 0)$$

$$\sigma_{xB} : 9.135 \cdot 10^{-5} \times (-4496) : -0.41 \text{ kg/cm}^2 : - \sigma_{xB}'$$

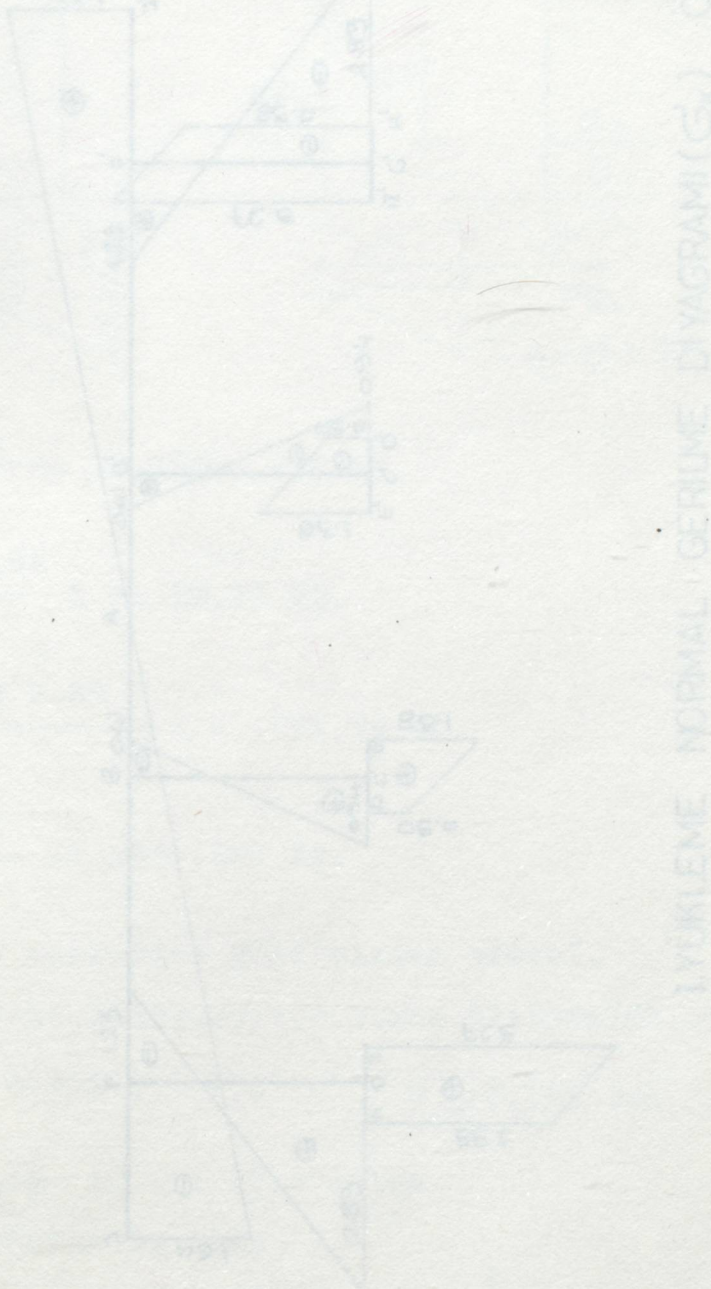
$$\sigma_{xC} : " \quad " \quad \times (10304) : 0.91 \quad " \quad " : - \sigma_{xC}'$$

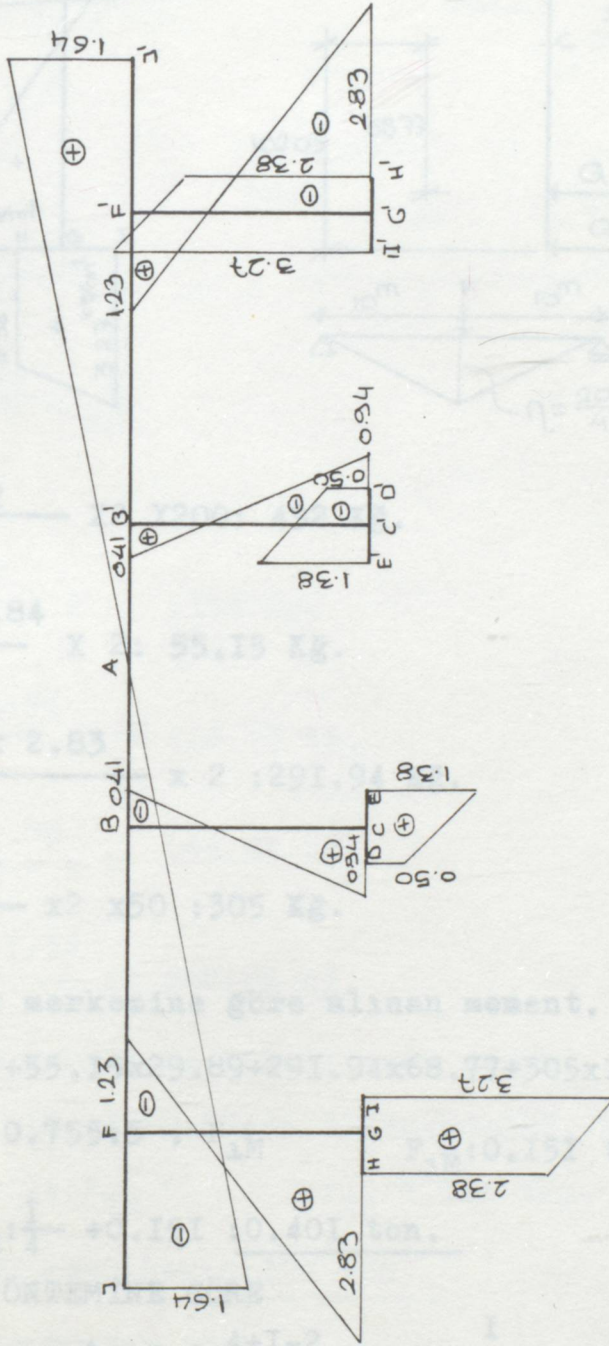
$$\sigma_{xD} : " \quad " \quad \times (5479) : 0.50 \quad " \quad " : - \sigma_{xD}'$$

$$\sigma_{xE} : " \quad " \quad \times (15128) : 1.38 \quad " \quad " : - \sigma_{xE}'$$

$$\sigma_{xF} : " \quad " \quad \times (-13488) : -1.23 \quad " \quad " : - \sigma_{xF}'$$

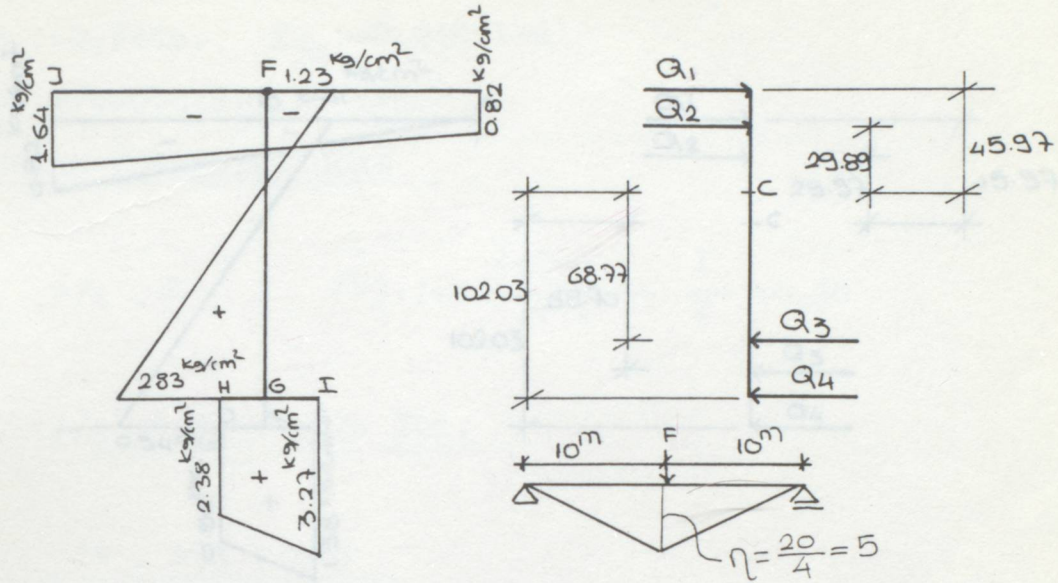
- $G_{xG}: 9.135 \cdot 10^{-5} \times (30912): 2.83 \text{ kg/cm}^2. \pm -G_{xG}'$
 $G_{xH}: \quad \quad \quad \times (26087): 2.38 \quad \quad \quad : -G_{xH}'$
 $G_{xI}: \quad \quad \quad \times (35735): 3.27 \quad \quad \quad : -G_{xI}'$
 $G_{xJ}: \quad \quad \quad \times (-17984): -1.67 \quad \quad \quad : -G_{xJ}'$





I.YÜKLEME NORMAL GERİLME DİYAGRAMI (G_x) Ö=1/1 - 1/50

- .. I. ANA KIRIŞ



$$Q_1: \frac{1.64+0.82}{2} \times 2 \times 200: 492 \text{ Kg.}$$

$$Q_2: \frac{1.23 \times 44.84}{2} \times 2: 55.15 \text{ Kg.}$$

$$Q_3: \frac{103.16 \times 2.83}{2} \times 2: 291.94 \text{ Kg.}$$

$$Q_4: \frac{2.83+3.27}{2} \times 2 \times 50: 305 \text{ Kg.}$$

Kesit ağırlık merkezine göre alınan moment.

$$M_c: 492 \times 45.97 + 55.15 \times 29.89 + 291.94 \times 68.77 + 305 \times 102.03: 0.755 \text{ tm.}$$

$$M_c: F_{1M} \cdot \eta \quad 0.755: 5 \cdot F_{1M} \quad F_{1M}: 0.151 \text{ ton.}$$

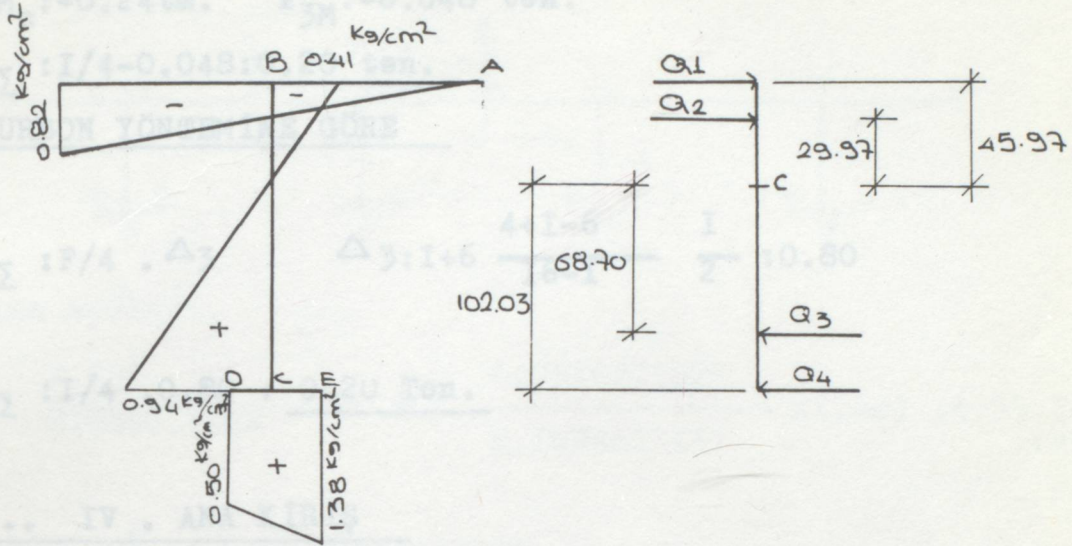
$$F_{I\Sigma}: \frac{F}{n} + F_{IM}: \frac{I}{4} + 0.151: 0.401 \text{ ton.}$$

- .. COURBON YÖNTEMİNE GÖRE

$$F_{I\Sigma}: \frac{F}{n} \cdot \Delta_1 \quad \Delta_1: I + 6 \frac{4+I-2}{16-I} - \frac{I}{2}: 1.6$$

$$F_{I\Sigma}: \frac{F}{4} \times 1.6: 0.40 \text{ ton.}$$

- .. II. ANA KIRIŞ



$$Q_1: \frac{0.82 \times 200}{2} \times 2 : 164 \text{ Kğ.}$$

$$Q_2: \frac{0.41 \times 44.95}{2} \times 2 : 18.43 \text{ Kğ.}$$

$$Q_3: \frac{0.94 \times 103.05}{2} \times 2 : 96.83 \text{ Kğ.}$$

$$Q_4: \frac{0.50 + 1.38}{2} \times 2 \times 50 : 94 \text{ Kğ.}$$

Kesit ağırlık merkezine göre alınan moment.

$$M_c: 164 \times 45.97 + 18.43 \times 29.97 + 96.87 \times 68.70 + 102.03 \times 94 : 0.24 \text{ tm.}$$

$$M_c: F_{2M} \cdot \eta \quad 0.24 : F_{2M} \cdot 5 \quad F_{2M} : 0.048 \text{ ton.}$$

$$F_{2\Sigma} : \frac{F}{n} + F_{2M} : 0.25 + 0.048 : 0.298 \text{ ton.}$$

-.. COURBON YÖNTEMİNE GÖRE

$$F_{2\Sigma} : \frac{F}{n} \cdot \Delta 2 \quad \Delta 2 : 1 + 6 \frac{4 + I - 4}{16 - I} \frac{I}{2} : 1.2$$

$$F_{2\Sigma} : 0.25 \times 1.2 : 0.30 \text{ ton.}$$

- .. III. ANA KIRIŞ

$$M_c = -0.24 \text{ tm.} \quad F_{3M} = -0.048 \text{ ton.}$$

$$F_{3\Sigma} = I/4 - 0.048 = \underline{0.20 \text{ ton.}}$$

COURBON YÖNTEMİNE GÖRE

$$F_{3\Sigma} = F/4 \cdot \Delta_3 \quad \Delta_3 = I+6 \frac{4+I-6}{I6-I} \frac{I}{2} = 0.80$$

$$F_{3\Sigma} = I/4 \cdot 0.80 = \underline{0.20 \text{ Ton.}}$$

- .. IV . ANA KIRIŞ

$$M_c = -0.755 \text{ tm.} \quad F_{4M} = -0.151 \text{ ton.}$$

$$F_{4\Sigma} = F/n + F_{4M} = I/4 - 0.151 = \underline{0.10 \text{ Ton.}}$$

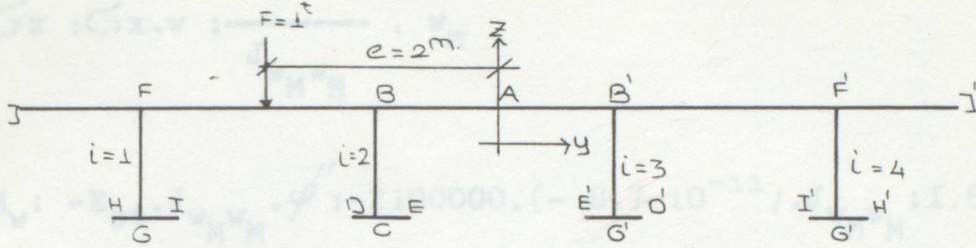
Courbon yöntemine göre

$$F_{4\Sigma} = F/n \cdot \Delta_4 \quad \Delta_4 = I+6 \frac{4+I-8}{I6-I} \frac{I}{2} = 0.40$$

$$F_{4\Sigma} = I/4 \cdot 0.40 = \underline{0.10 \text{ Ton.}}$$

3.2.b-.. II. YÜKLEME

M:F x e :I x 2 : 2 tm.



Dönme açıları.

$$\varphi' : \frac{2 \cdot 10^5}{810000 \cdot 4224} \left(0.50 - \frac{0.054627132}{0.109417157} \times 1.00 \right) : 4.35 \cdot 10^{-8} \text{ cm}^{-1}$$

$$\varphi'' : -\frac{2 \cdot 10^5}{810000 \cdot 4224} \cdot \frac{0.054627132}{0.109417157} \times 5.46 \cdot 10^{-5} \cdot 0.054627132 : 8.7 \cdot 10^{-11} \text{ cm}^{-2}$$

$$\varphi''' : -\frac{2 \cdot 10^5}{810000 \cdot 4224} \times \frac{0.054627132}{0.109417157} \times (5.46 \cdot 10^{-5}) \cdot 1.00 : 8.17 \cdot 10^{-14} \text{ cm}^{-3}$$

... St.Venant burulma momenti (M_t) :

x:0 için.

$$M_t : G_{st} \cdot J_t \cdot \varphi' : 810000 \times 4224 \times 4.35 \cdot 10^{-8} : 0.0015 \text{ tm.}$$

x:10 (açıklık ortası için)

Simetriden dolayı $\varphi' : 0$, $M_t : 0$

... Çarpılma burulması (M_z) :

x:0 için.

$$M_z : -E_{st} \cdot J_{wM} \cdot \varphi'' : -2100000 \cdot 5.46 \cdot 10^{11} \cdot 8.7 \cdot 10^{-11} : 0.989 \text{ tm.}$$

x:10 m. için tüm kesit tesiri burulma momenti çarpılma burulmasıdır. $M_z : 1.00 \text{ Tm.}$

- .. Açıklım ortasında normal gerilmelir (σ_x)

$$\sigma_x : \sigma_x \cdot w : \frac{M_w}{J_{w_M w_M}} \cdot w_M$$

$$M_w : -E_{st} \cdot J_{w_M w_M} \cdot \varphi'' : -2100000 \cdot (-8.7 \cdot 10^{-11}) \cdot J_{w_M w_M} : 1.83 \cdot 10^{-4} J_{w_M w_M}$$

$$\sigma_x : \frac{1.83 \cdot 10^{-4} \cdot J_{w_M w_M}}{J_{w_M w_M}} \cdot w_M : 1.83 \cdot 10^{-4} \cdot w_M$$

$$\sigma_{xA} : 0 \quad (w_{MA} : 0)$$

$$\sigma_{xB} : 1.83 \cdot 10^{-4} \times (-4496) : -0.82 \text{ Kg/cm}^2 : -\sigma_{xB}'$$

$$\sigma_{xC} : " " \times (10304) : 1.88 " " : -\sigma_{xC}'$$

$$\sigma_{xD} : " " \times (5479) : 1.00 " " : -\sigma_{xD}'$$

$$\sigma_{xE} : " " \times (15128) : 2.76 " " : -\sigma_{xE}'$$

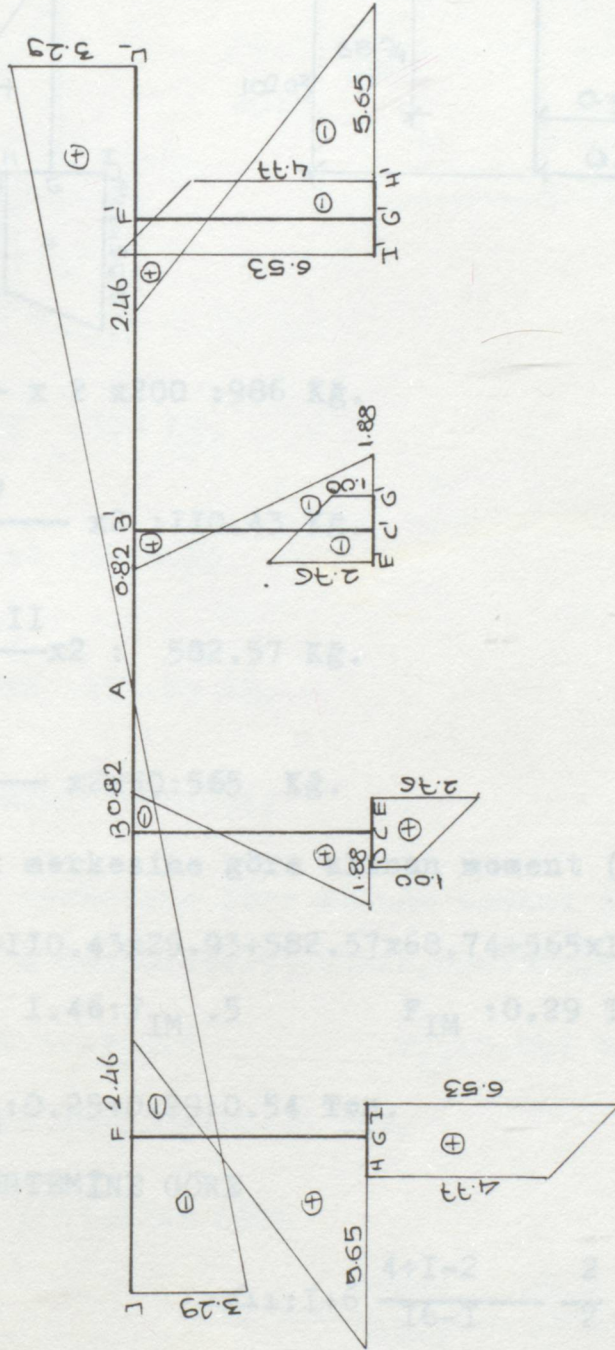
$$\sigma_{xF} : " " \times (-13488) : -2.46 " " : -\sigma_{xF}'$$

$$\sigma_{xG} : " " \times (30912) : 5.65 " " : -\sigma_{xG}'$$

$$\sigma_{xH} : " " \times (26087) : 4.77 " " : -\sigma_{xH}'$$

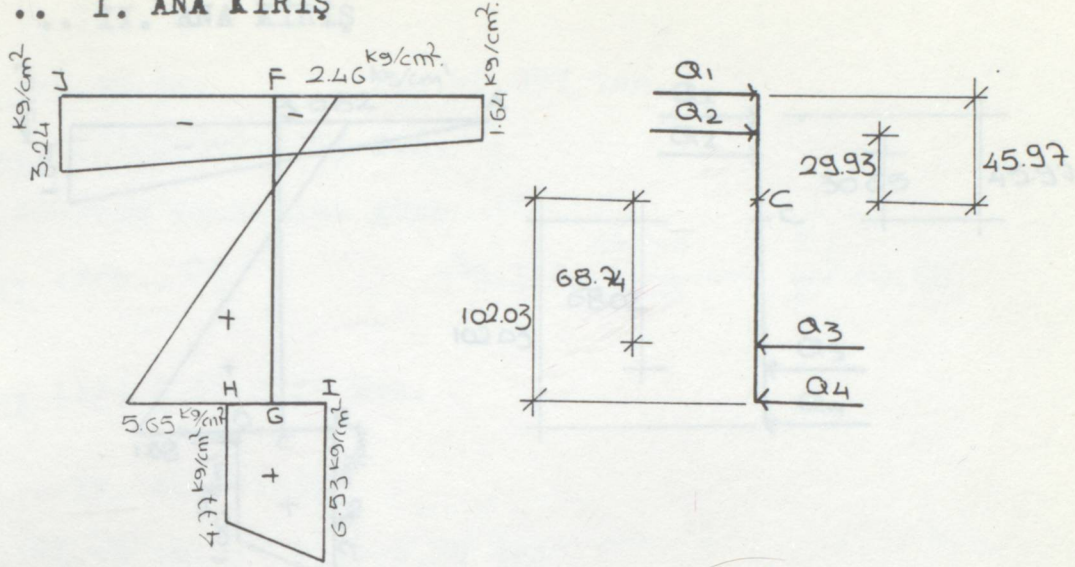
$$\sigma_{xI} : " " \times (35735) : 6.53 " " : -\sigma_{xI}'$$

$$\sigma_{xJ} : " " \times (-17984) : -3.29 " " : -\sigma_{xJ}'$$



II. YÜKLEME NORMAL GERİLME DİYAGRAMI (G_x) $\bar{O} = 1/2 - 1/50$

- ... I. ANA KIRIŞ



$$Q_1: \frac{3.29+1.64}{2} \times 2 \times 200 : 986 \text{ Kg.}$$

$$Q_2: \frac{2.46 \times 44.89}{2} \times 2 : 110.43 \text{ Kg.}$$

$$Q_3: \frac{5.65 \times 103.11}{2} \times 2 : 582.57 \text{ Kg.}$$

$$Q_4: \frac{4.77+6.53}{2} \times 2 \times 50 : 565 \text{ Kg.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_c: 986 \times 45.97 + 110.43 \times 29.93 + 582.57 \times 68.74 + 565 \times 102.03 : 1.46 \text{ Tm.}$$

$$M_c : F_{IM} \cdot \eta \quad 1.46 : F_{IM} \cdot 0.5 \quad F_{IM} : 0.29 \text{ Ton.}$$

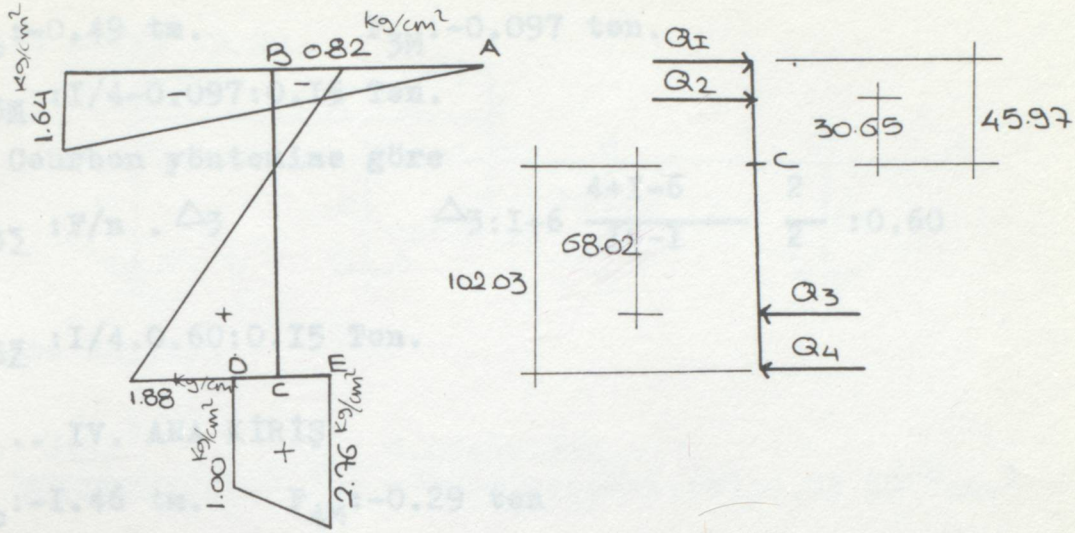
$$F_{I\Sigma} : F/n + F_{IM} : 0.25 + 0.29 : 0.54 \text{ Ton.}$$

-...COURBON YÖNTEMİNE GÖRE

$$F_{I\Sigma} : F/n \cdot \Delta_1 \quad \Delta_1 : 1+6 \frac{4+1-2}{16-1} \frac{2}{2} : 2.2$$

$$F_{I\Sigma} : 1/4 \cdot 2.2 : 0.55 \text{ Ton.}$$

- ... II. ANA KIRIŞ



$$Q_1: \frac{1.64 \times 200}{2} \times 2 : 328 \text{ Kg.}$$

$$Q_2: \frac{0.82 \times 44.95}{2} \times 2 : 36.86 \text{ Kg.}$$

$$Q_3: \frac{1.88 \times 103.11}{2} \times 2 : 193.85 \text{ Kg.}$$

$$Q_4: \frac{1.00 + 2.76}{2} \times 2 \times 50 : 188.05 \text{ Kg.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_c: 328 \times 45.97 + 36.86 \times 30.65 + 193.85 \times 68.02 + 102.03 \times 188.05 : 0.49 \text{ tm.}$$

$$M_c: F_{2M} \cdot \eta \quad 0.49 : F_{2M} \cdot 5 \quad F_{2M} : 0.097 \text{ ton.}$$

$$F_{2\Sigma} : F/n + F_{2M} : 0.25 + 0.097 : 0.35 \text{ Ton.}$$

- ... COURBON YÖNTEMİNE GÖRE

$$F_{2\Sigma} : F/n \cdot \Delta 2 \quad \Delta 2 : 1 + 6 \frac{4 + I - 4}{16 - I} \frac{2}{2} : 1.40$$

$$F_{2\Sigma} : 1/4 \cdot 1.40 : 0.35 \text{ Ton.}$$

- .. III. ANA KİRİŞ

$M_c: -0.49 \text{ tm.}$ $F_{3M}: -0.097 \text{ ton.}$

$F_{3E}: 1/4 - 0.097: 0.15 \text{ Ton.}$

Courbon yöntemine göre

$F_{3\Sigma}: F/n \cdot \Delta_3$ $\Delta_3: 1+6 \frac{4+1-6}{16-1} \frac{2}{2} : 0.60$

$F_{3\Sigma}: 1/4 \cdot 0.60: 0.15 \text{ Ton.}$

- .. IV. ANA KİRİŞ

$M_c: -1.46 \text{ tm.}$ $F_{4M}: -0.29 \text{ ton}$

$F_{4\Sigma}: 1/4 - 0.29: -0.0704 \text{ ton.}$

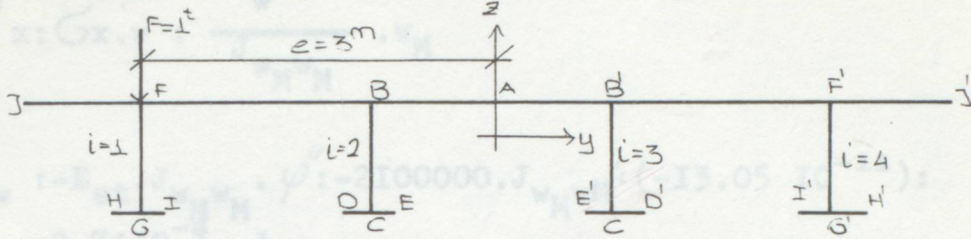
Courbon yöntemine göre

$F_{4\Sigma}: F/n \cdot \Delta_4$ $\Delta_4: 1+6 \frac{4+1-8}{16-1} \frac{2}{2} : -0.20$

$F_{4\Sigma}: 1/4 \cdot (-0.20): -0.05 \text{ Ton.}$

3.2.c-... III. YÜKLEME

M:Fx e:Ix3 :3 Tm.



Dönme açıları

$$\varphi' = \frac{3 \cdot 10^5}{810000 \cdot 4224} \left(0.50 - \frac{0.054627132}{0.109417157} \times 1.00 \right) : 6.53 \cdot 10^{-8} \text{ cm}^{-1}$$

$$\varphi'' = -\frac{3 \cdot 10^5}{810000 \cdot 4224} \frac{0.054627132}{0.109417157} \times 5.45 \cdot 10^{-5} \times 0.054627132 : 13.05 \text{ cm}^{-2}$$

$$\varphi''' = -\frac{3 \cdot 10^5}{810000 \cdot 4224} \frac{0.054627132}{0.109417157} \times (5.46 \cdot 10^{-5})^2 \times 1.00 : 13.05 \cdot 10^{-14} \text{ cm}^{-3}$$

-..St.Venant burulma momenti.(Mt):

x:0 için.

$$M_t = G_{st} \cdot J_t \cdot \varphi' : 810000 \times 4224 \times 6.53 \cdot 10^{-8} : 0.002 \text{ Tm.}$$

x:10 m.İçin (açıklık ortası)

$$\varphi' : 0, M_t : 0 \text{ (simetriden dolayı)}$$

-.. Çarpılma burulması.(Mz):

x:0 için.

$$M_z = -E_{st} \cdot J_{wM} \cdot \varphi''' : -2100000 \times 5.46 \cdot 10^{11} \cdot 13.05 \cdot 10^{-14} : 1.496 \text{ tm.}$$

x:10 m.İçin tüm kesit tesiri burulma momenti çarpılma burulmasıdır.

$$M_z : 1.50 \text{ Tm.}$$

- .. Açıklık ortasında normal gerilmeler. (σ_x)

$$\sigma_x: \sigma_{x.w} : \frac{M_w}{J_{w_M w_M}} \cdot w_M$$

$$M_w : -E_{st} \cdot J_{w_M w_M} \cdot \varphi'' : -2100000 \cdot J_{w_M w_M} \cdot (-13.05 \cdot 10^{-11}) : \\ : 2.74 \cdot 10^{-4} \cdot J_{w_M w_M}$$

$$\sigma_x : \frac{2.74 \cdot 10^{-4} \cdot J_{w_M w_M}}{J_{w_M w_M}} \cdot w_M : 2.74 \cdot 10^{-4} \cdot w_M$$

$$\sigma_{xA} : 0 \quad (w_{MA} : 0)$$

$$\sigma_{xB} : 2.74 \cdot 10^{-4} \times (-4496) : -1.23 \text{ Kg/cm}^2 : \sigma_{xB}'$$

$$\sigma_{xC} : " " \times (10304) : 2.82 " " : \sigma_{xC}'$$

$$\sigma_{xD} : " " \times (5479) : 1.50 " " : \sigma_{xD}'$$

$$\sigma_{xE} : " " \times (15128) : 4.15 " " : \sigma_{xE}'$$

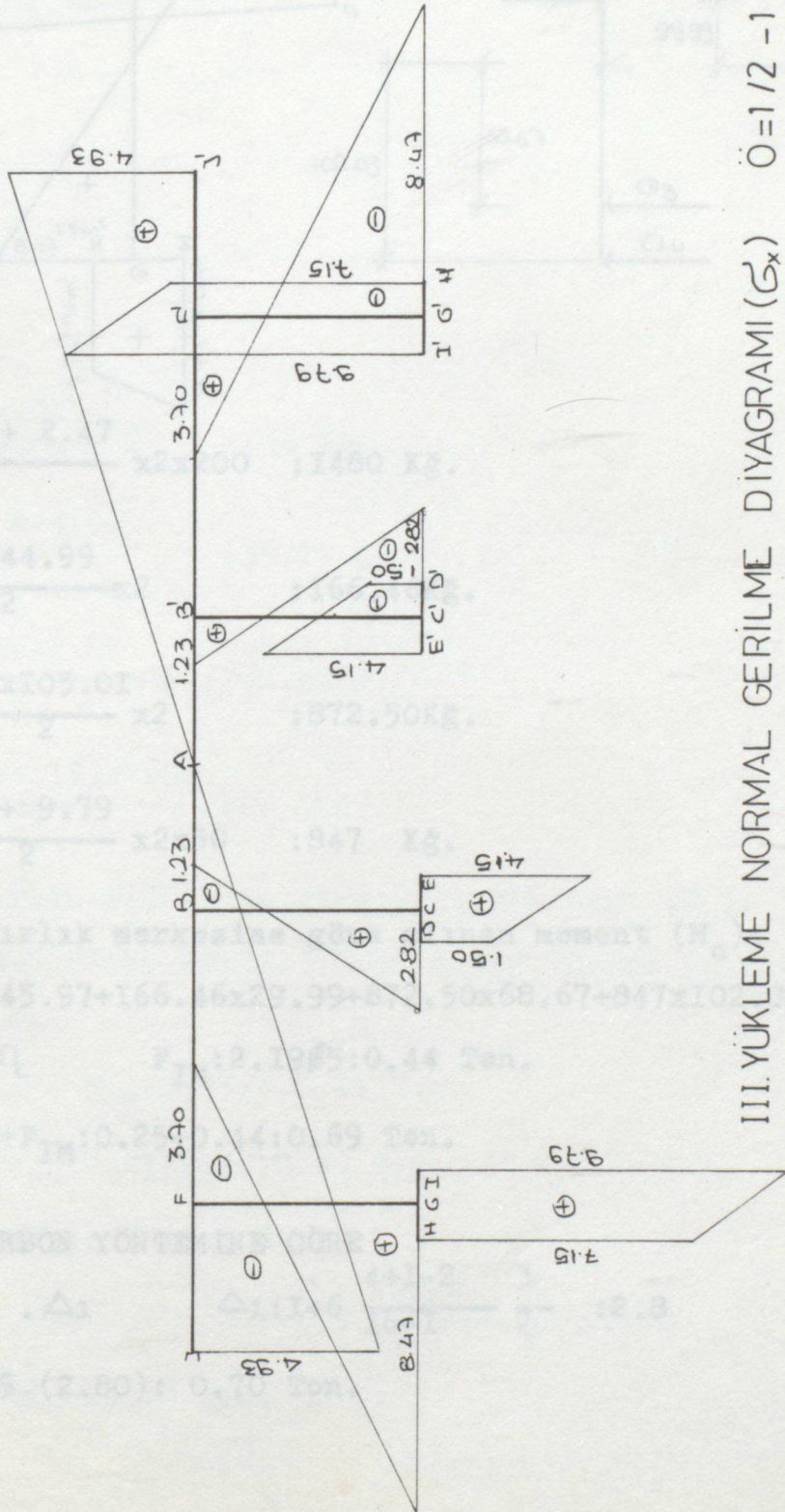
$$\sigma_{xF} : " " \times (-13488) : -3.70 " " : \sigma_{xF}'$$

$$\sigma_{xG} : " " \times (30912) : 8.47 " " : \sigma_{xG}'$$

$$\sigma_{xH} : " " \times (26087) : 7.15 " " : \sigma_{xH}'$$

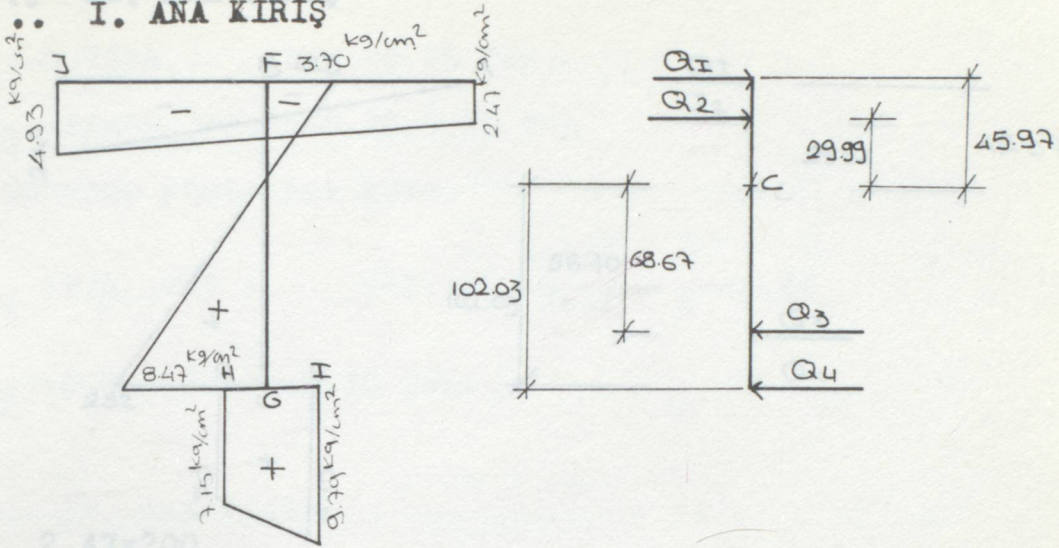
$$\sigma_{xI} : " " \times (35735) : 9.79 " " : \sigma_{xI}'$$

$$\sigma_{xJ} : " " \times (-17984) : -4.93 " " : \sigma_{xJ}'$$



III. YÜKLEME NORMAL GERİLME DİYAGRAMI (G_x) $\bar{\sigma} = 1/2 - 1/50$

I. ANA KIRIŞ



$$Q_1: \frac{4.93 + 2.47}{2} \times 2 \times 200 : 1480 \text{ Kğ.}$$

$$Q_2: \frac{3.7 \times 44.99}{2} \times 2 : 166.46 \text{ Kğ.}$$

$$Q_3: \frac{8.47 \times 103.01}{2} \times 2 : 872.50 \text{ Kğ.}$$

$$Q_4: \frac{7.15 + 9.79}{2} \times 2 \times 50 : 847 \text{ Kğ.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_c : 1480 \times 45.97 + 166.46 \times 29.99 + 872.50 \times 68.67 + 847 \times 102.03 : 2.19 \text{ Tm.}$$

$$M_c : F_{IM} \cdot \eta \quad F_{IM} : 2.19 \cdot 5 : 0.44 \text{ Ton.}$$

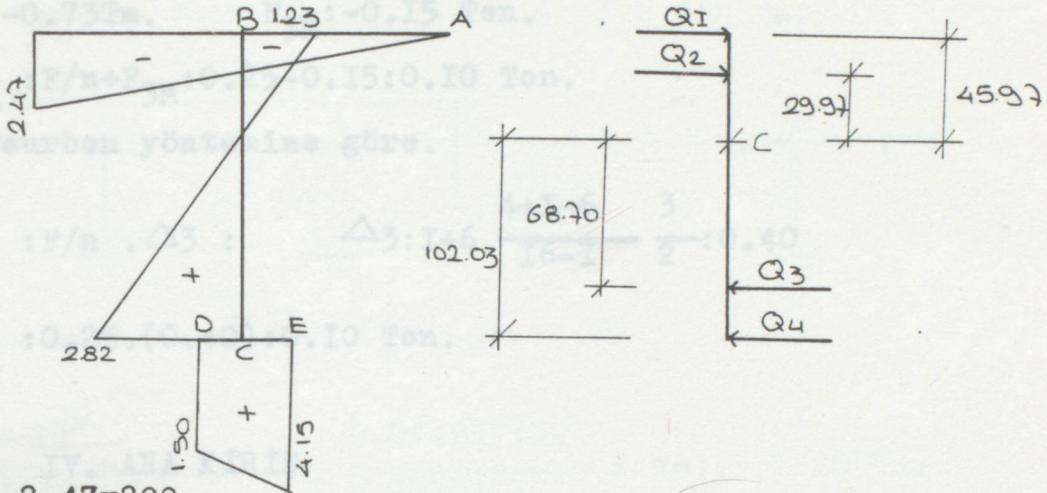
$$F_{I\Sigma} : F/n + F_{IM} : 0.25 + 0.44 : 0.69 \text{ Ton.}$$

- .. COURBON YÖNTEMİNE GÖRE

$$F_{I\Sigma} : F/n \cdot \Delta_1 \quad \Delta_1 : 1 + 6 \frac{4+1-2}{16-1} \frac{3}{2} : 2.8$$

$$F_{I\Sigma} : 0.25 \cdot (2.80) : 0.70 \text{ Ton.}$$

- ... II. ANA KIRIŞ



$$Q_1: \frac{2.47 \times 200}{2} \times 2 : 494 \text{ Kg.}$$

$$Q_2: \frac{1.23 \times 44.95}{2} \times 2 : 55.29 \text{ Kg.}$$

$$Q_3: \frac{103.05 \times 2.82}{2} \times 2 : 290.60 \text{ Kg.}$$

$$Q_4: \frac{(1.50 + 4.15) \times 2 \times 50}{2} : 282.5 \text{ Kg.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_c: 494 \times 45.97 + 55.29 \times 29.97 + 290.60 \times 68.70 + 282.5 \times 102.03 : 0.73 \text{ Tm.}$$

$$M_c: F_{2M} \cdot \eta \quad F_{2M}: 0.73/5: 0.15 \text{ Ton.}$$

$$F_{2\Sigma}: F/n + F_{2M}: 0.25 + 0.15: 0.40 \text{ Ton.}$$

-... COURBON YÖNTEMİNE GÖRE

$$F_{2\Sigma}: F/n \cdot \Delta 2 \quad \Delta 2: 1+6 \frac{4+1-4}{16-1} \frac{3}{2} : 1.60$$

$$F_{2\Sigma}: 0.25 \times 1.6: 0.40 \text{ Ton.}$$

... III. ANA KİRİŞ

$$M_c: -0.73 \text{ Tm.} \quad F_{3M}: -0.15 \text{ Ton.}$$

$$F_{3\Sigma}: F/n + F_{3M}: 0.25 - 0.15 = 0.10 \text{ Ton.}$$

Courben yöntemine göre.

$$F_{3\Sigma}: F/n \cdot \Delta_3 : \quad \Delta_3: I+6 \frac{4+I-6}{I6-I} \frac{3}{2} = 0.40$$

$$F_{3\Sigma}: 0.25 \cdot (0.40) = 0.10 \text{ Ton.}$$

... IV. ANA KİRİŞ

$$M_c: -2.19 \text{ Tm.} \quad F_{4M}: (-2.19)/5 = -0.44 \text{ Ton}$$

$$F_{4\Sigma}: F/n + F_{4M}: 0.25 - 0.44 = -0.19 \text{ Ton.}$$

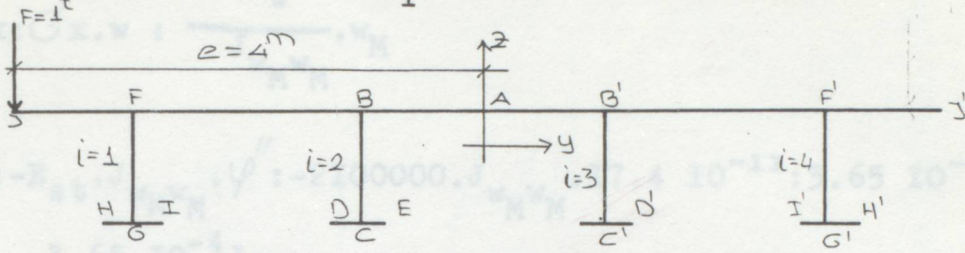
Courben yöntemine göre.

$$F_{4\Sigma}: F/n \cdot \Delta_4 \quad \Delta_4: I+6 \frac{4+I-8}{I6-I} \frac{3}{2} = -0.80$$

$$F_{4\Sigma}: 0.25 \cdot (-0.80) = -0.20 \text{ Ton.}$$

3-2.a-.. IV. YÜKLEME

Dış burulma momenti $M_T : F \times e : I \times 4:4 \text{ Tm.}$



Dönme açıları

$$\varphi' = \frac{4 \cdot 10^5}{810000 \cdot 4224} \left(0.50 = \frac{0.054627132}{0.109417157} \cdot 1.00 \right) : 8.7 \cdot 10^{-8} \text{ cm}^{-1}$$

$$\varphi'' = \frac{-4 \cdot 10^5}{810000 \cdot 4224} \frac{0.054627132}{0.109417157} \cdot 5.46 \cdot 10^{-5} \cdot 0.054627132 : 17 \cdot 10^{-11} \text{ cm}^{-2}$$

$$\varphi''' = \frac{-4 \cdot 10^5}{810000 \cdot 4224} \frac{0.054627132}{0.109417157} \left(5.46 \cdot 10^{-5} \right)^2 \cdot 1.00 : 17 \cdot 10^{-14} \text{ cm}^{-3}$$

-.. St.Venant burulma momenti (M_t):

x:0 için.

$$M_t : G_{st} \cdot J_t \cdot \varphi' : 810000 \times 4224 \times 8.7 \cdot 10^{-8} : 0.003 \text{ Tm.}$$

x:10 (açıklık ortası için)

$$\varphi' : 0, M_t : 0 \text{ (Simetriden dolayı)}$$

-..Çarpılma burulması (M_z):

x:0 için

$$M_z : -E_{st} \cdot J_{w_M w_M} \cdot \varphi''' : -2100000 \times 5.46 \cdot 10^{11} \cdot 17.4 \cdot 10^{-14} : 1.995 \text{ Tm.}$$

x:10 m.

Tüm kesit tesiri burulma momenti çarpılma burulmasıdır.

$$M_z : 2.00 \text{ Tm.}$$

- .. Açıklık ortasında normal gerilmeler (σ_x)

$$\sigma_x: \sigma_{x.w} : \frac{M_w}{J_{w_M w_M}} \cdot w_M$$

$$M_w: -E_{st} \cdot J_{w_M w_M} \cdot \psi'' : -2100000 \cdot J_{w_M w_M} \cdot 17.4 \cdot 10^{-11} : 3.65 \cdot 10^{-4} J_{w_M w_M}$$

$$\sigma_x: \frac{3.65 \cdot 10^{-4} J_{w_M w_M}}{J_{w_M w_M}} \cdot w_M : 3.65 \cdot 10^{-4} \cdot w_M$$

$$\sigma_{xA}: 0 \quad (w_{MA}: 0)$$

$$\sigma_{xB}: 3.65 \cdot 10^{-4} \times (-4496) : -1.64 \text{ Kğ/cm}^2 : \sigma_{xB}'$$

$$\sigma_{xC}: " " \times (10304) : 3.77 " " : \sigma_{xC}'$$

$$\sigma_{xD}: " " \times (5479) : 2.00 " " : \sigma_{xD}'$$

$$\sigma_{xE}: " " \times (15128) : 5.56 " " : \sigma_{xE}'$$

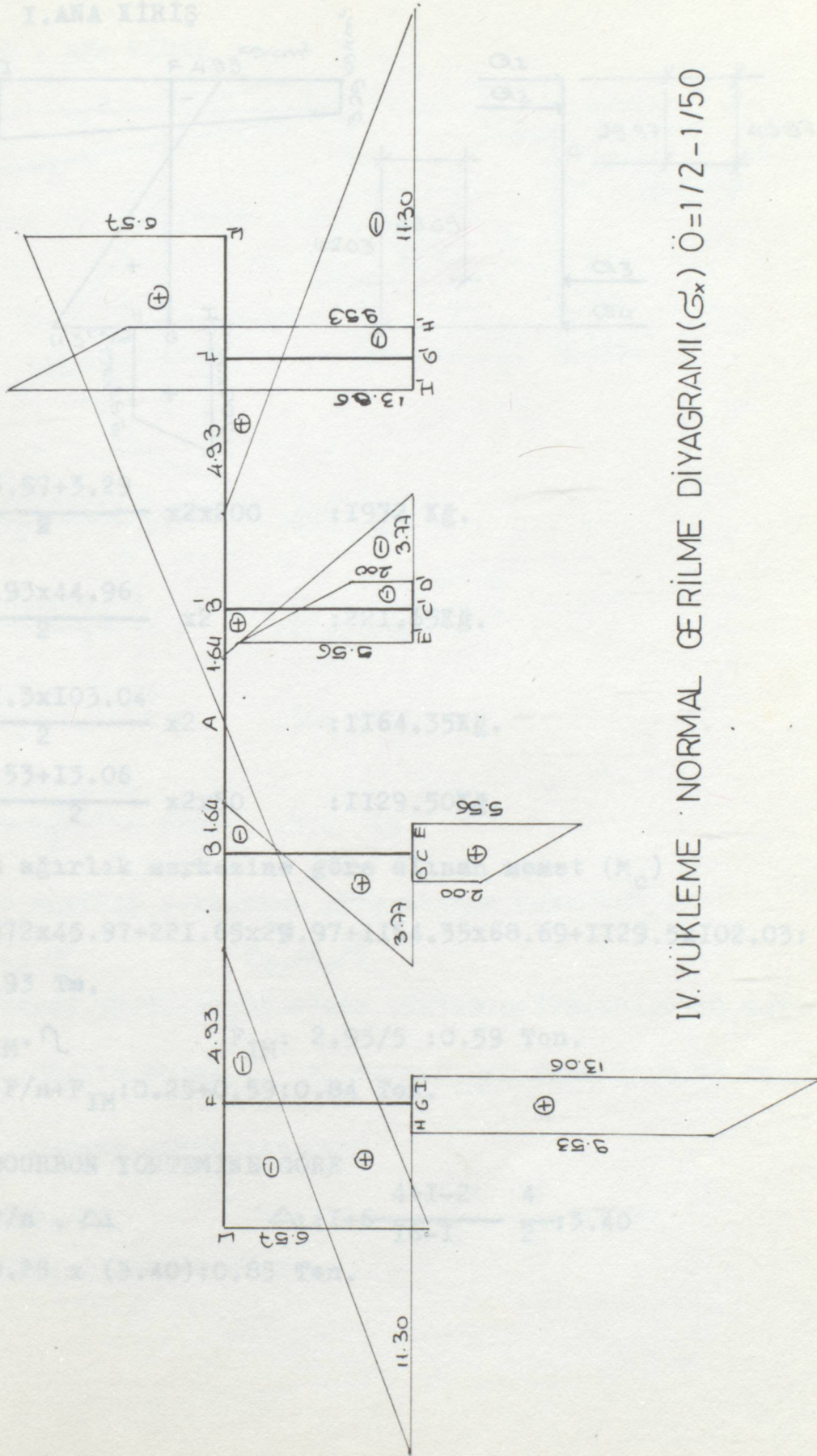
$$\sigma_{xF}: " " \times (-13488) : -4.93 " " : \sigma_{xF}'$$

$$\sigma_{xG}: " " \times (30912) : 11.30 " " : \sigma_{xG}'$$

$$\sigma_{xH}: " " \times (26087) : 9.53 " " : \sigma_{xH}'$$

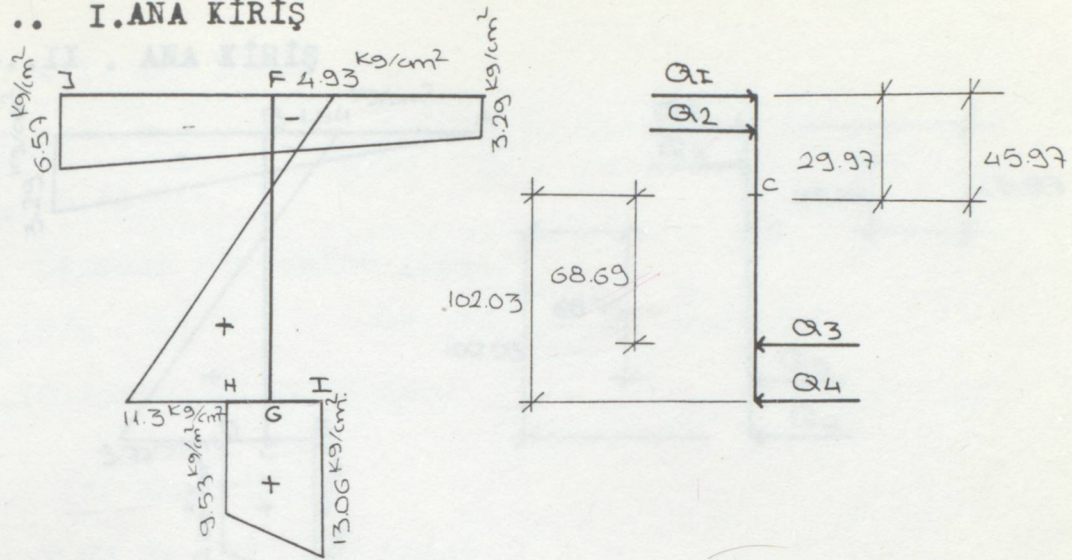
$$\sigma_{xI}: " " \times (35735) : 13.06 " " : \sigma_{xI}'$$

$$\sigma_{xJ}: " " \times (-17984) : 6.57 " " : \sigma_{xJ}'$$



IV. YÜKLEME NORMAL ÇERİLME DİYAGRAMI (G_x) Ö=1/2-1/50

- .. I.ANA KIRIŞ



$$Q_1: \frac{6.57+3.29}{2} \times 2 \times 200 : 1972 \text{ Kg.}$$

$$Q_2: \frac{4.93 \times 44.96}{2} \times 2 : 221.65 \text{ Kg.}$$

$$Q_3: \frac{11.3 \times 103.04}{2} \times 2 : 1164.35 \text{ Kg.}$$

$$Q_4: \frac{9.53+13.06}{2} \times 2 \times 50 : 1129.50 \text{ Kg.}$$

Kesit ağırlık merkezine göre alınan moment (M_c)

$$M_c: 1972 \times 45.97 + 221.65 \times 29.97 + 1164.35 \times 68.69 + 1129.5 \times 102.03 : 2.93 \text{ Tm.}$$

$$M_c: F_{IM} \cdot \rho \quad F_{IM}: 2.93/5 : 0.59 \text{ Ton.}$$

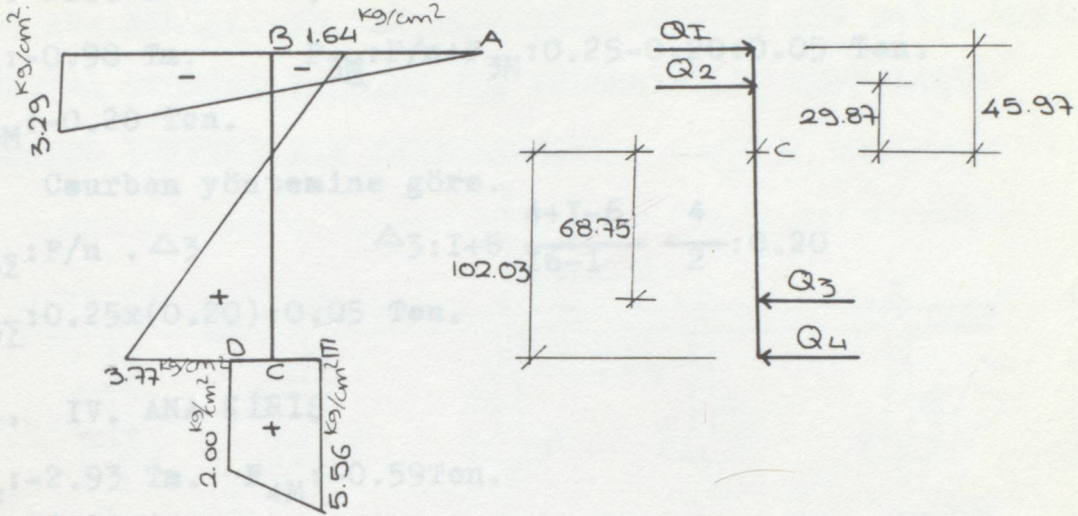
$$F_{I\Sigma} : F/n + F_{IM} : 0.25 + 0.59 : 0.84 \text{ Ton.}$$

-.. COURBON YÖNTEMİNE GÖRE

$$F_{I\Sigma} : F/n \cdot \Delta_1 \quad \Delta_1: 1 + 6 \frac{4+1-2}{16-1} \frac{4}{2} : 3.40$$

$$F_{I\Sigma} : 0.25 \times (3.40) : 0.85 \text{ Ton.}$$

...II . ANA KIRIŞ



$$Q_1: \frac{3.29 \times 200}{2} \times 2 : 658 \text{ Kg.}$$

$$Q_2: \frac{1.64 \times 44.88}{2} \times 2 : 73.57 \text{ Kg.}$$

$$Q_3: \frac{3.77 \times 103.13}{2} \times 2 : 388.80 \text{ Kg.}$$

$$Q_4: \frac{2.00 + 5.56}{2} \times 2 \times 50 : 378 \text{ Kg.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_c = F_{2M} \cdot r \quad F_{2M} = M_c / 5$$

$$M_c = 658 \times 45.97 + 73.57 \times 29.87 + 68.75 \times 388.8 + 378 \times 102.03 : 0.98 \text{ Tm.}$$

$$F_{2M} = 0.98 / 5 : 0.20 \text{ Ton.} \quad F_{2\Sigma} = F/n + F_{2M} = 0.25 + 0.20 : 0.45 \text{ Ton.}$$

... COURBON YÖNTEMİNE GÖRE

$$F_{2\Sigma} = F/n \cdot \Delta 2 \quad \Delta 2 = 1 + 6 \frac{4 + I - 4}{I6 - I} \frac{4}{2} : 1.80$$

$$F_{2\Sigma} = 0.25 \cdot (1.80) : 0.45 \text{ Ton.}$$

3.3 - ÖRNEK II
-.. III. ANA KIRIŞ

$M_c = -0.98 \text{ Tm.}$ $F_{3M} = F/n + F_{3M} = 0.25 - 0.20 = 0.05 \text{ Ton.}$

$F_{3M} = -0.20 \text{ Ton.}$

Courbon yöntemine göre.

$F_{3\Sigma} = F/n \cdot \Delta_3$ $\Delta_3 = I+6 \frac{4+I-6}{I6-I} \frac{4}{2} = 0.20$

$F_{3\Sigma} = 0.25 \times (0.20) = 0.05 \text{ Ton.}$

-.. IV. ANA KIRIŞ

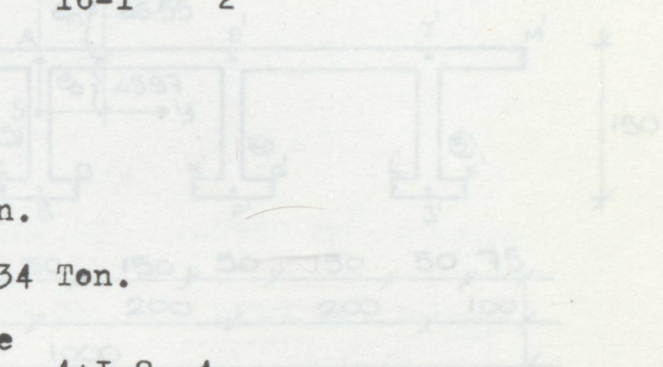
$M_c = -2.93 \text{ Tm.}$ $F_{4M} = -0.59 \text{ Ton.}$

$F_{4\Sigma} = F/n + F_{4M} = 0.25 - 0.59 = -0.34 \text{ Ton.}$

Courbon yöntemine göre

$F_{4\Sigma} = F/n \cdot \Delta_4$ $\Delta_4 = I+6 \frac{4+I-8}{I6-I} \frac{4}{2} = -1.40$

$F_{4\Sigma} = 0.25 \cdot (-1.40) = -0.35 \text{ Ton.}$



3.3.1 - AĞIRLIK MERKEZİ VE BURULMA ATALET MOMENTİNİN BULUNUŞU.

$$e_0 = \frac{2 \times 1000 \times 149 + 146 \times 75 \times 5 + 2 \times 50 \times 5}{2 \times 1000 + 2 \times 146 \times 5 + 2 \times 50 \times 5} = 103.03 \text{ cm.}$$

$$e_1 = 150 - 103.03 - 5 = 41.97 \text{ cm.}$$

$$I_x = 1/32 \sum x_j^2 \cdot A_j = 1/3 (2^3 \times 1000 + 2^3 \times 146 \times 5 + 2^3 \times 50 \times 5) = 5280 \text{ cm}^4$$

3.3.2- z-z ATALET MOMENTİNİN BULUNUŞU

$$I_{xz} = \int y^2 \cdot dA = 1000^2 \times 2 / 12 + 2 \times (146 \times 2^3 / 12 + 146 \times 2 \times 400^2) +$$

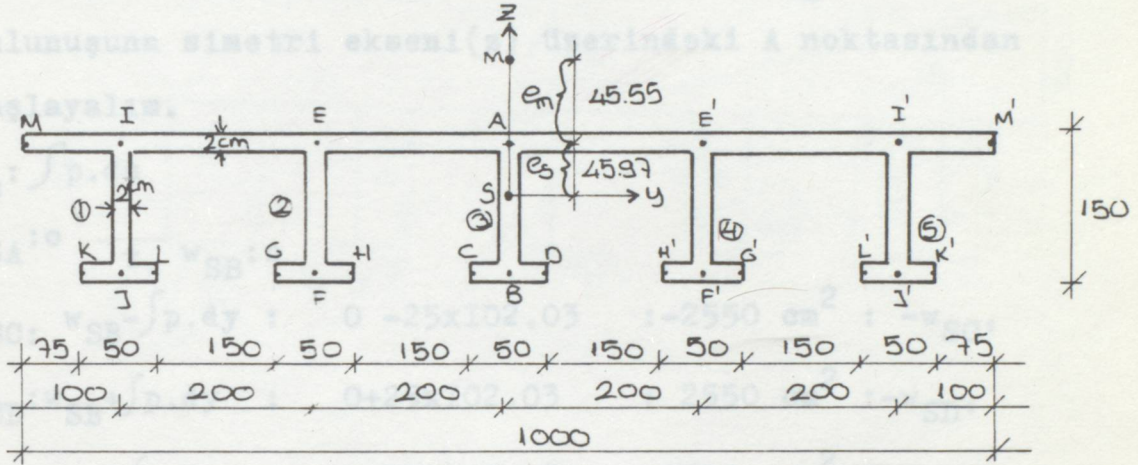
$$2 \times (50^2 \times 2 / 12 + 50 \times 2 \times 400^2) + 2 \times (146 \times 2^3 / 12 + 146 \times 2 \times 200^2) +$$

$$2 \times (50^2 \times 2 / 12 + 50 \times 2 \times 200^2) + 146 \times 2^3 / 12 + 50^2 \times 2 / 12 =$$

$$1323571320. \text{ cm}^4$$

3.3 - ÖRNEK II

BEŞ ANA KİRİŞLİ VE TEK AÇIKLIKLI KÖPRÜDE YÜK DAĞILIMININ BURULMA TEORİSİ YARDIMI İLE BULUNMASI VE SONUÇLARIN COURBON YÖNTEMİ İLE KIYASLANMASI:



3.3.1 - AĞIRLIK MERKEZİ VE BURULMA ATALET MOMENTİNİN BULUNUŞU.

$$E_s = \frac{2 \times I000 \times I49 + I46 \times 75 \times 5 + 2 \times 50 \times 5}{2 \times I000 + 2 \times I46 \times 5 + 2 \times 50 \times 5} : 103.03 \text{ cm.}$$

$$e_s : 150 - 103.03 - 1 : 45.97 \text{ cm.}$$

$$J_t : I/3 \sum s_j \cdot t_j^3 : I/3 (2^3 \times I000 + 2^3 \times I46 \times 5 + 2^3 \times 50 \times 5) : 5280 \text{ cm}^4$$

3.3.2- z-z ATALET MOMENTİNİN BULUNUŞU

$$J_{zz} : \int y^2 \cdot dA : I000^3 \times 2 / I2 + 2 \times (I46 \times 2^3 / I2 + I46 \times 2 \times 400^2) + 2 \times (50^3 \times 2 / I2 + 50 \times 2 \times 400^2) + 2 \times (I46 \times 2^3 / I2 + I46 \times 2 \times 200^2) + 2 \times (50^3 \times 2 / I2 + 50 \times 2 \times 200^2) + I46 \times 2^3 / I2 + 50^3 \times 2 / I2 : 323571320. \text{ cm}^4.$$

3.3.3- AĞIRLIK MERKEZİNE GÖRE BİRİM ÇARPILMA

KOORDİNATLARI (w_g):

Kesitinsimetri özelliğinden yararlanarak w_g değerlerinin bulunuşuna simetri eksenini (z) üzerindeki A noktasından başlayalım.

$$w_g : \int p \cdot ds$$

$$w_{SA} : 0 \quad + \quad w_{SB} : 0$$

$$w_{SC} : w_{SB} - \int p \cdot dy : 0 - 25 \times 102.03 : -2550 \text{ cm}^2 : -w_{SC}$$

$$w_{SD} : w_{SB} + \int p \cdot dy : 0 + 25 \times 102.03 : 2550 \text{ cm}^2 : -w_{SD}$$

$$w_{SE} : w_{SA} + \int p \cdot dy : 0 + 200 \times 45.97 : 9194 \text{ cm}^2 : -w_{SE}$$

$$w_{SF} : w_{SE} + \int p \cdot dz : 9194 + 148 \times 200 : 38794 \text{ cm}^2 : -w_{SF}$$

$$w_{SH} : w_{SF} + \int p \cdot dy : 38794 + 25 \times 102.02 : 41345 \text{ cm}^2 : -w_{SH}$$

$$w_{SG} : w_{SF} - \int p \cdot dy : 38794 - 25 \times 102.03 : 36243 \text{ cm}^2 : -w_{SG}$$

$$w_{SI} : w_{SA} + \int p \cdot dy : 0 + 45.97 \times 400 : 18388 \text{ cm}^2 : -w_{SI}$$

$$w_{SJ} : w_{SI} + \int p \cdot dz : 18388 + 148 \times 400 : 77588 \text{ cm}^2 : -w_{SJ}$$

$$w_{SL} : w_{SJ} + \int p \cdot dy : 77588 + 25 \times 102.03 : 80139 \text{ cm}^2 : -w_{SL}$$

$$w_{SK} : w_{SJ} - \int p \cdot dy : 77588 - 25 \times 102.03 : 75037 \text{ cm}^2 : -w_{SK}$$

$$w_{SM} : w_{SA} + \int p \cdot dy : 0 + 500 \times 45.97 : 22985 \text{ cm}^2 : -w_{SM}$$

(2) DİYAGRAMI

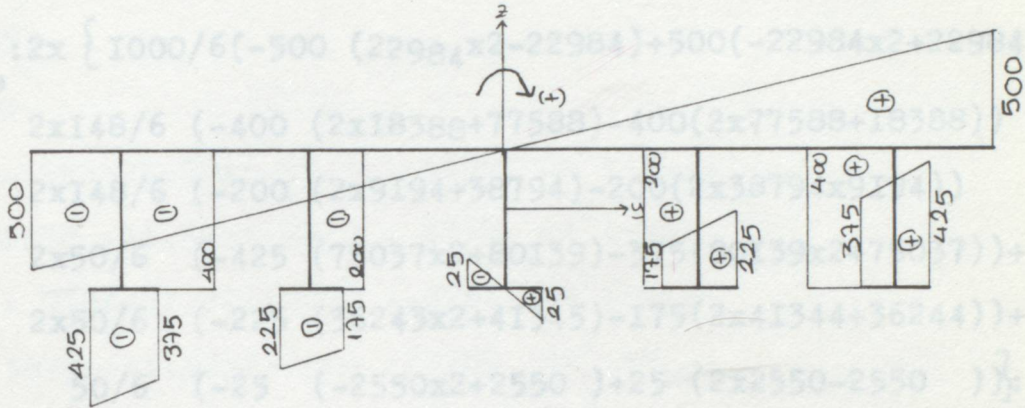
3.3.4- SEKTOR DEVIASYON MOMENTİ (J_{Dv}):

Kayma merkezini bulmak için gerekli olan bu değer

$$J_{Dv} = \int y \cdot v \cdot dA$$

$$J_{Dv} = 2x \left\{ 1000/6(-500(22984x^2 - 22984) + 500(-22984x + 22984)) \right. \\ \left. + 2x148/6(-400(2x18388x + 5895588) - 400(2x77588x - 18388)) \right. \\ \left. + 2x142/6(-425(2x1944x + 38794) - 425(2x1944x - 38794)) \right. \\ \left. + 2x175/6(-43x^2 + 41133x - 175(-41344 + 36244)) \right. \\ \left. + 2x225/6(-25(-2550x^2 + 2550) + 25(-2550x - 2550)) \right\}$$

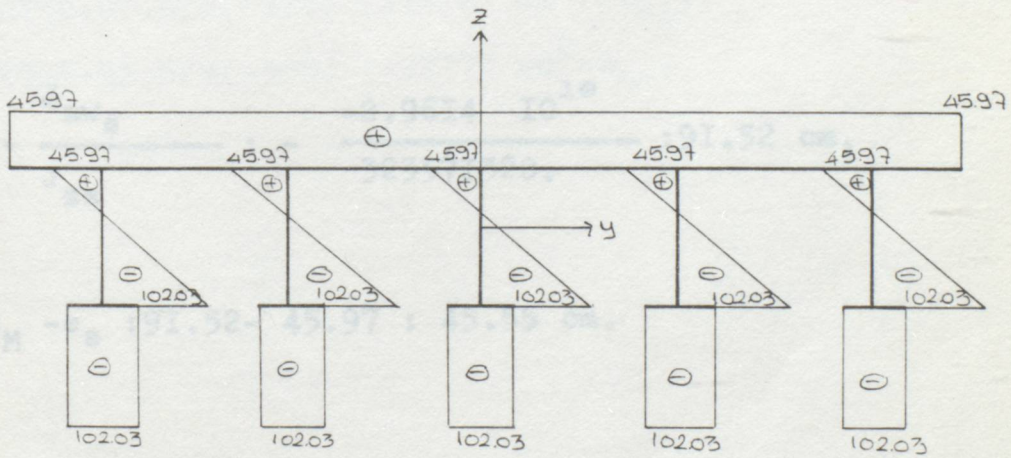
$= 2.9614 \cdot 10^{10} \text{ cm}^5$



(y) DİYAĞRAMI

3.3.5 - KAYMA MERKEZİ (M):

Simetrikten dolayı kayma merkezi (M) z-z eksenini içerindedir.



(z) DİYAĞRAMI

3.3.4- SEKTOR DEVIASYON MOMENTİ (J_{zw_s}):

Kayma merkezinin bulunması için gerekli olan bu değer

$$J_{zw_s} = \int y \cdot w_s \cdot dA$$

$$J_{zw_s} = 2x \left\{ 1000/6(-500 (22984x^2 - 22984) + 500(-22984x^2 + 22984)) \right. \\ 2xI48/6 (-400 (2xI8388 + 77588) - 400(2x77588 + I8388)) \\ 2xI48/6 (-200 (2x9I94 + 38794) - 200(2x38794x9I94)) \\ 2x50/6 (-425 (75037x^2 + 80I39) - 375(80I39x^2 + 75037)) + \\ 2x50/6 (-225 (36243x^2 + 4I345) - I75(2x4I344 + 36244)) + \\ \left. 50/6 (-25 (-2550x^2 + 2550) + 25 (2x2550 - 2550)) \right\} \\ : 2.96I4 \cdot 10^{10} \text{ cm}^5.$$

3.3.5 - KAYMA MERKEZİ (M):

Simetriden dolayı kayma merkezi (M) z-z eksenini üzerindedir

$$z_M = - \frac{J_{zw_s}}{J_{zz}} : - \frac{-2.96I4 \cdot 10^{10}}{32357I320} : 9I.52 \text{ cm.}$$

$$e_M = z_M - e_s : 9I.52 - 45.97 : 45.55 \text{ cm.}$$

3.3.6 - KAYMA MERKEZİNE GÖRE BULUNAN ÇARPILMA KOORDİNATLARI

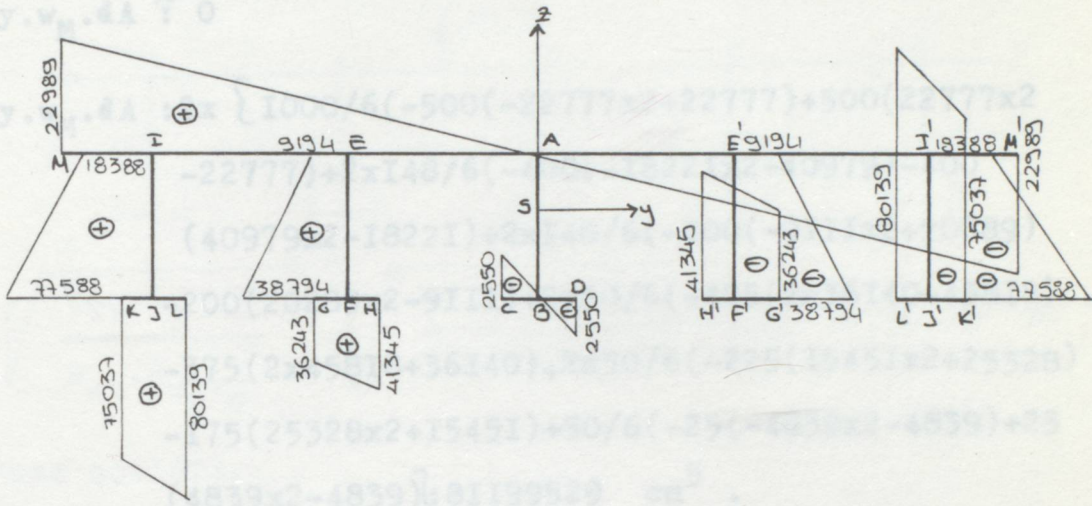
Benzer şekilde şu formülden bulunur. $w_M = w_S + z_M \cdot y$

$w_{MA} : 0$	
$w_{MB} : 0$	
$w_{MC} : -2550 + 91.52x(-25) : -4839$	$cm^2 : -w_{MC}$
$w_{MD} : 2550 + 91.52x(25) : 4839$	$cm^2 : -w_{MD}$
$w_{ME} : 9194 + 91.52(-200) : -9111$	$cm^2 : -w_{ME}$
$w_{MF} : 38794 + 91.52x(-200) : 20289$	$cm^2 : -w_{MF}$
$w_{MG} : 36243 + 91.52x(-225) : 15451$	$cm^2 : -w_{MG}$
$w_{MH} : 41345 + 91.53x(-175) : 25328$	$cm^2 : w_{MH}$
$w_{MI} : 18388 + 91.52x(-400) : -18221$	$cm^2 : -w_{MI}$
$w_{MJ} : 77588 + 91.52x(-400) : 40979$	$cm^2 : -w_{mj}$
$w_{MK} : 75037 + 91.52x(-425) : 36140$	$cm^2 : -w_{MK}$
$w_{ML} : 80139 + 91.52x(-375) : 45818$	$cm^2 : -w_{ML}$
$w_{MM} : 22985 + 91.52x(-500) : -22777$	$cm^2 : -w_{MM}$

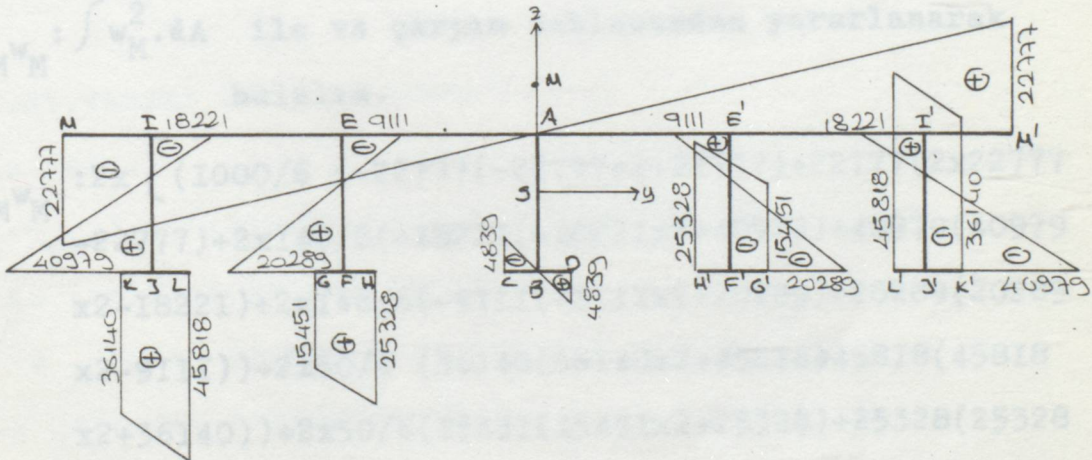
KONTROL DENKLEMLERİ.

$\int s.v_m.dA : 0$ (Simetri ve antisimetriken dolayı.)

$\int y.v_m.dA \neq 0$



(Ws) DİYAĞRAMI



(Wm) DİYAĞRAMI

KONTROL DENKLEMLERİ.

$$\int z \cdot w_M \cdot dA : 0 \quad (\text{Simetri ve antimetriiden dolayı.})$$

$$\int y \cdot w_M \cdot dA \approx 0$$

$$\int y \cdot w_M \cdot dA : 2x \left\{ \begin{aligned} &1000/6(-500(-22777x^2+22777))+500(22777x^2 \\ &-22777)+2xI48/6(-400(-I822Ix^2+40979)-400 \\ &(40979x^2-I822I))+2xI48/6(-200(-9IIIx^2+20289) \\ &-200(20289x^2-9III))+2x50/6(-425(2x36I40+458I8) \\ &-375(2x458I8+36I40))+2x50/6(-225(I545Ix^2+25328) \\ &-I75(25328x^2+I545I))+50/6(-25(-4839x^2-4839)+25 \\ &(4839x^2-4839)) \end{aligned} \right\} : 8II99529 \text{ cm}^5 .$$

Kıyaslama

$$\text{oranı} \dots \frac{8II99529}{2.96I4 \cdot 10^{10}} : 0.0027 \quad (\text{Uygundur}).$$

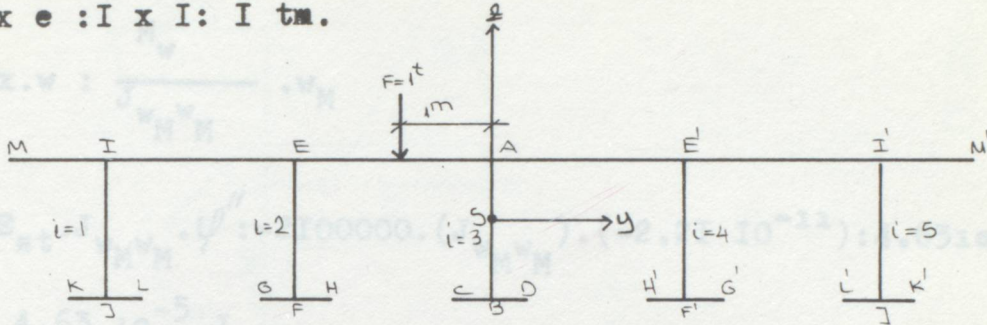
3.3.7 - ÇARPILMA MUKAVEMETİ ($J_{w_M w_M}$).

$J_{w_M w_M} : \int w_M^2 \cdot dA$ ile ve çarpım tablosundan yararlanarak bulalım.

$$J_{w_M w_M} : 2x \left\{ \begin{aligned} &(I000/6 (-22777(-22777x^2+22777))+22777(2x22777 \\ &-22777))+2xI48/6(-I822I(-I822Ix^2+40979)+40979(40979 \\ &x^2-I822I))+2xI48/6(-9III(-9IIIx^2+20289)+20289(20289 \\ &x^2-9III))+2x50/6 (36I40(36I40x^2+458I8)+458I8(458I8 \\ &x^2+36I40))+2x50/6(I545I(I545Ix^2+25328)+25328(25328 \\ &x^2+I545I))+50/6(-4838(-4838x^2+4838)+4838(4838x^2-4838)) \end{aligned} \right\} : \\ : I.0794985 \cdot 10^{I2} \text{ cm}^6 .$$

3.3.a-...I. YÜKLEME

M:F x e :I x I: I tm.



$$k: \sqrt{\frac{G_{st} \cdot J_t}{E_{st} \cdot J_{w_M w_M}}} : \sqrt{\frac{810000 \times 5280}{2100000 \times 1.079 \cdot 10^{12}}} : 4.35 \cdot 10^{-5} \text{ cm}^{-1}$$

Dönme açıları.

$$\varphi' : \frac{1 \cdot 10^5}{810000 \cdot 5280} \left(0.50 - \frac{0.0434}{0.0869} \cdot 1.00 \right) : 1.345 \cdot 10^{-8} \text{ cm}^{-1}$$

$$\varphi'' : - \frac{1 \cdot 10^5 \times 0.0434^2 \times 4.3445 \cdot 10^{-5}}{810000 \times 5280 \times 0.0869} : -2.21 \cdot 10^{-11} \text{ cm}^{-2}$$

$$\varphi''' : - \frac{1 \cdot 10^5 \times 0.0434 \times (4.3445 \cdot 10^{-5})^2}{810000 \times 5280 \times 0.0869} : -2.21 \cdot 10^{-14} \text{ cm}^{-3}$$

-..St.Venant burulma momenti (M_t) :

x:0 için.

$$M_t : G_{st} \cdot J_t \cdot \varphi' : 810000 \times 5280 \times 1.345 \cdot 10^{-8} : 5.75 \cdot 10^{-4} \text{ tm.}$$

x:10 (açıklık ortası için)

$$\varphi : 0, M_t : 0 \text{ (Simetriden dolayı)}$$

-.. Çarpılma burulması (M_z):

x:0 için

$$M_z : -E_{st} \cdot J_{w_M w_M} \cdot \varphi''' : -2100000 \times 1.0794885 \cdot 10^{12} \times 2.21 \cdot 10^{-14} : 0.499 \text{ tm.}$$

x:10 m. için tüm kesit tesirleri burulma momenti çarpılma

burulmasıdır. $M_z : 0.50 \text{ tm.}$

... Açıklık ortasında normal gerilmeler (σ_x)

$$\sigma_x: \sigma_{x.w} : \frac{M_w}{J_{w_M w_M}} \cdot w_M$$

$$M_w: -E_{st} \cdot J_{w_M w_M} \cdot \varphi'' : -2100000 \cdot (J_{w_M w_M}) \cdot (-2.21 \cdot 10^{-11}) : 4.63 \cdot 10^{-5} J_{w_M w_M}$$

$$\sigma_x: \frac{4.63 \cdot 10^{-5} \cdot J_{w_M w_M}}{J_{w_M w_M}} \cdot w_M : 4.63 \cdot 10^{-5} \cdot w_M$$

$$\sigma_{xA}: 0 \quad (w_{MA}: 0)$$

$$\sigma_{xB}: 0 \quad (w_{MB}: 0)$$

$$\sigma_{xC}: 4.63 \cdot 10^{-5} \cdot x - 4839 : -0.22 \text{ Kg/cm}^2 : -\sigma_{xC}'$$

$$\sigma_{xD}: \quad " \quad " \quad x \quad 4839 : 0.22 \quad " \quad " : -\sigma_{xD}'$$

$$\sigma_{xE}: \quad " \quad " \quad x - 9111 : -0.42 \quad " \quad " : -\sigma_{xE}'$$

$$\sigma_{xF}: \quad " \quad " \quad x 20289 : 0.94 \quad " \quad " : -\sigma_{xF}'$$

$$\sigma_{xG}: \quad " \quad " \quad x 15451 : 0.71 \quad " \quad " : -\sigma_{xG}'$$

$$\sigma_{xH}: \quad " \quad " \quad x 25328 : 1.17 \quad " \quad " : -\sigma_{xH}'$$

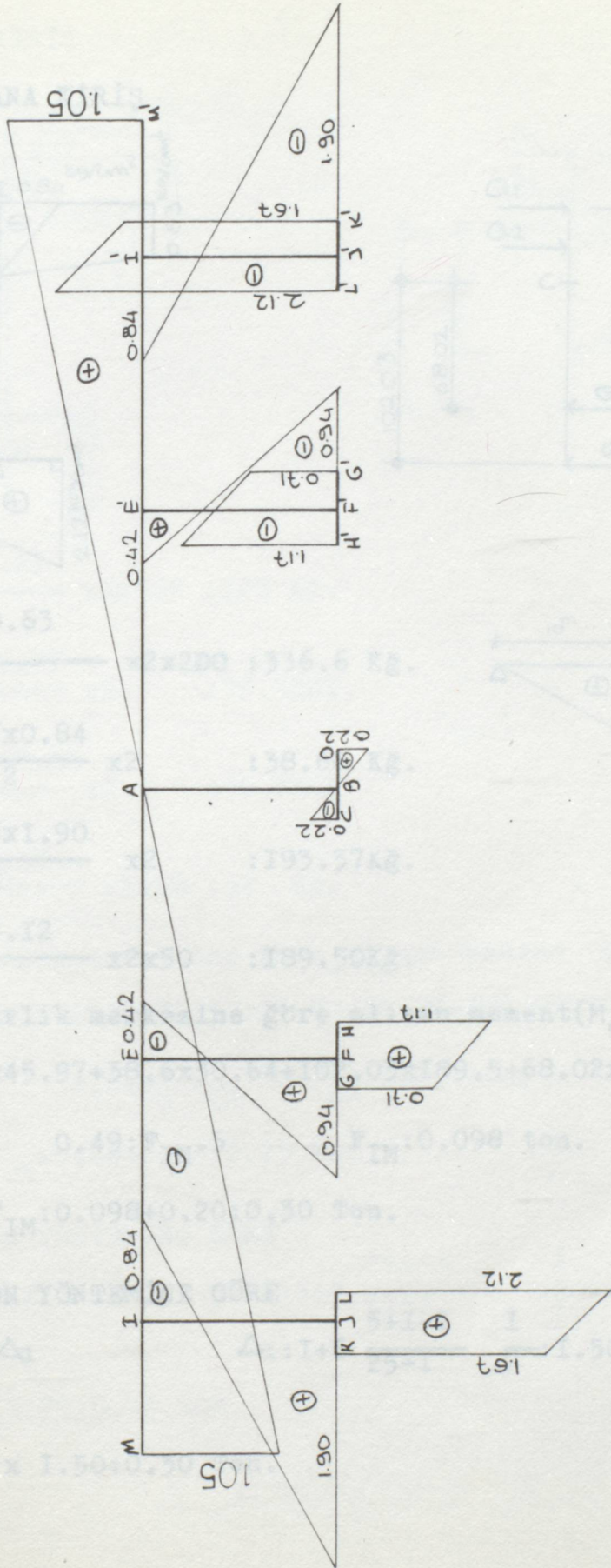
$$\sigma_{xI}: \quad " \quad " \quad x -18221 : -0.84 \quad " \quad " : -\sigma_{xI}'$$

$$\sigma_{xJ}: \quad " \quad " \quad x 40979 : 1.90 \quad " \quad " : -\sigma_{xJ}'$$

$$\sigma_{xK}: \quad " \quad " \quad x 36140 : 1.67 \quad " \quad " : -\sigma_{xK}'$$

$$\sigma_{xL}: \quad " \quad " \quad x 45818 : 2.12 \quad " \quad " : -\sigma_{xL}'$$

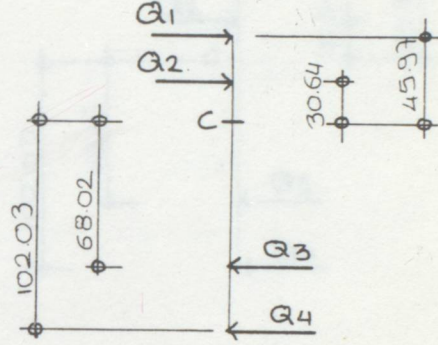
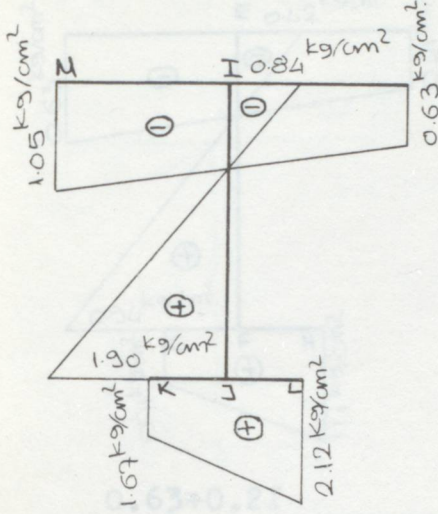
$$\sigma_{xM}: \quad " \quad " \quad x -22777 : -1.05 \quad " \quad " : -\sigma_{xM}'$$



I. YÜKLEME NORMAL GERİLME DİYAGRAMI(G_x) Ö: Z/1 - 1/50

- II. ANA KIRIŞ

- .. I. ANA KIRIŞ



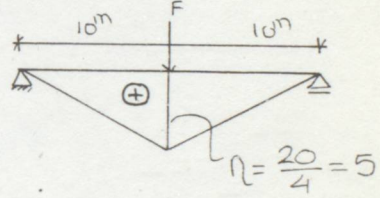
$$1.05 + 0.63$$

$$Q_1: \frac{\quad}{2} \times 2 \times 200 : 336.6 \text{ Kg.}$$

$$Q_2: \frac{45.97 \times 0.84}{2} \times 2 : 38.60 \text{ Kg.}$$

$$Q_3: \frac{102.03 \times 1.90}{2} \times 2 : 193.37 \text{ Kg.}$$

$$Q_4: \frac{1.67 + 2.12}{2} \times 2 \times 50 : 189.50 \text{ Kg.}$$



Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_c : 336.6 \times 45.97 + 38.6 \times 30.64 + 102.03 \times 189.5 + 68.02 \times 193.37 : 0.49 \text{ tm.}$$

$$M_c : F_{IM} \cdot n \quad 0.49 : F_{IM} \cdot 5 \quad F_{IM} : 0.098 \text{ ton.}$$

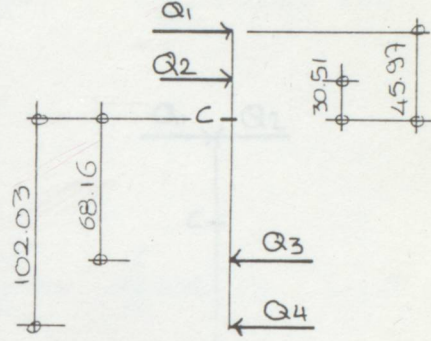
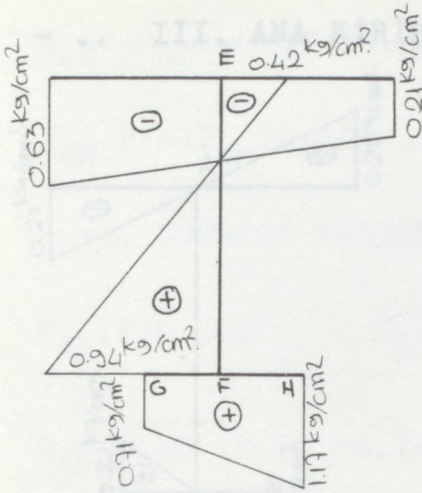
$$F_{I\Sigma} : F/n + F_{IM} : 0.098 + 0.20 : 0.30 \text{ Ton.}$$

-.. COURBON YÖNTEMİNE GÖRE

$$F_{I\Sigma} : F/n \cdot \Delta_1 \quad \Delta_1 : 1 + 6 \frac{5 + 1 - 2}{25 - 1} \frac{1}{2} : 1.50$$

$$F_{I\Sigma} : 0.20 \times 1.50 : 0.30 \text{ Ton.}$$

-II, ANA KIRIŞ



$$Q_1 = \frac{0.63 + 0.21}{2} \times 2 \times 200 = 168 \text{ Kg.}$$

$$Q_2 = \frac{0.42 \times 45.97}{2} \times 2 = 19.30 \text{ Kg.}$$

$$Q_3 = \frac{0.94 \times 102.03}{2} \times 2 = 95.71 \text{ Kg.}$$

$$Q_4 = \frac{0.71 + 1.17}{2} \times 2 \times 50 = 94 \text{ Kg.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_c = 168 \times 45.97 + 19.3 \times 30.51 + 95.71 \times 68.16 + 102.03 \times 94 = 0.24 \text{ tm.}$$

$$M_c = F_{2M} \cdot r \quad 0.24 = 5 \cdot F_{2M} \quad F_{2M} = 0.05 \text{ ton.}$$

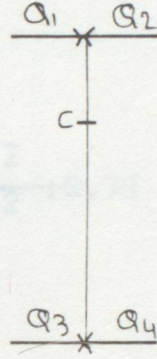
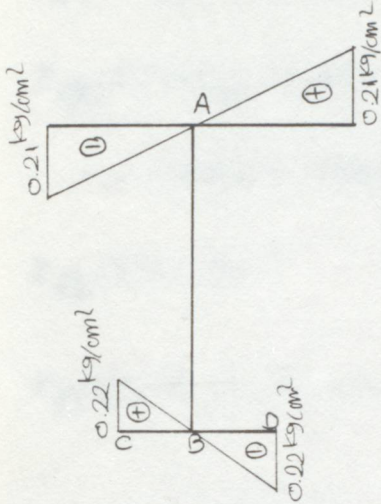
$$F_{2\Sigma} = F/n + F_{2M} = 0.20 + 0.05 = 0.25 \text{ Ton.}$$

-..COURBON YÖNTEMİNE GÖRE

$$F_{2\Sigma} = F/n \cdot \Delta_2 \quad \Delta_2 = 1 + 6 \frac{5+1-4}{25-1} \cdot \frac{1}{2} = 1.25$$

$$F_{2\Sigma} = 0.20 \cdot 1.25 = 0.25 \text{ Ton.}$$

- ... III. ANA KIRIŞ



$$Q_1 + Q_2 = 0, \quad Q_3 + Q_4 = 0, \quad M_C = 0, \quad F_{3M} = 0$$

$$F_{3\Sigma} = F/5 = 0.20 \text{ Ton.}$$

-... COURBON YÖNTEMİNE GÖRE.

$$F_{3\Sigma} = F/n \cdot \Delta_3 \quad \Delta_3 = I+6 \frac{5+I-6}{25-I} \frac{I}{2} = I.00$$

$$F_{3\Sigma} = 0.20 \times I.00 = 0.20 \text{ Ton.}$$

- ... IV. ANA KİRİŞ

$$M_{2C} = -M_{4C} = -0.24 \text{ Tm.} \quad -0.24 : F_{4M} \cdot 5 \quad F_{4M} = -0.05 \text{ ton.}$$

$$F_{4\Sigma} = F/n + F_{4M} = 0.20 - 0.05 = 0.15 \text{ Ton.}$$

- ... COURBON YÖNTEMİNE GÖRE.

$$F_{4\Sigma} = F/n \cdot \Delta_4 \quad \Delta_4 = 1 + 6 \frac{5+1-8}{25-1} \frac{1}{2} = 0.75$$

$$F_{4\Sigma} = 0.20 \cdot 0.75 = 0.15 \text{ Ton.}$$

- ... V. ANA KİRİŞ

$$M_{1C} = -M_{VC} = -0.49 \text{ Tm.} \quad F_{5M} = -0.10 \text{ Ton.}$$

$$F_{5\Sigma} = F/n + F_{5M} = 0.20 - 0.10 = 0.10 \text{ Ton.}$$

- ... COURBON YÖNTEMİNE GÖRE.

$$F_{5\Sigma} = F/n \cdot \Delta_5 \quad \Delta_5 = 1 + 6 \frac{5+1-10}{25-1} \frac{1}{2} = 0.50$$

$$F_{5\Sigma} = 0.20 \cdot 0.50 = 0.10 \text{ Ton.}$$

- ... Çarpılma burulması (M_2)

x:0 için.

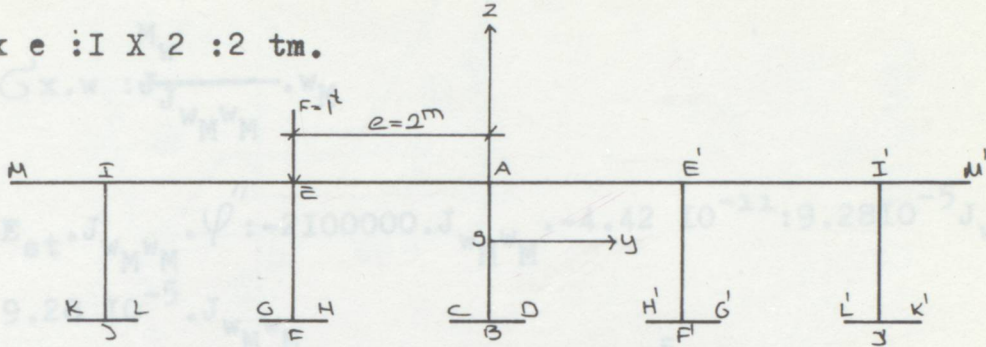
$$M_2 = -B_{st} \cdot J_w \cdot w'' = 2100000 \times 1.0794885 \cdot 10^{12} \times 4.42 \cdot 10^{-14} = 0.997 \text{ Tm.}$$

x:10 m için tüm kesit tesiri burulma momenti çarpılma

burulmasıdır. $M_2 = 1.00 \text{ Tm.}$

3.3.b -.. II. YÜKLEME

M:F x e :I X 2 :2 tm.



Dönme açıları.

$$\varphi' = \frac{2 \cdot 10^5}{810000 \cdot 5280} \left(0.50 - \frac{0.0434}{0.0869} \cdot 1.00\right) : 2.69 \cdot 10^{-8} \text{ cm}^{-1}.$$

$$\varphi'' = \frac{2 \cdot 10^5 \times 0.0434^2 \times 4.3445 \cdot 10^{-5}}{810000 \times 5280 \times 0.0869} : -4.42 \cdot 10^{-11} \text{ cm}^{-2}.$$

$$\varphi''' = \frac{2 \cdot 10^5 \times 0.0434 \times (4.3445 \cdot 10^{-5})^2}{810000 \times 5280 \times 0.0869} : -4.42 \cdot 10^{-14} \text{ cm}^{-3}.$$

-.. St.Venant burulma momenti (M_t):

x:0 için

$$M_t : G_{st} \cdot J_t \cdot \varphi' : 810000 \times 5280 \times 2.69 \cdot 10^{-8} : 1.15 \cdot 10^{-4} \text{ tm.}$$

x:10 m.(açıklık ortası için)

$$\varphi' : 0, M_t : 0 \text{ (Simetriden dolayı)}$$

- .. Çarpılma burulması (M_z)

x:0 için.

$$M_z : -E_{st} \cdot J_w \cdot \varphi''' : 2100000 \times 1.0794885 \cdot 10^{12} \times 4.42 \cdot 10^{-14} : 0.99 \text{ Tm.}$$

x:10 m.için tüm kesit tesiri burulma momenti çarpılma

burulmasıdır. $M_z : 1.00 \text{ Tm.}$

...Açıklık ortasında normal gerilmeler (σ_x)

$$\sigma_x: \sigma_{x.w} = \frac{M_w}{J_{w_M w_M}} \cdot w_M$$

$$M_w: -E_{st} \cdot J_{w_M w_M} \cdot \psi'' = -2100000 \cdot J_{w_M w_M} \cdot -4.42 \cdot 10^{-11} : 9.28 \cdot 10^{-5} J_{w_M w_M}$$

$$\sigma_x: \frac{9.28 \cdot 10^{-5} \cdot J_{w_M w_M}}{J_{w_M w_M}} \cdot w_M = 9.28 \cdot 10^{-5} \cdot w_M$$

$$\sigma_{xA}: 0 \quad (w_{MA}: 0)$$

$$\sigma_{xB}: 0 \quad (w_{MB}: 0)$$

$$\sigma_{xC}: 9.28 \cdot 10^{-5} \quad x-4839 \quad : -0.45 \text{ Kg/cm}^2 : -\sigma_{xC}'$$

$$\sigma_{xD}: \text{ " " } \quad x 4839 \quad : 0.45 \text{ Kg/cm}^2 : -\sigma_{xD}'$$

$$\sigma_{xE}: \text{ " " } \quad x-9111 \quad : -0.85 \text{ Kg/cm}^2 : -\sigma_{xE}'$$

$$\sigma_{xF}: \text{ " " } \quad x 20289 \quad : 1.88 \text{ " " } : -\sigma_{xF}'$$

$$\sigma_{xG}: \text{ " " } \quad x 15451 \quad : 1.43 \text{ " " } : -\sigma_{xG}'$$

$$\sigma_{xH}: \text{ " " } \quad x 25328 \quad : 2.35 \text{ " " } : -\sigma_{xH}'$$

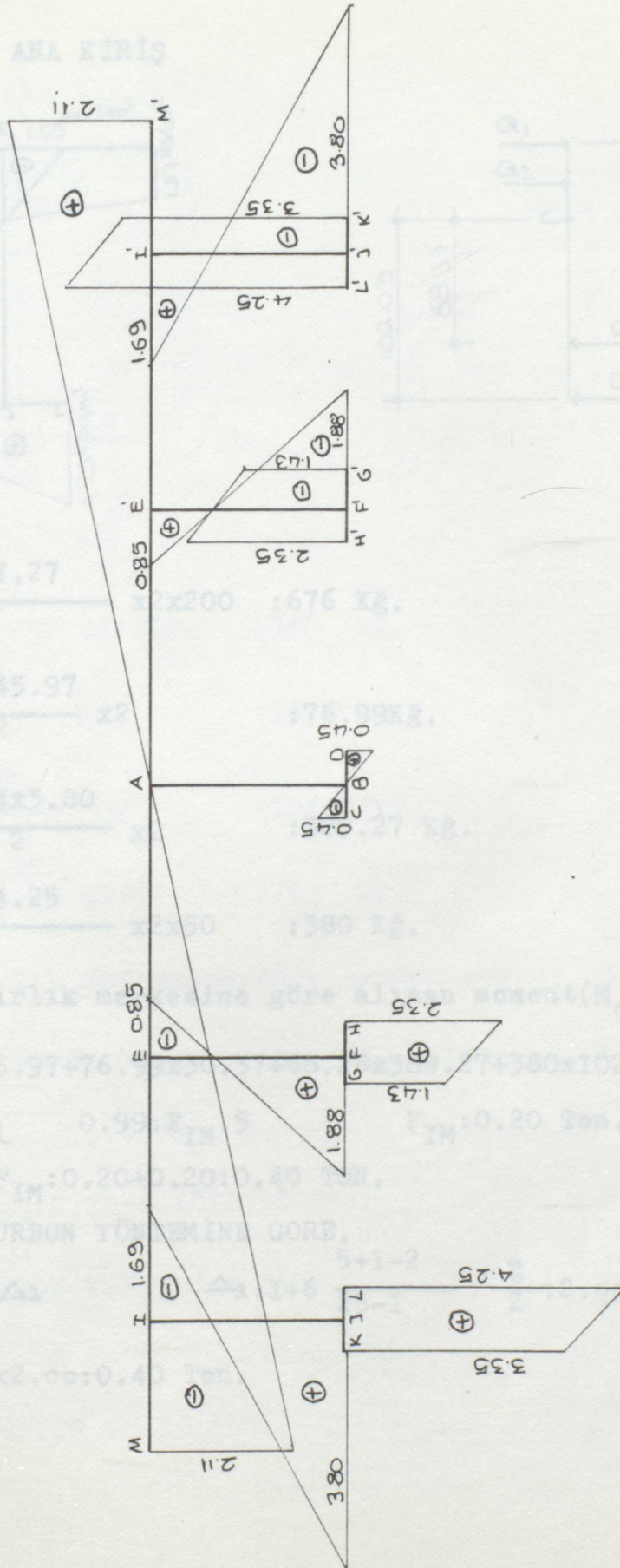
$$\sigma_{xI}: \text{ " " } \quad x-18221 \quad : 1.69 \text{ " " } : -\sigma_{xI}'$$

$$\sigma_{xJ}: \text{ " " } \quad x 40979 \quad : 3.80 \text{ " " } : -\sigma_{xJ}'$$

$$\sigma_{xK}: \text{ " " } \quad x 36140 \quad : 3.35 \text{ " " } : -\sigma_{xK}'$$

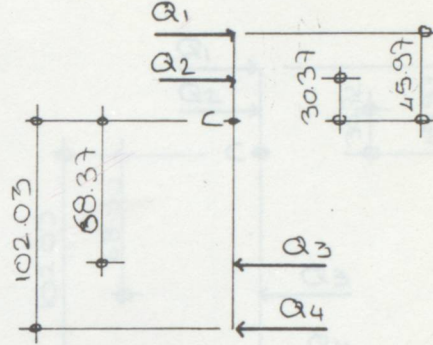
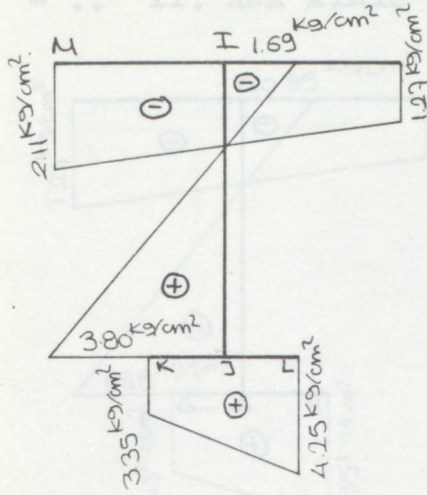
$$\sigma_{xL}: \text{ " " } \quad x 45818 \quad : 4.25 \text{ " " } : -\sigma_{xL}'$$

$$\sigma_{xM}: \text{ " " } \quad x 22777 \quad : 2.11 \text{ " " } : -\sigma_{xM}'$$



II. YÜKLEME NORMAL GERİLME DİYAGRAMI (G_x) Ö: 1/1 - 1/50

- ... I. ANA KIRIŞ



$$Q_1: \frac{2 \cdot II + I \cdot 27}{2} \times 2 \times 200 : 676 \text{ Kğ.}$$

$$Q_2: \frac{1.69 \times 45.97}{2} \times 2 : 76.99 \text{ Kğ.}$$

$$Q_3: \frac{102.44 \times 3.80}{2} \times 2 : 389.27 \text{ Kğ.}$$

$$Q_4: \frac{3.35 + 4.25}{2} \times 2 \times 50 : 380 \text{ Kğ.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_c: 676 \times 45.97 + 76.99 \times 30.37 + 68.28 \times 389.27 + 380 \times 102.03 : 0.99 \text{ Tm.}$$

$$M_c: F_{IM} \cdot \eta \quad 0.99: F_{IM} \cdot 5 \quad F_{IM}: 0.20 \text{ Ton.}$$

$$F_{I\Sigma}: F/n + F_{IM}: 0.20 + 0.20 : 0.40 \text{ TON.}$$

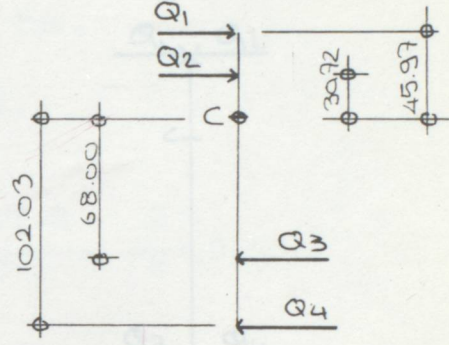
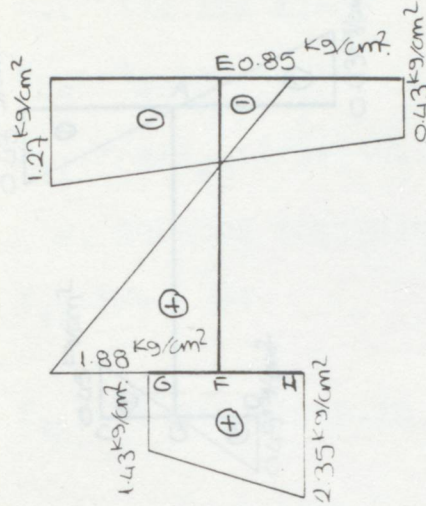
- ... COURBON YÖNTEMİNE GÖRE.

$$F_{I\Sigma}: F/n \cdot \Delta_1 \quad \Delta_1: I + 6 \frac{5 + I - 2}{25 - I} \cdot \frac{2}{2} : 2.00$$

$$F_{I\Sigma}: 0.20 \times 2.00 : 0.40 \text{ Ton.}$$

$$F_2: 0.20 \times 1.5 : 0.30 \text{ Ton.}$$

- ... II. ANA KIRIŞ



$$Q_I: \frac{1.27+0.43}{2} \times 2 \times 200 : 340 \text{ Kg.}$$

$$Q_2: \frac{0.85 \times 46}{2} \times 2 : 39.10 \text{ Kg.}$$

$$Q_3: \frac{102 \times 1.88}{2} \times 2 : 191.76 \text{ Kg.}$$

$$Q_4: \frac{1.43+2.35}{2} \times 2 \times 50 : 189 \text{ Kg.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_c: 340 \times 45.97 + 30.72 \times 39.10 + 191.76 \times 68 + 189 \times 102.03 : 0.49 \text{ Tm.}$$

$$M_c: F_{2M} \cdot \eta \quad 0.49: F_{2M} \cdot 5 \quad F_{2M}: 0.10 \text{ Ton.}$$

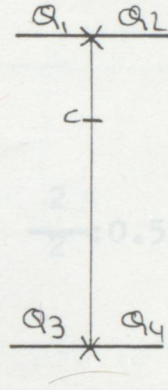
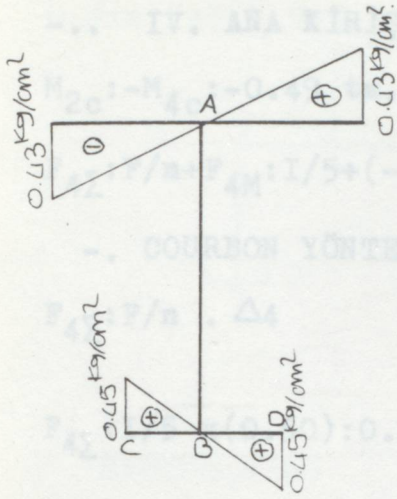
$$F_{2\Sigma}: F/n + F_{2M}: 0.20 + 0.10: 0.30 \text{ Ton.}$$

-... COURBON YONTEMİNE GÖRE.

$$F_{2\Sigma}: F/n \cdot \Delta_2 \quad \Delta_2: 1 + 6 \frac{5+1-4}{25-1} \frac{2}{2}: 1.5$$

$$F_{2\Sigma}: 0.20 \times 1.5 : 0.30 \text{ Ton.}$$

- ... III. ANA KIRIŞ



$Q_1 + Q_2 = 0$, $Q_3 + Q_4 = 0$, $M_c = 0$

$F_{3\Sigma} : F/n : 1/5 : 0.20 \text{ Ton.}$

- ... COURBON YÖNTEMİNE GÖRE

$F_{3\Sigma} : F/n \cdot \Delta_3$

$\Delta_3 : 1 + 6 \frac{5 + 1 - 2 \times 3}{25 - 1} \frac{2}{2} : 1$

$F_{3\Sigma} : 1/5 \times (1.00) : 0.20 \text{ Ton.}$

... IV. ANA KİRİŞ

$$M_{2c}:-M_{4c}:-0.49 \text{ tm.} \quad F_{4M}:-0.10 \text{ Ton.}$$

$$F_{4\Sigma}:F/n+F_{4M}:I/5+(-0.10):0.10 \text{ TON.}$$

.. COURBON YÖNTEMİNE GÖRE

$$F_{4\Sigma}:F/n \cdot \Delta 4 \quad \Delta 4:I+6 \frac{5+I-8}{25-I} \frac{2}{2}:0.50$$

$$F_{4\Sigma}:I/5 \times (0.50):0.10 \text{ TON.}$$

... V. ANA KİRİŞ

$$- M_{5c}:M_{1c}:0.99 \text{ tm.} \quad F_{5M}:-0.20 \text{ Ton.}$$

$$F_{5\Sigma}:F/n+F_{5M}:0.20-0.20:0$$

... COURBON YÖNTEMİNE GÖRE

$$F_{5\Sigma}:F/n \cdot \Delta 5 \quad \Delta 5:I+6 \frac{5+I-10}{25-I} \frac{2}{2}:0$$

$$F_{5\Sigma}:I/5.0 :0$$

x:10 m. (açıklık ortası için)

ie, M:10 (Sizetiden dolayı)

...Çarpılma burulması(M_y):

x:10 için.

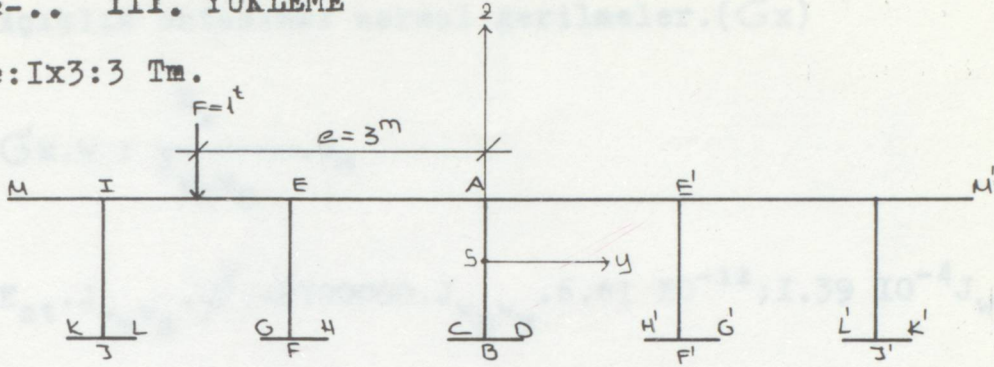
$$M_{y1}-2 \cdot 3 \cdot w \cdot v \cdot \sigma: -2100000 \times 1.0794885 \cdot 10^{12} \times 5.62 \cdot 10^{-14} : 1.49 \text{ tm.}$$

x:10 m. (20m kesit tesiri burulma sonucu çarpılma

burulmasıdır) M_y:1.50 tm.

3.3.c-.. III. YÜKLEME

M: Fxe: Ix3:3 Tm.



$$\varphi' = \frac{3 \cdot 10^5}{810000 \cdot 5280} \left(0.50 - \frac{0.0434}{0.0869} \cdot 1.00\right) : 4.036 \cdot 10^{-8} \text{ cm}^{-1}$$

$$\varphi'' = \frac{-3 \cdot 10^5 \times (0.0434)^2 \times 4.3445 \cdot 10^{-5}}{810000 \times 5280 \times 0.0869} : 6.61 \cdot 10^{-11} \text{ cm}^{-2}$$

$$\varphi''' = \frac{-3 \cdot 10^5 \times 0.0434 \times (4.3445 \cdot 10^{-5})^2}{810000 \times 5280 \times 0.0869} \times 1.00 : 6.61 \cdot 10^{-14} \text{ cm}^{-3}$$

...st.Venant burulma momenti (M_t) :

x:0 için.

$$M_t = G_{st} \cdot J_t \cdot \varphi' : 810000 \times 5280 \times 4.036 \cdot 10^{-8} : 0.0017 \text{ Tm.}$$

x:10 m. (açıklık ortası için)

$\varphi' : 0$, $M_t : 0$ (Simetriden dolayı)

...Çarpılma burulması (M_z):

x:0 için.

$$M_z = -E_{st} \cdot J_{w_M} \cdot \varphi''' : -2100000 \times 1.0794885 \cdot 10^{12} \times 6.62 \cdot 10^{-14} : 1.49 \text{ Tm.}$$

x:10 m. (Tüm kesit tesiri burulma momenti çarpılma burulmasıdır) $M_z : 1.50 \text{ Tm.}$

... Açıklık ortasında normal gerilmeler.(Gx)

$$G_x: G_{x.w} : \frac{M_w}{J_{w_M w_M}} \cdot w_M$$

$$M_w: -E_{st} \cdot J_{w_M w_M} \cdot \varphi'' : -2100000 \cdot J_{w_M w_M} \cdot 6.61 \cdot 10^{-11} : 1.39 \cdot 10^{-4} J_{w_M w_M}$$

$$G_x: \frac{1.39 \cdot 10^{-4} J_{w_M w_M}}{J_{w_M w_M}} \cdot w_M : 1.39 \cdot 10^{-4} x w_M$$

GxA:0 (wMA:0)

GxB:0 (wMB:0)

GxC: 1.39 10⁻⁴ x- 4839 :-0.67 Kğ/cm² :-GxC'

GxD: " " x 4839 : 0.67 " " :-GxD'

GxE: " " x- 9111 :-1.27 " " :-GxE'

GxF: " " x 20289 : 2.82 " " :-GxF'

GxG: " " x 15451 : 2.15 " " :-GxG'

GxH: " " x 25328 : 3.52 " " :-GxH'

GxI: " " x-18221 :-2.53 " " :-GxI'

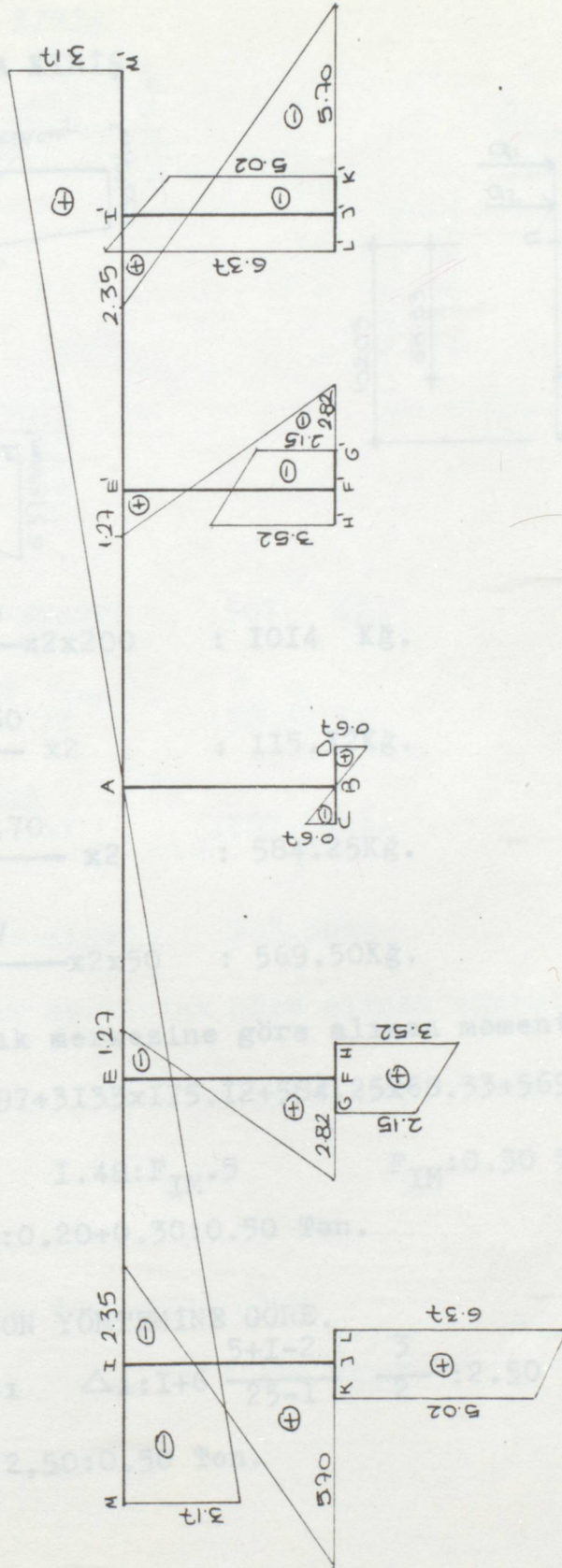
GxJ: " " x 40979 : 5.70 " " :-GxJ'

GxK: " " x 36140 : 5.02 " " :-GxK'

GxL: " " x 45818 : 6.37 " " :-GxL'

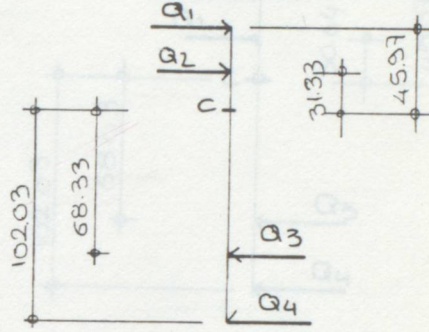
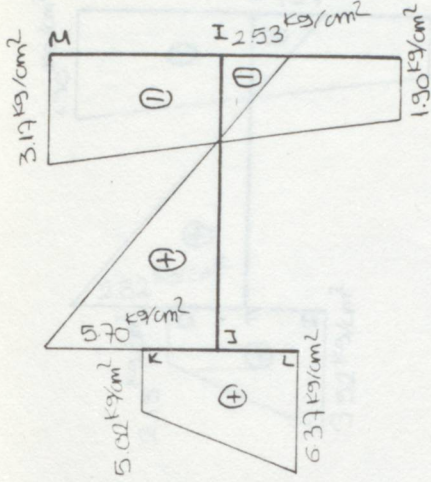
GxM: " " x 22777 : 3.17 " " :-GxM'

III YÜKLEME NORMAL GERİLME DİYAGRAMI (G_x) (1/2-1/50)



III. YÜKLEME NORMAL GERİLME DİYAGRAMI (σ_x) Ö:1/2 - 1/50

I. ANA KIRIŞ



$$Q_1: \frac{3.17+1.90}{2} \times 2 \times 200 : 1014 \text{ Kg.}$$

$$Q_2: \frac{2.53 \times 45.50}{2} \times 2 : 115.12 \text{ Kg.}$$

$$Q_3: \frac{102.50 \times 5.70}{2} \times 2 : 584.25 \text{ Kg.}$$

$$Q_4: \frac{5.02+6.37}{2} \times 2 \times 50 : 569.50 \text{ Kg.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_c: 1014 \times 45.97 + 3133 \times 115.12 + 584.25 \times 68.33 + 569.50 \times 102.03 : 1.48 \text{ Tm.}$$

$$M_c: F_{IM} \cdot \eta \quad 1.48: F_{IM} \cdot 5 \quad F_{IM}: 0.30 \text{ Ton.}$$

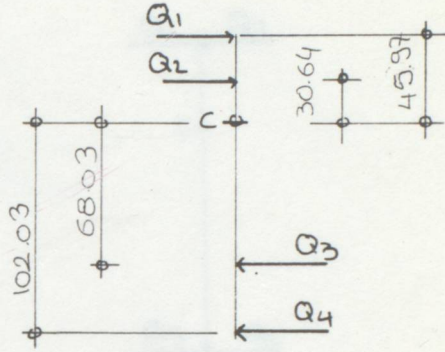
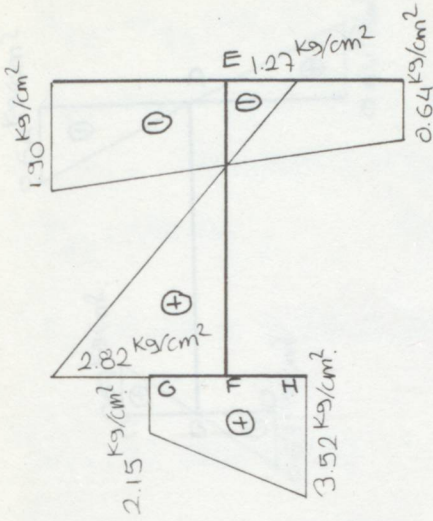
$$F_{I\Sigma}: F/n + F_{IM}: 0.20 + 0.30: 0.50 \text{ Ton.}$$

... COURBON YÖNTEMİNE GÖRE.

$$F_{I\Sigma}: F/n \cdot \Delta_1 \quad \Delta_1: 1+6 \frac{5+1-2}{25-1} \frac{3}{2} : 2.50$$

$$F_{I\Sigma}: 0.20 \times 2.50: 0.50 \text{ Ton.}$$

... II. ANA KIRIŞ



$$Q_I: \frac{1.90+0.64}{2} \times 2 \times 200 : 507 \text{ Kğ.}$$

$$Q_2: \frac{1.27 \times 45.97}{2} \times 2 : 58.37 \text{ Kğ.}$$

$$Q_3: \frac{2.82 \times 102.03}{2} \times 2 : 287.75 \text{ Kğ.}$$

$$Q_4: \frac{2.15+3.52}{2} \times 2 \times 50 : 283.50 \text{ Kğ.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_c: 507 \times 45.97 + 30.64 \times 58.37 + 287.75 \times 68.03 + 102.03 \times 283.50 : 0.74 \text{ Tm.}$$

$$M_c: F_{2M} \cdot \eta \quad 0.74: F_{2M} \cdot 5 \quad F_{2M}: 0.15 \text{ Ton.}$$

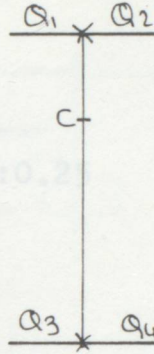
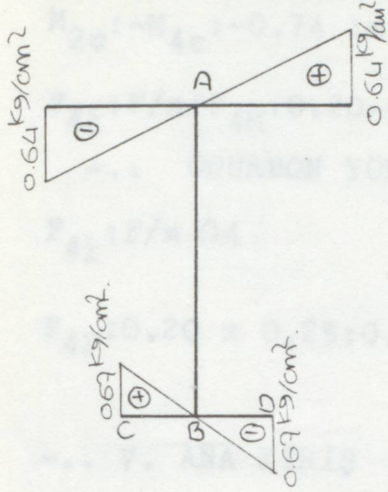
$$F_{2\Sigma}: F/n + F_{2M}: 0.20 + 0.15 : 0.35 \text{ Ton.}$$

... COURBON YÖNTEMİNE GÖRE.

$$F_{2\Sigma}: F/n \cdot \Delta 2 \quad \Delta 2: 1+6 \frac{5+1-4}{25-1} \frac{3}{2}: 1.75$$

$$F_{2\Sigma}: 0.20 \times 1.75 : 0.35 \text{ Ton.}$$

... III. ANA KIRIŞ



$$Q_1 + Q_2 = 0, \quad Q_3 + Q_4 = 0, \quad M_C = 0$$

$$F_{3\Sigma} = F/n: 1/5: 0.20 \text{ Ton.}$$

... COURBON YÖNTEMİNE GÖRE.

$$F_{3\Sigma} = F/n \cdot \Delta 3 \quad \Delta 3: 1+6 \frac{5+1-2 \times 3}{25-1} \frac{3}{2}: 1.00$$

$$F_{3\Sigma} = 0.20 \times 1.00: 0.20 \text{ Ton.}$$

- .. IV. ANA KIRIŞ

$$M_{2c}:-M_{4c}:-0.74 \text{ tm.} \quad F_{4M}:-0.15 \text{ Ton.}$$

$$F_{4\Sigma}:F/n+F_{4M}:0.20-0.15:0.05 \text{ Ton.}$$

-.. COURBON YÖNTEMİNE GÖRE.

$$F_{4\Sigma}:F/n \cdot \Delta 4 \quad \Delta 4:I+6 \frac{5+I-2x4}{25-I} \frac{3}{2} :0.25$$

$$F_{4\Sigma}:0.20 \times 0,25:0.05 \text{ Ton.}$$

-.. V. ANA KIRIŞ

$$M_{1c}:-M_{5c}:-1.48 \text{ Tm.} \quad F_{5M}:-0.30 \text{ Ton.}$$

$$F_{5\Sigma}:F/n+F_{5M}:0.20+(-0.30):-0.10 \text{ Ton.}$$

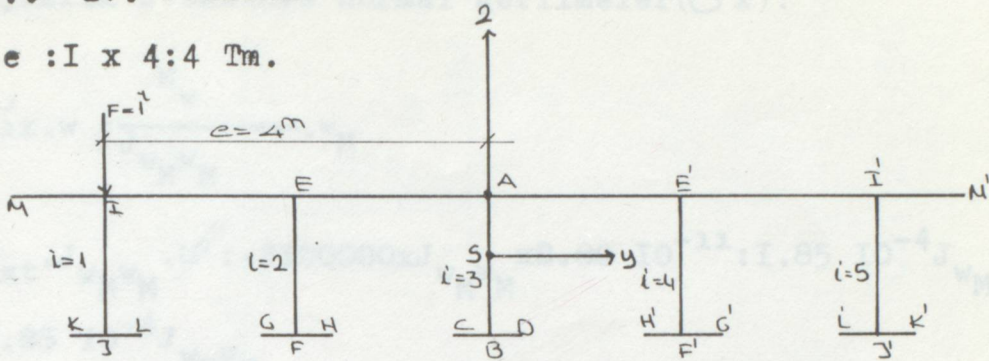
- .. COURBON YÖNTEMİNE GÖRE.

$$F_{5\Sigma}:F/n \cdot \Delta 5 \quad \Delta 5:I+6 \frac{5+I-2x5}{25-I} \frac{3}{2}:-0.50$$

$$F_{5\Sigma}:0.20 \times (-0.50):-0.10 \text{ Ton.}$$

3.3.d-... IV. YÜKLEME

M:F x e :I x 4:4 Tm.



$$\varphi' = \frac{4 \cdot 10^5}{810000 \cdot 5280} \left(0.50 - \frac{0.0434}{0.0869} \cdot 1.00 \right) : 5.38 \cdot 10^{-8} \text{ cm}^{-1}$$

$$\varphi'' = \frac{-4 \cdot 10^5 \times 0.0434 \times 4.3445 \cdot 10^{-5} \times 0.0434}{810000 \times 5280 \times 0.0869} : 8.80 \cdot 10^{-11} \text{ cm}^{-2}$$

$$\varphi''' = \frac{-4 \cdot 10^5 \times 0.0434 \times (4.3445 \cdot 10^{-5})^2 \times 1.00}{810000 \times 5280 \times 0.0869} : 8.80 \cdot 10^{-14} \text{ cm}^{-3}$$

... St.Venant burulma momenti (M_t):

x:0 için

$$M_t = G_{st} \cdot J_t \cdot \varphi' : 810000 \times 5280 \times 5.38 \cdot 10^{-8} : 0.0023 \text{ tm.}$$

x:10 m. (Açıklık ortası için)

$$\varphi' : 0 \text{ - , } M_t : 0 \text{ (simetriden dolayı)}$$

... Çarpılma burulması (M_z):

x:0 için

$$M_z = -E_{st} \cdot J_{wM} \cdot \varphi''' : -2100000 \times 1.0794885 \cdot 10^{12} \times 8.80 \cdot 10^{-14} : 1.99 \text{ Tm.}$$

x:10 m. (Tüm kesit tesiri burulma momenti çarpılma

burulmasıdır) $M_z : 2.00 \text{ Tm.}$

... Açıklık ortasında normal gerilmeler(σ_x):

$$\sigma_x: \sigma_{x.w} = \frac{M_w}{J_{w_M w_M}} \cdot w_M$$

$$M_w: -E_{st} \cdot J_{w_M w_M} \cdot \varphi'' = -2100000 \times J_{w_M w_M} \times 8.80 \cdot 10^{-11} = 1.85 \cdot 10^{-4} J_{w_M w_M}$$

$$\sigma_x: \frac{1.85 \cdot 10^{-4} J_{w_M w_M}}{J_{w_M w_M}} \cdot w_M = 1.85 \cdot 10^{-4} \times w_M$$

$$\sigma_{xA}: 0 \quad (w_{MA}: 0)$$

$$\sigma_{xB}: 0 \quad (w_{MB}: 0)$$

$$\sigma_{xC}: 1.85 \cdot 10^{-4} \times -4838 : -0.89 \text{ Kğ/cm}^2 : -\sigma_{xC}'$$

$$\sigma_{xD}: " \quad " \quad \times 4838 : 0.89 \quad " \quad " : -\sigma_{xD}'$$

$$\sigma_{xE}: " \quad " \quad \times -9111 : 1.68 \quad " \quad " : -\sigma_{xE}'$$

$$\sigma_{xF}: " \quad " \quad \times 20289 : 3.75 \quad " \quad " : -\sigma_{xF}'$$

$$\sigma_{xG}: " \quad " \quad \times 15451 : 2.86 \quad " \quad " : -\sigma_{xG}'$$

$$\sigma_{xH}: " \quad " \quad \times 25328 : 4.68 \quad " \quad " : -\sigma_{xH}'$$

$$\sigma_{xI}: " \quad " \quad \times -18221 : -3.37 \quad " \quad " : -\sigma_{xI}'$$

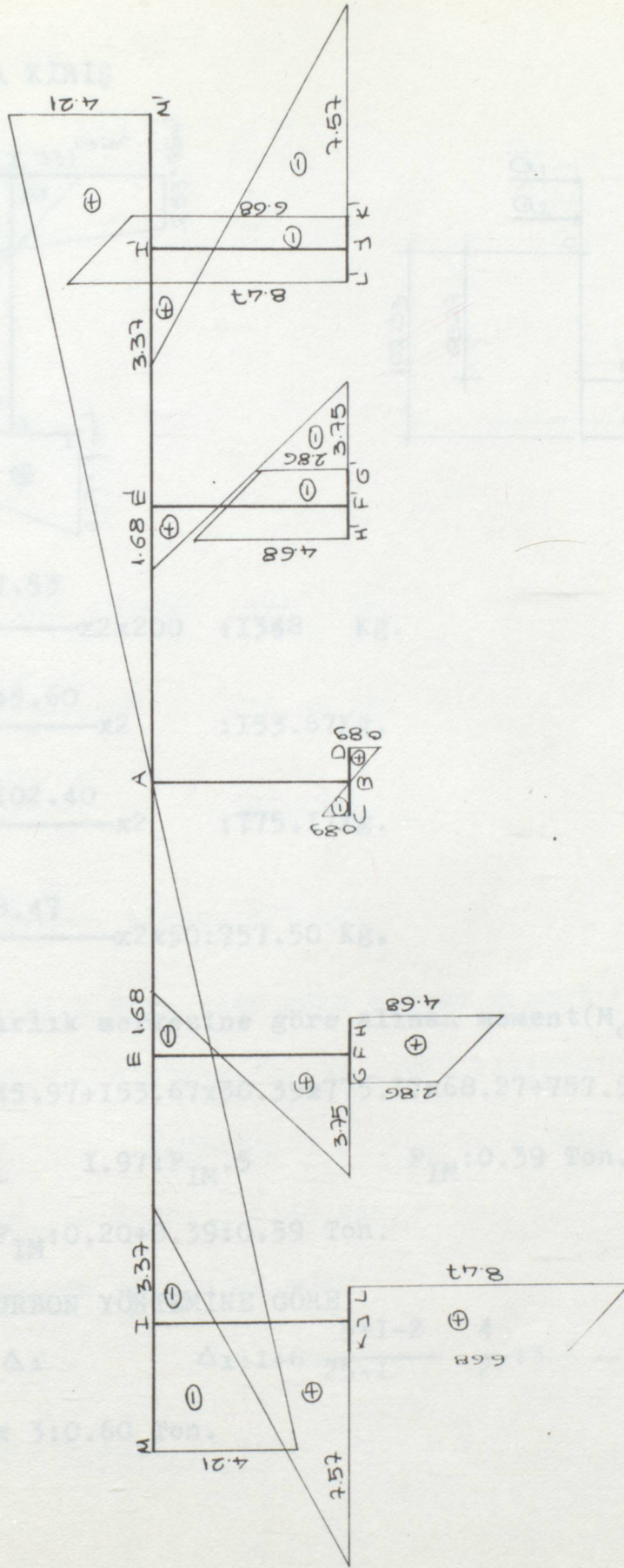
$$\sigma_{xJ}: " \quad " \quad \times 40979 : 7.57 \quad " \quad " : -\sigma_{xJ}'$$

$$\sigma_{xK}: " \quad " \quad \times 36140 : 6.68 \quad " \quad " : -\sigma_{xK}'$$

$$\sigma_{xL}: " \quad " \quad \times 45818 : 8.47 \quad " \quad " : -\sigma_{xL}'$$

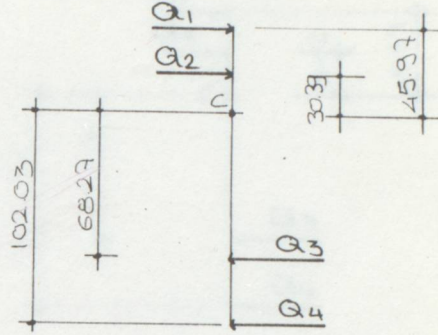
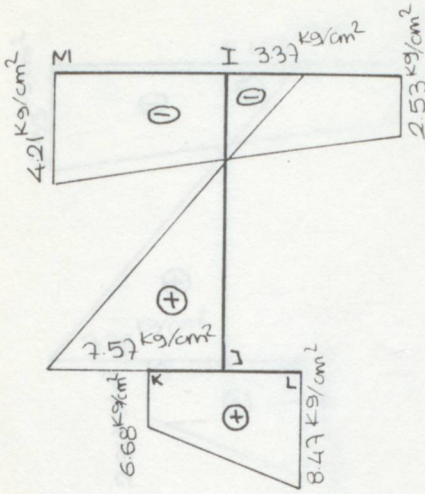
$$\sigma_{xM}: " \quad " \quad \times -22777 : -4.21 \quad " \quad " : -\sigma_{xM}'$$

IV YÜKLEME NORMAL GERİLME DİYAGRAMI (σ_x)



IV. YÜKLEME NORMAL GERİLME DİYAGRAMI (G_x) $\bar{\sigma} = 1/2 - 1/50$

.. I. ANA KIRIŞ



$$Q_1: \frac{4.21+2.53}{2} \times 2 \times 200 : 1348 \text{ Kğ.}$$

$$Q_2: \frac{3.37 \times 45.60}{2} \times 2 : 153.67 \text{ Kğ.}$$

$$Q_3: \frac{7.57 \times 102.40}{2} \times 2 : 775.17 \text{ Kğ.}$$

$$Q_4: \frac{6.68+8.47}{2} \times 2 \times 50 : 757.50 \text{ Kğ.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_c: 1348 \times 45.97 + 153.67 \times 30.39 + 775.17 \times 68.27 + 757.5 \times 102.03 : 1.97 \text{ tm.}$$

$$M_c: F_{IM} \cdot \eta \quad 1.97: F_{IM} \cdot 5 \quad F_{IM}: 0.39 \text{ Ton.}$$

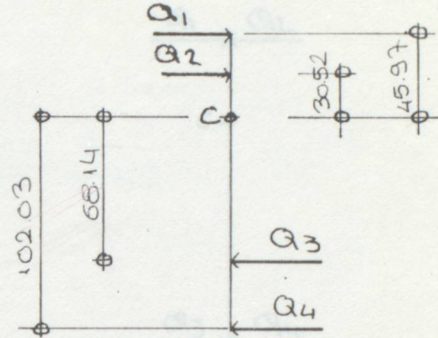
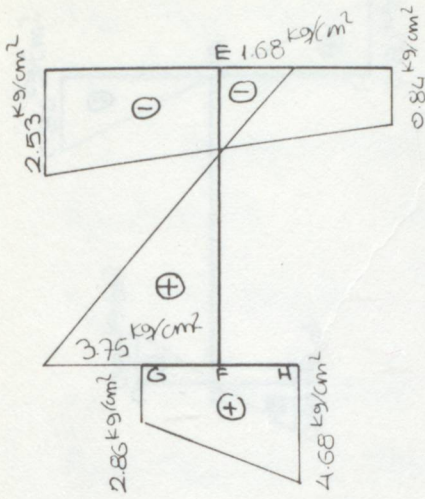
$$F_{I\Sigma}: F/n + F_{IM}: 0.20 + 0.39: 0.59 \text{ Ton.}$$

... COURBON YÖNTEMİNE GÖRE.

$$F_{I\Sigma}: F/n \cdot \Delta_1 \quad \Delta_1: 1 + 6 \frac{5+1-2}{25-1} \frac{4}{2}: 3$$

$$F_{I\Sigma}: 0.20 \times 3: 0.60 \text{ Ton.}$$

... II. ANA KIRIŞ



$$Q_1: \frac{2.53+0.84}{2} \times 2 \times 200 : 674 \text{ Kğ.}$$

$$Q_2: \frac{1.68 \times 45.79}{2} \times 2 : 76.93 \text{ Kğ.}$$

$$Q_3: \frac{3.75 \times 102.21}{2} \times 2 : 383.29 \text{ Kğ.}$$

$$Q_4: \frac{2.86+4.68}{2} \times 2 \times 50 : 377 \text{ Kğ.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_c: 674 \times 45.97 + 76.93 \times 30.52 + 383.29 \times 68.14 + 377 \times 102.03 : 0.98 \text{ Tm.}$$

$$M_c: F_{2M} \cdot \eta \quad 0.98: F_{2M} \cdot 5 \quad F_{2M}: 0.20 \text{ Ton.}$$

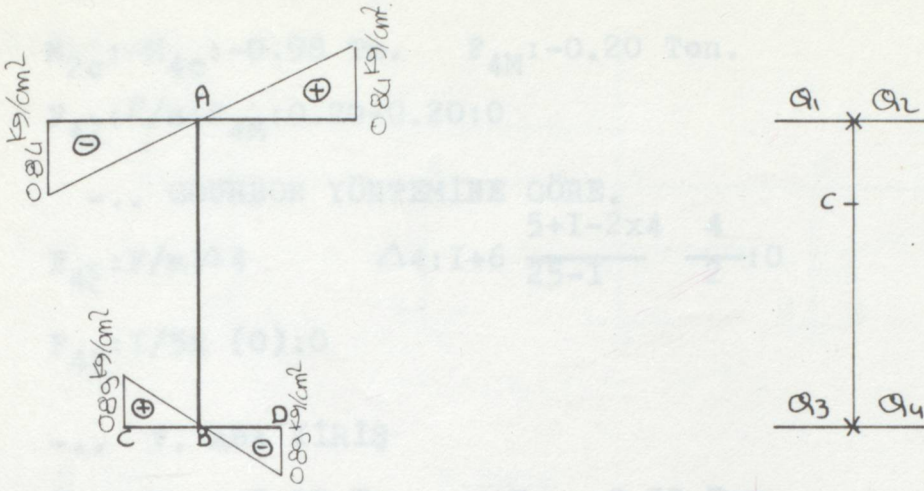
$$F_{2\Sigma}: F/n + F_{2M}: 0.20 + 0.20 : 0.40 \text{ Ton.}$$

... COURBON YÖNTEMİNE GÖRE.

$$F_{2\Sigma}: F/n \cdot \Delta 2 \quad \Delta 2: 1+6 \frac{5+1-4}{25-1} \frac{4}{2} : 2$$

$$F_{2\Sigma}: 0.20 \times 2.00 : 0.40 \text{ Ton.}$$

... III. ANA KIRIŞ



$$Q_1 + Q_2 = 0, \quad Q_3 + Q_4 = 0, \quad M_C = 0$$

$$F_{3\Sigma} = F/n = 1/5 = 0.20 \text{ Ton.}$$

... COURBON YÖNTEMİNE GÖRE.

$$F_{3\Sigma} = F/n \cdot \Delta_3 \quad \Delta_3 = 1 + 6 \frac{5+1-6}{25-1} \cdot \frac{4}{2} = 1.00$$

$$F_{3\Sigma} = 0.20 \times 1.00 = 0.20 \text{ Ton.}$$

-.. IV. ANA KIRIŞ

$$M_{2c}:-M_{4c}:-0.98 \text{ Tm.} \quad F_{4M}:-0.20 \text{ Ton.}$$

$$F_{4\Sigma}:F/n+F_{4M}:0.20-0.20:0$$

-.. COURBON YÖNTEMİNE GÖRE.

$$F_{4\Sigma}:F/n \cdot \Delta 4 \quad \Delta 4:I+6 \frac{5+I-2x4}{25-I} \frac{4}{2}:0$$

$$F_{4\Sigma}:I/5x(0):0$$

-.. V. ANA KIRIŞ

$$M_{Ic}:-M_{5c}:-1.97 \text{ Tm.} \quad F_{5M}:-0.39 \text{ Ton.}$$

$$F_{5\Sigma}:F/n+F_{5M}:I/5-0.39:-0.19 \text{ Ton.}$$

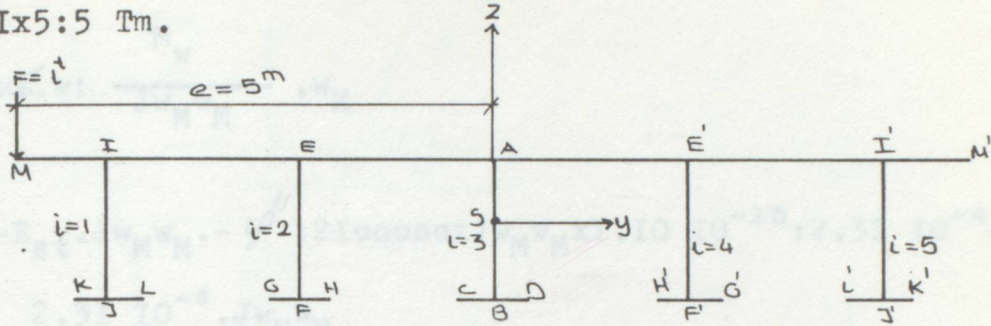
-.. COURBON YÖNTEMİNE GÖRE.

$$F_{5\Sigma}:F/n \cdot \Delta 5 \quad \Delta 5:I+6 \frac{5+I-2x5}{25-I} \frac{4}{2}:-1.00$$

$$F_{5\Sigma}:F/n \cdot \Delta 5 :0.20x(-1.00):-0.20 \text{ Ton.}$$

3.3.e- V. YÜKLEME

M: Fxe: Ix5:5 Tm.



$$\psi' = \frac{5 \cdot 10^5}{810000 \cdot 5280} \left(0.50 - \frac{0.0434}{0.0869} \cdot 1.00 \right) : 6.73 \cdot 10^{-8} \text{ cm}^{-1}.$$

$$\psi'' = \frac{-5 \cdot 10^5 \times 0.0434^2 \times 4.3445 \cdot 10^{-5}}{810000 \times 5280 \times 0.0869} : -1.1 \cdot 10^{-10} \text{ cm}^{-2}.$$

$$\psi''' = \frac{-5 \cdot 10^5 \times 0.0434 \times (4.3445 \cdot 10^5)^2}{810000 \times 5280 \times 0.0869} : -1.1 \cdot 10^{-13} \text{ cm}^{-3}$$

-.. St. Venant burulma momenti (M_t):

x:0 için.

$$M_t : G_{st} \cdot J_t \cdot \psi' : 810000 \times 5280 \times 6.73 \cdot 10^{-8} : 0.003 \text{ Tm.}$$

x:10 m. (Açıklık ortası için)

$$\psi' : 0, M_t : 0 \quad (\text{Simetriden dolayı})$$

-.. Çarpılma burulması (M_z):

x:0 için

$$M_z : -E_{st} \cdot J_w \cdot \psi'' : 2100000 \times 1.079 \cdot 10^{12} \times 1.10 \cdot 10^{-10} : 2.49 \text{ Tm.}$$

x:10 m. (Tüm kesit tesirleri burulma momenti çarpılma

burulmasıdır.) $M_z : 2.50 \text{ Tm.}$

... Açıklık ortasında normal gerilmeler (σ_x):

$$\sigma_x: \sigma_w = \frac{M_w}{J_w w_M} \cdot w_M$$

$$M_w: -E_{st} \cdot J_w w_M'' - \varphi'' : 2100000 \times J_w w_M'' \times 1.10 \cdot 10^{-10} : 2.31 \cdot 10^{-4} J_w w_M''$$

$$\sigma_x: \frac{2.31 \cdot 10^{-4} \cdot J_w w_M''}{J_w w_M} \cdot w_M : 2.31 \cdot 10^{-4} \cdot w_M$$

$$\sigma_{xA}: 0 \quad (w_{MA}: 0)$$

$$\sigma_{xB}: 0 \quad (w_{MB}: 0)$$

$$\sigma_{xC}: 2.31 \cdot 10^{-4} \times -4838 \quad : -1.12 \text{ Kg/cm}^2 \quad : -\sigma_{xC}'$$

$$\sigma_{xD}: \quad " \quad " \quad \times 4838 \quad : 1.12 \quad " \quad " \quad : -\sigma_{xD}'$$

$$\sigma_{xE}: \quad " \quad " \quad \times -9111 \quad : -2.11 \quad " \quad " \quad : -\sigma_{xE}'$$

$$\sigma_{xF}: \quad " \quad " \quad \times 20289 \quad : 4.69 \quad " \quad " \quad : -\sigma_{xF}'$$

$$\sigma_{xG}: \quad " \quad " \quad \times 15451 \quad : 3.57 \quad " \quad " \quad : -\sigma_{xG}'$$

$$\sigma_{xH}: \quad " \quad " \quad \times 25328 \quad : 5.85 \quad " \quad " \quad : -\sigma_{xH}'$$

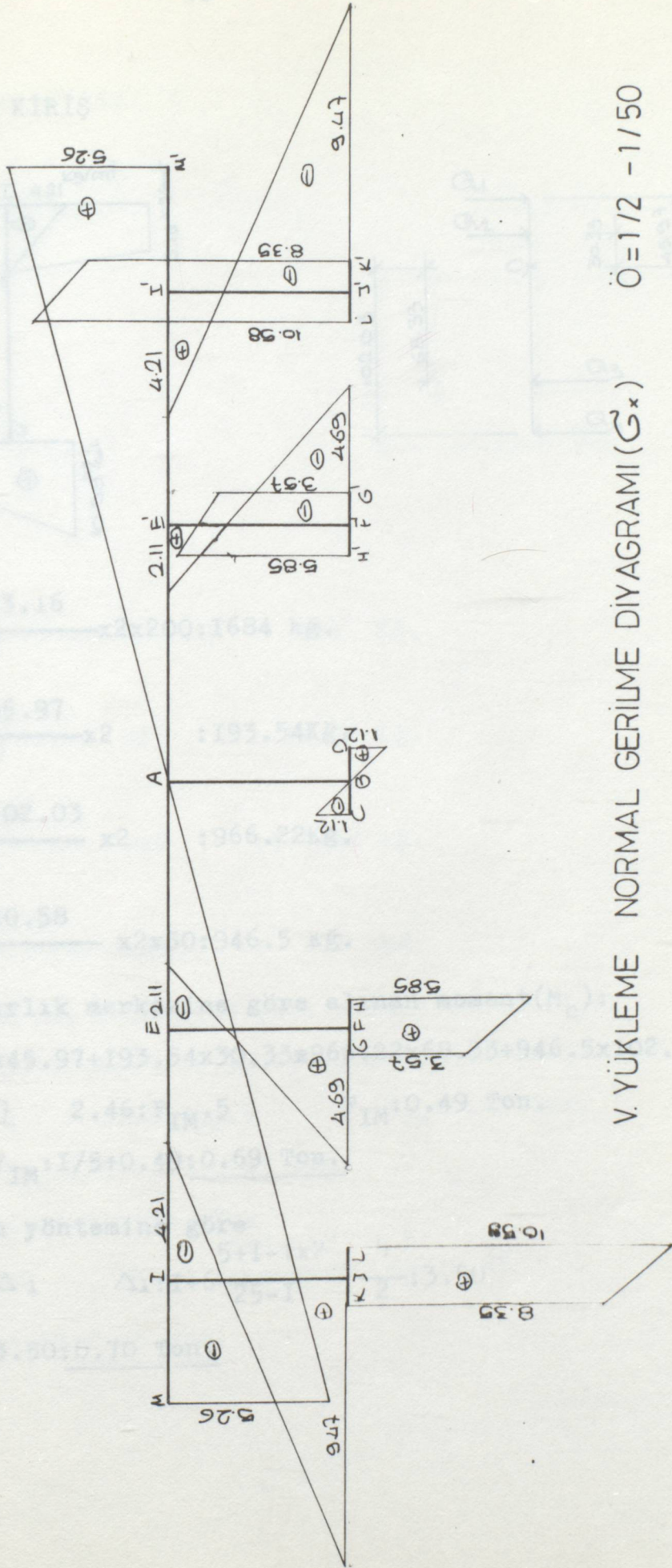
$$\sigma_{xI}: \quad " \quad " \quad \times -18221 \quad : -4.21 \quad " \quad " \quad : -\sigma_{xI}'$$

$$\sigma_{xJ}: \quad " \quad " \quad \times 40979 \quad : 9.47 \quad " \quad " \quad : -\sigma_{xJ}'$$

$$\sigma_{xK}: \quad " \quad " \quad \times 36140 \quad : 8.35 \quad " \quad " \quad : -\sigma_{xK}'$$

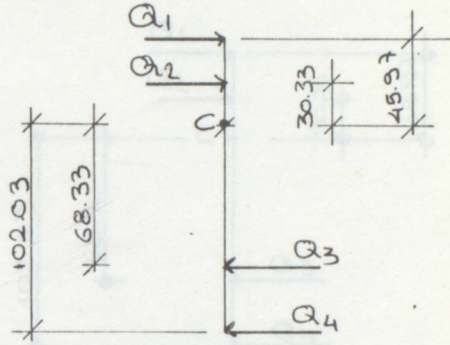
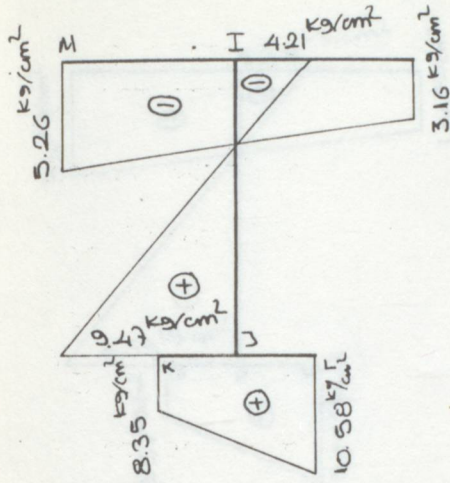
$$\sigma_{xL}: \quad " \quad " \quad \times 45818 \quad : 10.58 \quad " \quad " \quad : -\sigma_{xL}'$$

$$\sigma_{xM}: \quad " \quad " \quad \times -22777 \quad : -5.26 \quad " \quad " \quad : -\sigma_{xM}'$$



V. YÜKLEME NORMAL GERİLME DİYAGRAMI (G*) $\bar{\sigma} = 1/2 - 1/50$

-. I. ANA KIRIŞ



$$Q_1: \frac{5.26+3.16}{2} \times 2 \times 200: 1684 \text{ Kğ.}$$

$$Q_2: \frac{4.21 \times 45.97}{2} \times 2 : 193.54 \text{ Kğ.}$$

$$Q_3: \frac{9.47 \times 102.03}{2} \times 2 : 966.22 \text{ Kğ.}$$

$$Q_4: \frac{8.35+10.58}{2} \times 2 \times 50: 946.5 \text{ Kğ.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_{1c}: 1684 \times 45.97 + 193.54 \times 30.33 + 966.22 \times 68.33 + 946.5 \times 102.03: 2.46 \text{ Tm.}$$

$$M_{1c}: F_{IM} \cdot \eta \quad 2.46: F_{IM} \cdot 5 \quad F_{IM}: 0.49 \text{ Ton.}$$

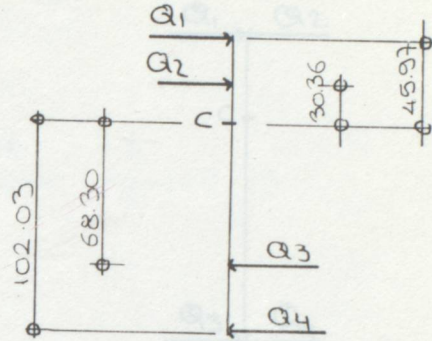
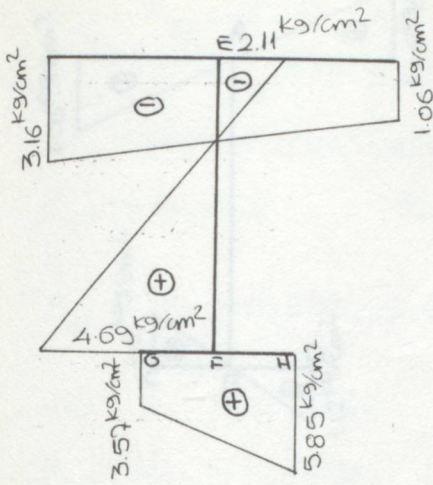
$$F_{I\Sigma}: F/n + F_{IM}: 1/5 + 0.49: 0.69 \text{ Ton.}$$

- Courbon yöntemine göre

$$F_{I\Sigma}: F/n \cdot \Delta_1 \quad \Delta_1: 1 + 6 \frac{5+1-1 \times 2}{25-1} \frac{5}{2}: 3.50$$

$$F_{I\Sigma}: 1/5 \times 3.50: 0.70 \text{ Ton.}$$

... II. ANA KİRİŞ



$$Q_1: \frac{3.16+1.06}{2} \times 2 \times 200 : 844 \text{ Kğ.}$$

$$Q_2: \frac{45.97 \times 2.11}{2} \times 2 : 96.97 \text{ Kğ.}$$

$$Q_3: \frac{4.69 \times 102.03}{2} \times 2 : 478.52 \text{ Kğ.}$$

$$Q_4: \frac{3.57+5.85}{2} \times 2 \times 50 : 471 \text{ Kğ.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_c: 844 \times 45.97 + 96.97 \times 30.36 + 478.52 \times 68.30 + 471 \times 102.03 : 1.23 \text{ Tm.}$$

$$M_{2c}: F_{2M} \cdot \Delta \quad 1.23: F_{2M} \cdot 5 \quad F_{2M}: 0.25 \text{ ton.}$$

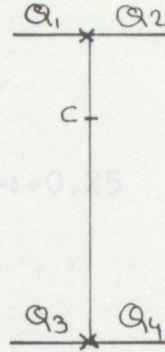
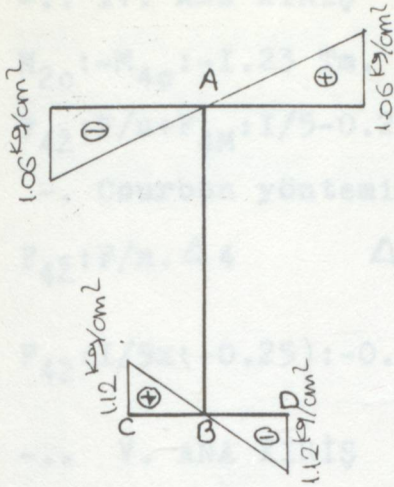
$$F_{2\Sigma}: F/n + F_{2M}: 1/5 + 0.25: 0.45 \text{ Ton.}$$

- Courbon yöntemine göre.

$$F_{2\Sigma}: F/n \cdot \Delta^2 \quad \Delta^2: 1 + 6 \frac{5+1-2 \times 2}{25-1} \quad \frac{5}{2}: 2.25$$

$$F_{2\Sigma}: 1/5 \times 2.25: 0.45 \text{ Ton.}$$

... III. ANA KIRIŞ



$$Q_1 + Q_2 = 0, \quad Q_3 + Q_4 = 0, \quad M_{3c} = 0$$

$$F_{3\bar{z}} = F/n : 1/5 = 0.20 \text{ Ton.}$$

.. Courbon yöntemine göre.

$$F_{3\bar{z}} = F/n \cdot \Delta_3 \quad \Delta_3 = 1 + 6 \frac{5 + 1 - 2 \times 3}{25 - 1} \cdot \frac{5}{2} = 1.00$$

$$F_{3\bar{z}} = 1/5 \times 1.00 = 0.20 \text{ Ton.}$$

IV. ANA KİRİŞ

$$M_{2c} = -M_{4c} = -1.23 \text{ Tm.} \quad F_{4M} = -0.25 \text{ ton.}$$

$$F_{4\bar{z}} = F/n + F_{4M} = I/5 - 0.25 + 0.05 \text{ Ton.}$$

-. Courbon yöntemine göre.

$$F_{4\bar{z}} = F/n \cdot \Delta 4 \quad \Delta 4 = I + 6 \frac{5 + 1 - 2 \times 4}{25 - 1} \cdot \frac{5}{2} = -0.25$$

$$F_{4\bar{z}} = I/5 \times (-0.25) = -0.05 \text{ Ton.}$$

V. ANA KİRİŞ

$$M_{1c} = -M_{5c} = -2.46 \text{ Tm.} \quad F_{5M} = -0.49 \text{ ton.}$$

$$F_{5\bar{z}} = I/5 \pm (-0.49) = -0.29 \text{ Ton.}$$

-. Courbon yöntemine göre

$$F_{5\bar{z}} = F/n \cdot \Delta 5 \quad \Delta 5 = I + 6 \frac{5 + 1 - 2 \times 5}{25 - 1} \cdot \frac{5}{2} = -1.50$$

$$F_{5\bar{z}} = I/5 \times (-1.50) = -0.30 \text{ Ton.}$$

BULUNUŞU.

$$I_x = \frac{2 \times I_{200} \times 149^2 + 2 \times I_{146} \times 75^2 + 2 \times I_{50} \times 6^2}{2 \times I_{200} + 2 \times I_{146} + 2 \times I_{50}} = 103.03 \text{ cm.}$$

$$e_x = 150 - 103.03 = 46.97 \text{ cm.}$$

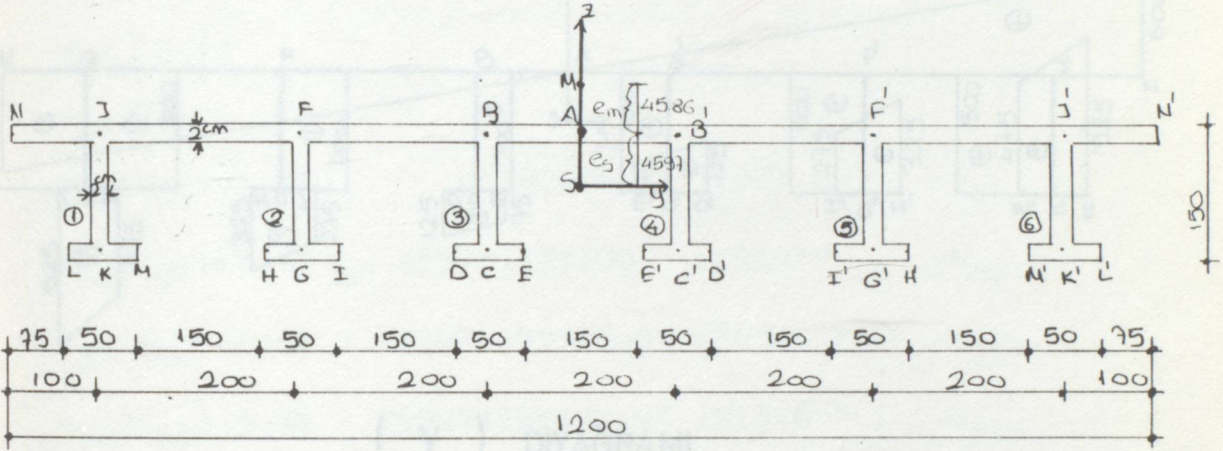
$$I_{x-x} = \frac{1}{3} (2^3 \times I_{200} + 2^3 \times I_{146} \times 6 + 2^3 \times I_{50} \times 6) = 16936 \text{ cm}^4.$$

3.4-2.. B-B AĞAĞUT MOMENTİNİN BULUNUŞU.

$$I_{y-y} = \int y^2 \cdot dA = 2 \times \left(\frac{200^3 \times 2}{12} + 2 \times \left(\frac{146 \times 2^3}{12} + 146 \times 2 \times 100^2 \right) + 2 \times \left(\frac{146 \times 2^3}{12} + 146 \times 2 \times 300^2 \right) + 2 \times \left(\frac{50^3 \times 2}{12} + 50 \times 2 \times 100^2 \right) + 2 \times \left(\frac{50^3 \times 2}{12} + 50 \times 2 \times 300^2 \right) \right) = 562525584 \text{ cm}^4.$$

3.4- ÖRNEK III

ALTI ANA KIRIŞLI VE TEK AÇIKLIKLI KÖPRÜDE YÜK DAĞILIMININ BURULMA TEORİSİ YARDIMI İLE BULUNMASI VE SONUÇLARIN COURBON YÖNTEMİ İLE KIYASLAMASI.



3.4-1.. AĞIRLIK MERKEZİ VE BURULMA ATALET MOMENTİNİN BULUNUŞU.

$$2 \times I_{200} \times I_{49} + 2 \times I_{46} \times 75 \times 6 + 2 \times 50 \times 6$$

$$E_s = \frac{2 \times I_{200} + 2 \times I_{46} \times 6 + 2 \times 6 \times 50}{103.03} \text{ cm.}$$

$$e_s = 150 - 103.03 - 1 = 45.97 \text{ cm.}$$

$$J_t = \frac{1}{3} \sum s_j \cdot t_j^3 = \frac{1}{3} (2^3 \times I_{200} + 2^3 \times I_{46} \times 6 + 2^3 \times 50 \times 6) = 6336 \text{ cm}^4.$$

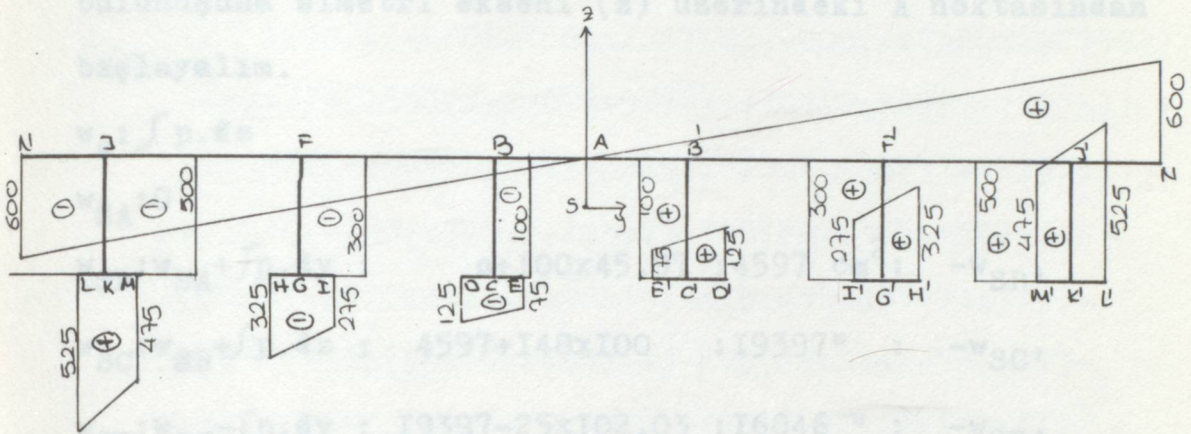
3.4-2.. z-z ATALET MOMENTİNİN BULUNUŞU.

$$J_{z-z} = \int y^2 \cdot dA = I_{200} \times 2 / 12 + 2 \times (I_{46} \times 2^3 / 12 + I_{46} \times 2 \times 100^2) + 2 \times (I_{46} \times 2^3 / 12 + I_{46} \times 2 \times 300^2) + 2 \times (50^3 \times 2 / 12 + 50 \times 2 \times 100^2) + 2 \times (50^3 \times 2 / 12 + 50 \times 2 \times 300^2) + 2 \times (50^3 \times 2 / 12 + 50 \times 2 \times 500^2) = 562525584 \text{ cm}^4.$$

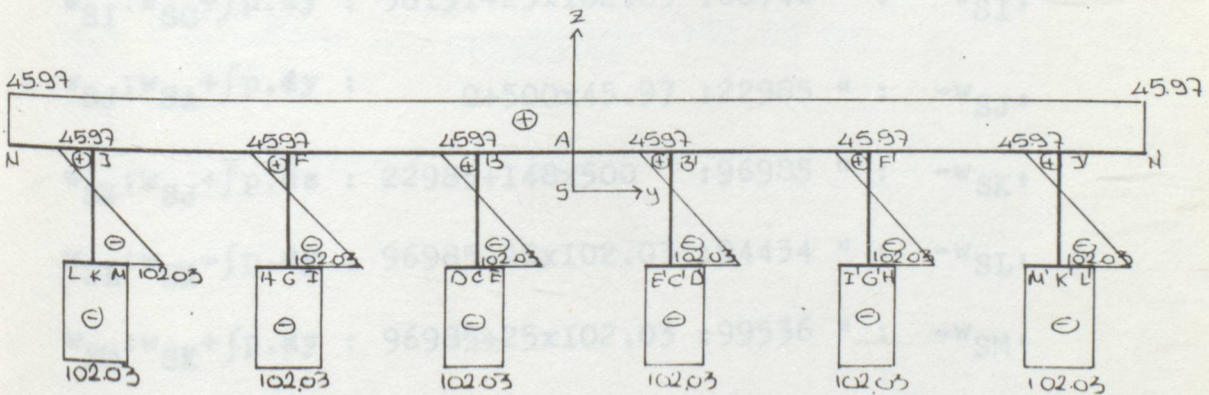
3.4-3.. AĞIRLIK MERKEZİNE GÖRE BİRİM ÇARPIMA

KOORDİNATLARI (w_y):

İsittin simetri özelliklerinden yararlanarak w_y değerlerinin bulunmasına simetri eksenini (z) üzerindeki A noktasından başlayalım.



(y) DİYAĞRAMI.



(z) DİYAĞRAMI.

3.4-3.. AĞIRLIK MERKEZİNE GÖRE BİRİM ÇARPILMA

KOORDİNATLARI(w_s):

Kesitin simetri özelliğinden yararlanarak w_s değerlerinin bulunuşuna simetri eksenini (z) üzerindeki A noktasından başlayalım.

$$w_s : \int p \cdot ds$$

$$w_{SA} : 0$$

$$w_{SB} : w_{SA} + \int p \cdot dy : 0 + 100 \times 45.97 : 4597 \text{ cm}^2 : -w_{SB}'$$

$$w_{SC} : w_{SB} + \int p \cdot dz : 4597 + 148 \times 100 : 19397'' : -w_{SC}'$$

$$w_{SD} : w_{SC} - \int p \cdot dy : 19397 - 25 \times 102.03 : 16846'' : -w_{SD}'$$

$$w_{SE} : w_{SC} + \int p \cdot dy : 19397 + 25 \times 102.03 : 21948'' : -w_{SE}'$$

$$w_{SF} : w_{SA} + \int p \cdot dy : 0 + 300 \times 45.97 : 13791'' : -w_{SF}'$$

$$w_{SG} : w_{SF} + \int p \cdot dz : 13791 + 148 \times 300 : 58191'' : -w_{SG}'$$

$$w_{SH} : w_{SG} - \int p \cdot dy : 58191 + 25 \times 102.03 : 55640'' : -w_{SH}'$$

$$w_{SI} : w_{SG} + \int p \cdot dy : 58191 + 25 \times 102.03 : 60742'' : -w_{SI}'$$

$$w_{SJ} : w_{SA} + \int p \cdot dy : 0 + 500 \times 45.97 : 22985'' : -w_{SJ}'$$

$$w_{SK} : w_{SJ} + \int p \cdot dz : 22985 + 148 \times 500 : 96985'' : -w_{SK}'$$

$$w_{SL} : w_{SK} - \int p \cdot dy : 96985 - 25 \times 102.03 : 94434'' : -w_{SL}'$$

$$w_{SM} : w_{SK} + \int p \cdot dy : 96985 + 25 \times 102.03 : 99536'' : -w_{SM}'$$

$$w_{SN} : w_{SA} + \int p \cdot dy : 0 + 600 \times 45.97 : 27582'' : -w_{SN}'$$

3.4-4..SEKTOR DEVIASYON MOMENTİ ($J_{z_w_s}$):

Kayma merkezinin bulunması için gerekli olan bu değer

$$J_{z_w_s} : \int y \cdot w_s \cdot dA$$

$$J_{z_w_s} : 2x \left[1200/6(-600(27582x^2-27582)+600(-27582x^2+27582)) \right. \\ + 2xI48/6(-500(2x22975+96985)-500(2x96985+22975)) + \\ 2xI48/6(-300(I397Ix^2+58I9I)-300(2x58I9I+I379I)) + \\ 2xI48/6(-I00(4597x^2+I9397)-I00(2xI9397+4597)) + \\ 2x50/6(-525(94434x^2+99535)-475(2x99535+94434))+ \\ 2x50/6(-325(55640x^2+6074I)-275(2x6074I+55640))+ \\ \left. 2x50/6(-I25(I6846x^2+2I947)-75(2x2I947+I6846)) \right] : \\ : -5,17 \cdot 10^{10} \text{ cm}^5.$$

3.4-5.. KAYMA MERKEZİ (M):

Simetriden dolayı kayma merkezi (M) z-z eksenindedir.

$$z_M : - \frac{J_{z_w_s}}{J_{z-z}} : - \frac{-5.17 \cdot 10^{10}}{562525584} : 91.83 \text{ cm.}$$

$$e_M : z_M - e_s : 91.83 - 45.97 : 45.86 \text{ cm.}$$

3.4.6 -KAYMA MERKEZİNE GÖRE BULUNAN ÇARPII MA KOORDİNATLARI

Benzer şekilde şu formülden bulunur.

$$w_M = w_S + z_M \cdot y$$

$$w_{MA} = 0$$

$$w_{MB} = 4597 + 91.83 \times (-100) = -4586 \text{ cm}^2 = -w_{MB}'$$

$$w_{MC} = 19397 + 91.83 \times (-100) = 10214 \text{ " } = -w_{MC}'$$

$$w_{MD} = 16846 + 91.83 \times (-125) = 5367 \text{ " } = -w_{MD}'$$

$$w_{ME} = 21947 + 91.83 \times (-75) = 15060 \text{ " } = -w_{ME}'$$

$$w_{MF} = 13791 + 91.83 \times (-300) = -13758 \text{ " } = -w_{MF}'$$

$$w_{MG} = 58191 + 91.83 \times (-300) = 30642 \text{ " } = -w_{MG}'$$

$$w_{MH} = 55640 + 91.83 \times (-325) = 25795 \text{ " } = -w_{MH}'$$

$$w_{MI} = 60741 + 91.83 \times (-275) = 35488 \text{ " } = -w_{MI}'$$

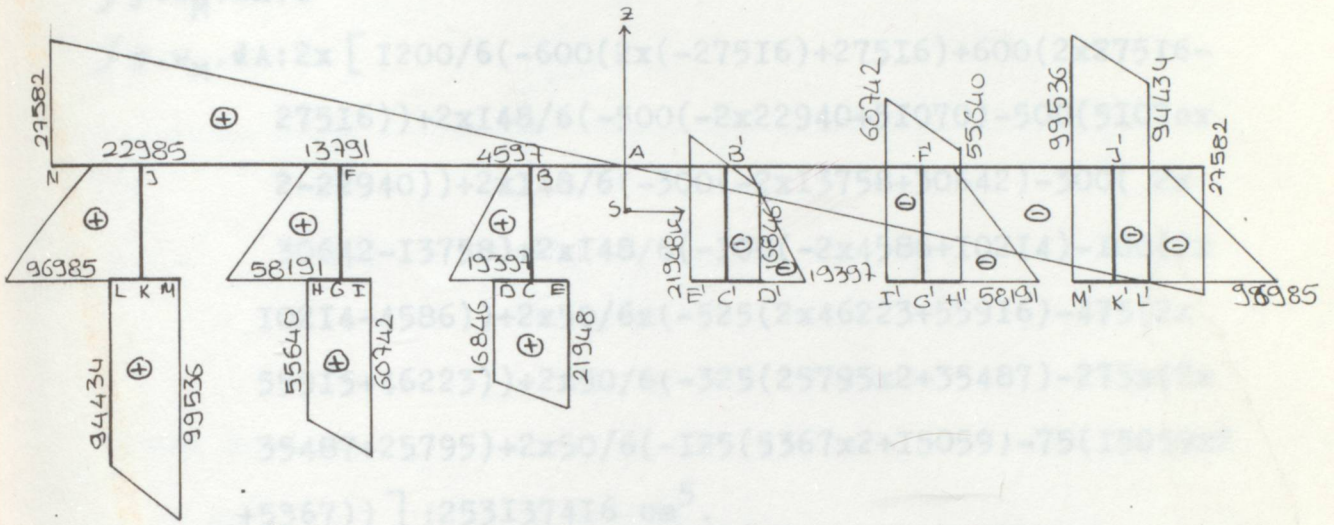
$$w_{MJ} = 22975 + 91.83 \times (-500) = -22940 \text{ " } = -w_{MJ}'$$

$$w_{MK} = 96985 + 91.83 \times (-500) = 51070 \text{ " } = -w_{MK}'$$

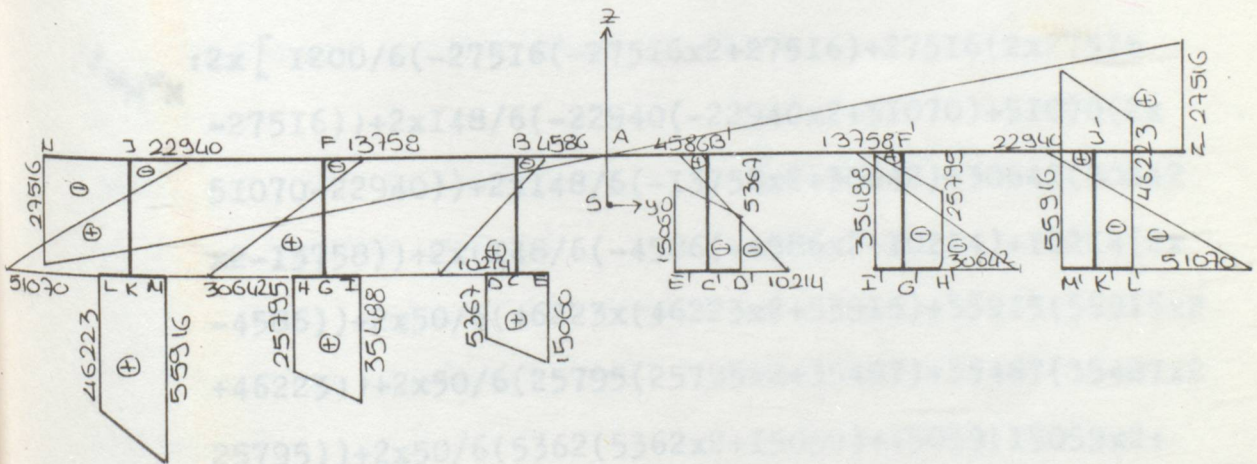
$$w_{ML} = 94434 + 91.83 \times (-525) = 46223 \text{ " } = -w_{ML}'$$

$$w_{MM} = 99535 + 91.83 \times (-475) = 55916 \text{ " } = -w_{MM}'$$

$$w_{MN} = 27582 + 91.83 \times (-600) = -27516 \text{ " } = -w_{MN}'$$



(W_s) DİYAĞRAMI



(W_m) DİYAGRAMI

KONTROL DENKLEMLERİ

$$\int z \cdot w_M \cdot dA : 0 \text{ (Simetrive antimetriden dolayı)}$$

$$\int y \cdot w_M \cdot dA : 0$$

$$\int y \cdot w_M \cdot dA : 2x \left[1200/6(-600(2x(-27516)+27516)+600(2x27516-27516))+2x148/6(-500(-2x22940+51070)-500(51070x2-22940))+2x148/6(-300(-2x13758+30642)-300(2x30642-13758))+2x148/6(-100(-2x4586+10214)-100(2x10214-4586))+2x50/6x(-525(2x46223+55916)-475(2x55915+46223))+2x50/6(-325(25795x2+35487)-275x(2x35487+25795))+2x50/6(-125(5367x2+15059)-75(15059x2+5367)) \right] : 253137416 \text{ cm}^5.$$

Kıyaslama oranı $\frac{253137416}{5,17 \cdot 10^{10}} : 0.0049 \text{ (uygundur)}$

3.4.7- ÇARPILMA MUKAVEMETİ ($J_{w_M w_M}$):

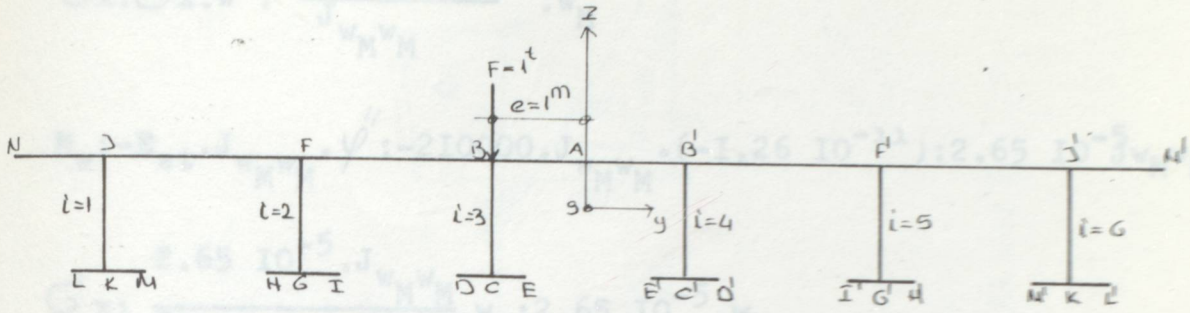
$J_{w_M w_M} : \int w_M^2 \cdot dA$ ile ve çarpım tablosundan yararlanarak bulalım.

$$J_{w_M w_M} : 2x \left[1200/6(-27516(-27516x2+27516)+27516(2x27516-27516))+2x148/6(-22940(-22940x2+51070)+51070(2x51070-22940))+2x148/6(-13758x2+30642)+30642(30642x2-13758))+2x(148/6(-4586(-4586x2+10214)+10214(2x-4586))+2x50/6(46223x(46223x2+55915)+55915(55915x2+46223))+2x50/6(25795(25795x2+35487)+35487(35487x2+25795))+2x50/6(5362(5362x2+15059)+15059(15059x2+5362)) \right] : 1.88 \cdot 10^{12} \text{ cm}^6.$$

$$k : \sqrt{\frac{G_{st} \cdot J_t}{E_{st} \cdot J_{w_M w_M}}} : \sqrt{\frac{810000 \cdot 6336}{2100000 \cdot 1.88 \cdot 10^{12}}} : 3.6 \cdot 10^{-5} \text{ cm}^{-1}.$$

3.4.a- I. YÜKLEME DA NORMAL GERİLMELER (G_x):

M: Fxe: IxI: I Tm.



Dönme açıları

$$\varphi' = \frac{I \cdot 10^5}{810000 \cdot 6336} \left(0.50 - \frac{0.036033}{0.072113} \cdot 100 \right) : 6,14 \cdot 10^{-9} \text{ cm}^{-1}.$$

$$\varphi'' = \frac{-I \cdot 10^5 \times 0.036033^2 \times 3,603 \cdot 10^{-5}}{810000 \times 6336 \times 0.072113} : -1,26 \cdot 10^{-11} \text{ cm}^{-2}.$$

$$\varphi''' = \frac{I \cdot 10^5 \times 0.036033 \times (3.603 \cdot 10^{-5})^2}{810000 \times 6336 \times 0.072113} : -1,26 \cdot 10^{-14} \text{ cm}^{-3}.$$

... St.Venant Burulma momenti. (M_t):

x:0 için.

$$M_t : G_{st} \cdot J_t \cdot \varphi' : 810000 \times 6336 \times 6,14 \cdot 10^{-9} : 3,24 \cdot 10^{-4} \text{ tm.}$$

x:10 m. (Açıklık ortası)

$$\varphi' : 0, M_t : 0 \text{ (simetriden dolayı)}$$

... Çarpılma burulması (M_z):

x:0 için.

$$M_z : -\frac{1}{2} G_{st} \cdot J_{W_M} \cdot \varphi''' : -2100000 \times 1,88 \cdot 10^{12} \times 1,26 \cdot 10^{-14} : 0,499 \text{ tm.}$$

x:10m. Tüm kesit tesirleri burulma momenti çarpılma

burulmasıdır. $M_z : 0.50 \text{ tm.}$

... AÇIKLIK ORTASINDA NORMAL GERİLMELER(σ_x):

$$\sigma_x: \sigma_{x.w} : \frac{M_w}{J_{w_M w_M}} \cdot w_M$$

$$M_w: -E_{st} \cdot J_{w_M w_M} \cdot \varphi'' : -210000 \cdot J_{w_M w_M} \cdot (-1,26 \cdot 10^{-11}) : 2,65 \cdot 10^{-5} \cdot J_{w_M w_M}$$

$$\sigma_x: \frac{2,65 \cdot 10^{-5} \cdot J_{w_M w_M}}{J_{w_M w_M}} \cdot w_M : 2,65 \cdot 10^{-5} \cdot w_M$$

$$\sigma_{xA}: 0 \quad (w_{MA}: 0)$$

$$\sigma_{xB}: 2,65 \cdot 10^{-5} \times -4586 : 0,12 \text{ Kg/cm}^2 : -\sigma_{xB}'$$

$$\sigma_{xC}: \quad " \quad " \quad \times 10314 : 0,27 \quad " \quad " : -\sigma_{xC}'$$

$$\sigma_{xD}: \quad " \quad " \quad \times 5367 : 0,14 \quad " \quad " : -\sigma_{xD}'$$

$$\sigma_{xE}: \quad " \quad " \quad \times 15060 : 0,40 \quad " \quad " : -\sigma_{xE}'$$

$$\sigma_{xF}: \quad " \quad " \quad \times -13758 : -0,37 \quad " \quad " : -\sigma_{xF}'$$

$$\sigma_{xG}: \quad " \quad " \quad \times 30642 : 0,81 \quad " \quad " : -\sigma_{xG}'$$

$$\sigma_{xH}: \quad " \quad " \quad \times 25795 : 0,69 \quad " \quad " : -\sigma_{xH}'$$

$$\sigma_{xI}: \quad " \quad " \quad \times 35488 : 0,94 \quad " \quad " : -\sigma_{xI}'$$

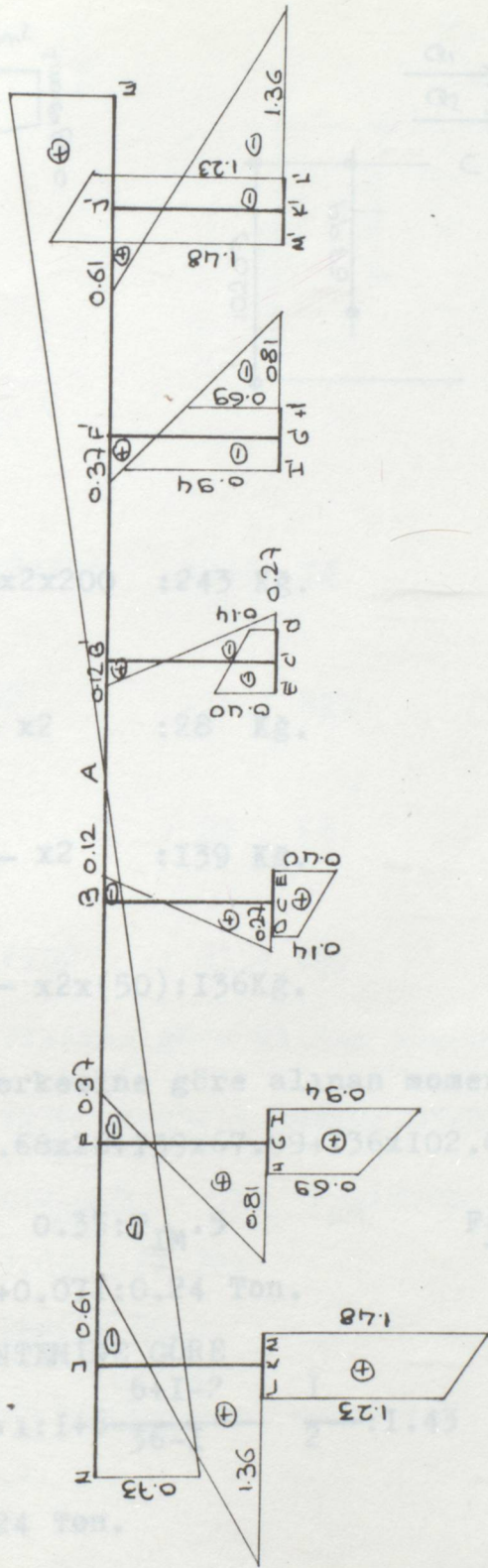
$$\sigma_{xJ}: \quad " \quad " \quad \times -22940 : -0,61 \quad " \quad " : -\sigma_{xJ}'$$

$$\sigma_{xK}: \quad " \quad " \quad \times 51070 : 1,36 \quad " \quad " : -\sigma_{xK}'$$

$$\sigma_{xL}: \quad " \quad " \quad \times 46223 : 1,23 \quad " \quad " : -\sigma_{xL}'$$

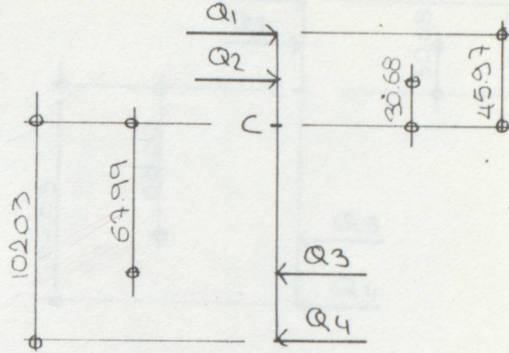
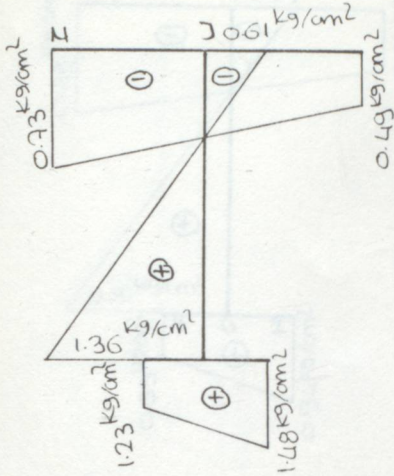
$$\sigma_{xM}: \quad " \quad " \quad \times 55916 : 1,48 \quad " \quad " : -\sigma_{xM}'$$

$$\sigma_{xN}: \quad " \quad " \quad \times -27516 : -0,73 \quad " \quad " : -\sigma_{xN}'$$



I. YÜKLEME NORMAL GERİLME DİYAGRAMI (G_x) Ö=2/1 - 1/ 67

... I. ANA KIRIŞ



$$Q_1: \frac{0.73 \times 0.49}{2} \times 2 \times 200 : 243 \text{ Kg.}$$

$$Q_2: \frac{45.86 \times 0.61}{2} \times 2 : 28 \text{ Kg.}$$

$$Q_3: \frac{102.13 \times 1.36}{2} \times 2 : 139 \text{ Kg.}$$

$$Q_4: \frac{1.23 + 1.48}{2} \times 2 \times (50) : 136 \text{ Kg.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_c : 243 \times 45.97 + 30.68 \times 28 + 139 \times 67.99 + 136 \times 102.03 : 0.35 \text{ Tm.}$$

$$M_c : F_{IM} \cdot \eta \quad 0.35 : F_{IM} \cdot 5 \quad F_{IM} : 0.071 \text{ Ton.}$$

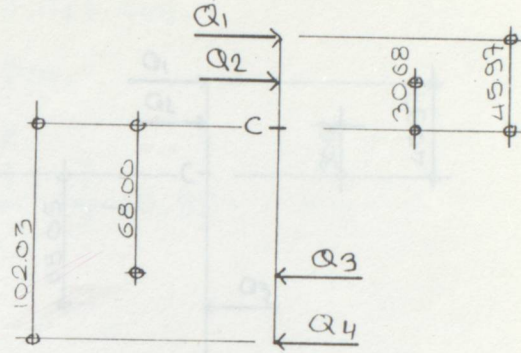
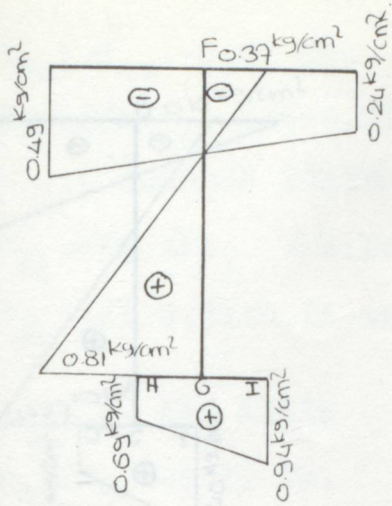
$$F_{I\Sigma} : F/n + F_{IM} : 1/6 + 0.071 : 0.24 \text{ Ton.}$$

... COURBON YÖNTEMİNE GÖRE

$$F_{I\Sigma} : F/n \cdot \Delta_1 \quad \Delta_1 : 1 + 6 \frac{6 + I - ?}{36 - I} \frac{1}{2} : 1.43$$

$$F_{I\Sigma} : 1/6 \cdot 1.43 : 0.24 \text{ Ton.}$$

-... II. ANA KIRIŞ



$$Q_1: \frac{0.49+0.24}{2} \times 2 \times 200 : 146 \text{ Kg.}$$

$$Q_2: \frac{45.86 \times 0.37}{2} \times 2 : 16.7 \text{ Kg.}$$

$$Q_3: \frac{102.13 \times 0.81}{8} \times 2 : 83 \text{ Kg.}$$

$$Q_4: \frac{0.69 \times 0.94}{2} \times 2 \times 50 : 81.4 \text{ Kg.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_c: 146 \times 45.97 + 16.7 \times 30.68 + 83 \times 67.99 + 102.03 \times 81.4 : 0.21 \text{ Tm.}$$

$$M_c: F_{2M} \cdot \rho \quad 0.21: F_{2M} \cdot 5 \quad F_{2M}: 0.04 \text{ Ton.}$$

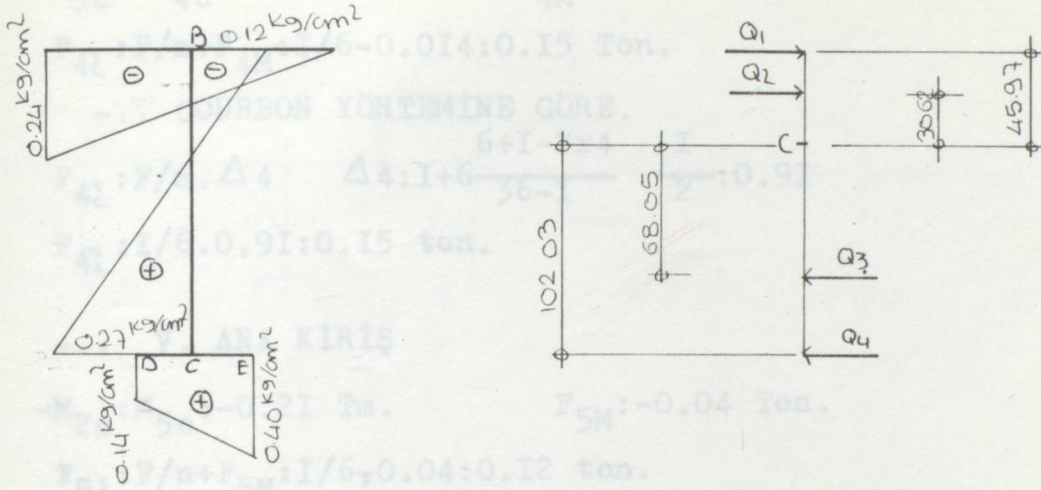
$$F_{2\Sigma}: F/n + F_{2M}: 1/6 + 0.04 : 0.21 \text{ Ton.}$$

-...COURBON YÖNTEMİNE GÖRE.

$$F_{2\Sigma}: F/n \cdot \Delta_2 \quad \Delta_2: 1+6 \frac{6+1-4}{36-1} \frac{1}{2}: 1.26$$

$$F_{2\Sigma}: 1/6 \cdot (1.26) : 0.21 \text{ Ton.}$$

... III. ANA KİRİŞ



$$Q_1 = \frac{0.24 \times 200}{2} \times 2 = 48.8 \text{ Kg.}$$

$$Q_2 = \frac{0.12 \times 46.06}{2} \times 2 = 5.62 \text{ Kg.}$$

$$Q_3 = \frac{0.27 \times 102.03}{2} \times 2 = 27.55 \text{ Kg.}$$

$$Q_4 = \frac{0.14 + 0.40}{2} \times 2 \times 50 = 27.14 \text{ Kg.}$$

(M_c): Kesit ağırlık merkezine göre alınan moment.

$$M_c = 48.8 \times 45.97 + 5.62 \times 30.62 + 27.55 \times 68.05 + 27.14 \times 102.03 = 0.07 \text{ tm.}$$

$$M_c = F_{3M} \cdot l \quad 0.07 = F_{3M} \cdot 5 \quad F_{3M} = 0.014 \text{ Ton.}$$

$$F_{3\Sigma} = F/n + F_{3M} = 1/6 + 0.014 = 0.18 \text{ Ton.}$$

... COURBON YÖNTEMİNE GÖRE

$$F_3 = F/n \cdot \Delta_3 \quad \Delta_3 = 1 + 6 \frac{6 + I - 2 \times 3}{36 - I} \quad \frac{I}{2} = 1.08 \text{ Ton.}$$

$$F_{3\Sigma} = 1/6 \times (1.08) = 0.18 \text{ Ton}$$

... IV. ANA KİRİŞ

$$M_{3c} = -M_{4c} = -0.07 \text{ Tm.} \quad F_{4M} = 0.014 \text{ ton.}$$

$$F_{4\Sigma} = F/n + F_{4M} = I/6 - 0.014 = 0.15 \text{ Ton.}$$

... COURBON YÖNTEMİNE GÖRE.

$$F_{4\Sigma} = F/n \cdot \Delta 4 \quad \Delta 4 = I + 6 \frac{6+I-2x4}{36-I} \frac{I}{2} = 0.9I$$

$$F_{4\Sigma} = I/6 \cdot 0.9I = 0.15 \text{ ton.}$$

... V. ANA KİRİŞ

$$-M_{2c} = M_{5c} = -0.2I \text{ Tm.} \quad F_{5M} = -0.04 \text{ Ton.}$$

$$F_{5\Sigma} = F/n + F_{5M} = I/6 + 0.04 = 0.12 \text{ ton.}$$

... COURBON YÖNTEMİNE GÖRE

$$F_{5\Sigma} = F/n \cdot \Delta 5 \quad \Delta 5 = I + 6 \frac{6+I-2x5}{36-I} \frac{I}{2} = 0.74$$

$$F_{5\Sigma} = I/6 \cdot (0.74) = 0.12 \text{ Ton.}$$

... VI. ANA KİRİŞ

$$M_{1c} = -M_{6c} = -0.35 \text{ Tm.} \quad F_{6M} = -0.07 \text{ Tm.}$$

$$F_{6\Sigma} = F/n + F_{6M} = I/6 + 0.07 = 0.10 \text{ Ton.}$$

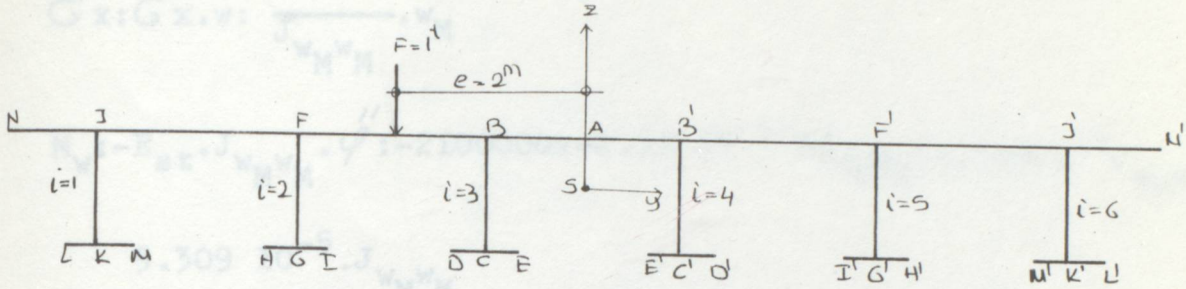
... COURBON YÖNTEMİNE GÖRE.

$$F_6 = F/n \cdot \Delta 6 \quad \Delta 6 = I + 6 \frac{6+I-2x6}{36-I} \frac{I}{2} = 0.57$$

$$F_{6\Sigma} = I/6 \cdot (0.57) = 0.10 \text{ Ton.}$$

3.4.b- II. YÜKLEME

M: Fxe: Ix2: 2Tm.



Dönme açıları

$$\varphi' = \frac{2 \cdot 10^5}{810000 \cdot 6336} (0.50 - \frac{0.036033}{0.072113} \cdot 1.00) : 1.26 \cdot 10^{-8} \text{ cm}^{-1}.$$

$$\varphi'' = \frac{-2 \cdot 10^5 \times 0.036033^2 \times 3,603 \cdot 10^{-5}}{810000 \times 6336 \times 0.072113} : 2.53 \cdot 10^{-11} \text{ cm}^{-2}$$

$$\varphi''' = \frac{-2 \cdot 10^5 \times 0.036033 \times (3.603 \cdot 10^{-5})^2}{810000 \times 6336 \times 0.072113} : 2.53 \cdot 10^{-14} \text{ cm}^{-3}$$

-.. St.Venant burulma momenti (M_t):

x:0 için.

$$M_t = G_{st} \cdot J_t \cdot \varphi' : 810000 \times 6336 \times 1.26 \cdot 10^{-8} : 6.49 \cdot 10^{-4} \text{ Tm.}$$

x:10 (Açıklık ortası için)

$$\varphi : 0, \quad M_t : 0 \quad (\text{Simetriden dolayı})$$

-.. Çarpılma burulması (M_z):

x:0 için

$$M_z = -E_{st} \cdot J_{wMwM} \cdot \varphi''' : 2100000 \times 1.8810^{12} \times 2.53 \cdot 10^{-14} : 0.99 \text{ Tm.}$$

x:10m. (Tüm kesitlerdeki burulma momentâ çarpılma

burulmasıdır. $M_z : 1.00 \text{ Tm.}$

... AÇIKLIK ORTASINDA NORMAL GERİLMELER (σ_x):

$$\sigma_x: \sigma_{x.w} = \frac{M_w}{J_{w_M w_M}} \cdot w_M$$

$$M_w: -E_{st} \cdot J_{w_M w_M} \cdot \psi'' : -2100000 \times -2.53 \cdot 10^{-11} \times J_{w_M w_M} : 5.309 \cdot 10^{-5} J_{w_M w_M}$$

$$\sigma_x: \frac{5.309 \cdot 10^{-5} \cdot J_{w_M w_M}}{J_{w_M w_M}} \cdot w_M : 5.309 \cdot 10^{-5} \cdot w_M$$

$$\sigma_{xA}: 0 \quad (w_{MA}: 0)$$

$$\sigma_{xB}: 5,309 \cdot 10^{-5} \times -4586 : -0.24 \text{ Kg/cm}^2 : -\sigma_{xB}'$$

$$\sigma_{xC}: \quad " \quad " \quad \times 10214 : 0.54 \quad " \quad " : -\sigma_{xC}'$$

$$\sigma_{xD}: \quad " \quad " \quad \times 5367 : 0.29 \quad " \quad " : -\sigma_{xD}'$$

$$\sigma_{xE}: \quad " \quad " \quad \times 15060 : 0.80 \quad " \quad " : -\sigma_{xE}'$$

$$\sigma_{xF}: \quad " \quad " \quad \times -13758 : -0.73 \quad " \quad " : -\sigma_{xF}'$$

$$\sigma_{xG}: \quad " \quad " \quad \times 30642 : 1.63 \quad " \quad " : -\sigma_{xG}'$$

$$\sigma_{xH}: \quad " \quad " \quad \times 25795 : 1.37 \quad " \quad " : -\sigma_{xH}'$$

$$\sigma_{xI}: \quad " \quad " \quad \times 35488 : 1.88 \quad " \quad " : -\sigma_{xI}'$$

$$\sigma_{xJ}: \quad " \quad " \quad \times -22940 : -1.22 \quad " \quad " : -\sigma_{xJ}'$$

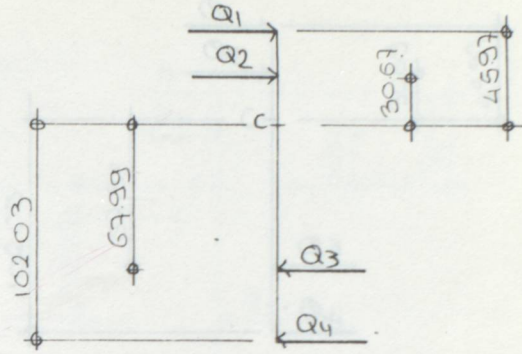
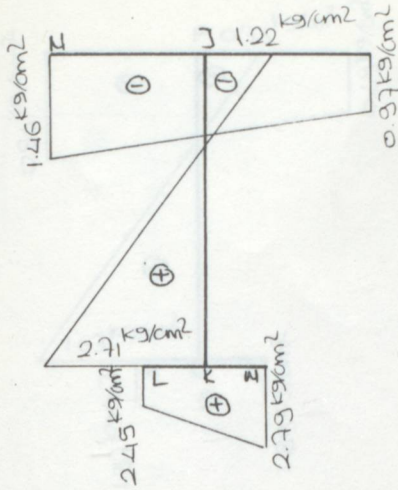
$$\sigma_{xK}: \quad " \quad " \quad \times 51070 : 2.71 \quad " \quad " : -\sigma_{xK}'$$

$$\sigma_{xL}: \quad " \quad " \quad \times 46223 : 2.45 \quad " \quad " : -\sigma_{xL}'$$

$$\sigma_{xM}: \quad " \quad " \quad \times 55916 : 2.97 \quad " \quad " : -\sigma_{xM}'$$

$$\sigma_{xN}: \quad " \quad " \quad \times -27516 : -1.46 \quad " \quad " : -\sigma_{xN}'$$

-... I. ANA KİRİŞ



$$Q_1: \frac{1.46+0.97}{2} \times 2 \times 200 : 487 \text{ Kg.}$$

$$Q_2: \frac{1.22 \times 45.89}{2} \times 2 : 55.89 \text{ Kg.}$$

$$Q_3: \frac{2.71 \times 102.11}{2} \times 2 : 276.2 \text{ Kg.}$$

$$Q_4: \frac{2.45+2.79}{2} \times 2 \times 50 : 271 \text{ Kg.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_c: 487 \times 45.97 + 55.89 \times 30.67 + 276.7 \times 67.99 + 271 \times 102.03 : 0.71 \text{ Tm.}$$

$$M_c: F_{IM} \cdot \eta \quad 0.71 : F_{IM} \cdot 5 \quad F_{IM} : 0.14 \text{ Ton.}$$

$$F_{I\sum} : F/n + F_{IM} : 1/6 + 0.14 : 0.31 \text{ Ton.}$$

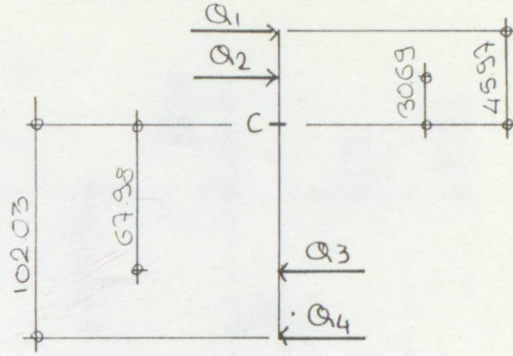
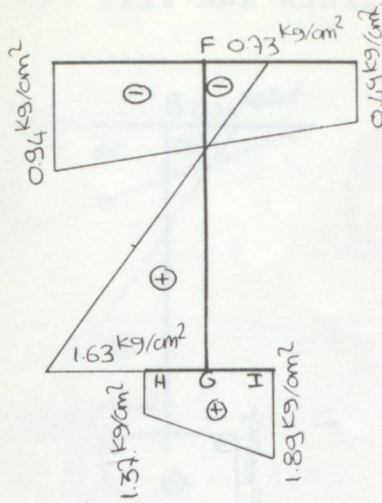
-... COURBON YÖNTEMİNE GÖRE.

$$F_{I\sum} : F/n \cdot \Delta_1 \quad \Delta_1 : 1 + 6 \frac{6+1-2}{36-1} \frac{2}{2} : 1.86$$

$$F_{I\sum} : 1/6 \times 1.86 : 0.31 \text{ Ton.}$$

$$F_{I\sum} : 1/6 \times 1.51 : 0.25 \text{ Ton.}$$

-... II. ANA KİRİŞ



$$Q_1: \frac{0.94+0.49}{2} \times 2 \times 200 : 292.2 \text{ Kğ.}$$

$$Q_2: \frac{0.73 \times 45.84}{2} \times 2 : 33.46 \text{ Kğ.}$$

$$Q_3: \frac{102.16 \times 1.63}{2} \times 2 : 166.21 \text{ Kğ.}$$

$$Q_4: \frac{1.37+1.89}{2} \times 2 \times 50 : 162.65 \text{ Kğ.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_c: 292.2 \times 45.97 + 33.46 \times 30.69 + 166.21 \times 67.98 + 162.65 \times 102.03 : 0.42 \text{ Tm.}$$

$$0.42: F_{2M} \cdot \eta \quad 0.42: F_{2M} \cdot 5 \quad F_{2M}: 0.09 \text{ Ton.}$$

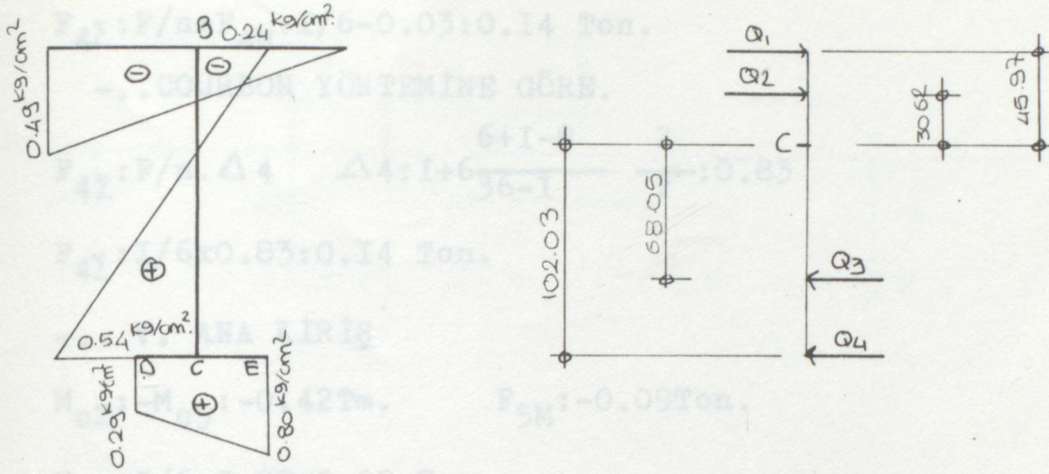
$$F_{2\Sigma}: F/n + F_{2M}: 1/6 + 0.09: 0.25 \text{ Ton.}$$

-... COURBON YÖNTEMİNE GÖRE.

$$F_{2\Sigma}: F/n \cdot \Delta 2 \quad \Delta 2: 1 + 6 \frac{6+1-4}{36-1} \cdot \frac{2}{2}: 1.51$$

$$F_{2\Sigma}: 1/6 \times 1.51: 0.25 \text{ Ton.}$$

... III. ANA KIRIŞ



$$Q_1 = \frac{0.49 \times 200}{2} \times 2 = 97.40 \text{ Kğ.}$$

$$Q_2 = \frac{45.97 \times 0.24}{2} \times 2 = 11.22 \text{ Kğ.}$$

$$Q_3 = \frac{102.03 \times 0.54}{2} \times 2 = 55.09 \text{ Kğ.}$$

$$Q_4 = \frac{0.29 + 0.80}{2} \times 2 \times 50 = 54.25 \text{ Kğ.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_c = 97.4 \times 45.97 + 11.22 \times 30.62 + 55.09 \times 68.05 + 54.25 \times 102.03 = 0.14 \text{ Tm.}$$

$$M_c = F_{3M} \cdot \eta \quad 0.14 = F_{3M} \cdot 5 \quad F_{3M} = 0.03 \text{ Ton.}$$

$$F_{3\Sigma} = F/n + F_{3M} = 1/6 + 0.03 = 0.20 \text{ Ton.}$$

... COURBON YÖNTEMİNE GÖRE.

$$F_{3\Sigma} = F/n \cdot \Delta_3 \quad \Delta_3 = 1 + \frac{6+1-6}{36-1} \cdot \frac{2}{2} = 1.71$$

$$F_{3\Sigma} = 1/6 \times 1.71 = 0.20 \text{ Ton.}$$

...IV. ANA KİRİŞ

$$M_{c3}:-M_{c4}:-0.14 \text{ Tm.} \quad F_{4M}:-0.03 \text{ Ton.}$$

$$F_{4\Sigma}: F/n + F_{4M}: I/6 - 0.03: 0.14 \text{ Ton.}$$

...COURBON YÖNTEMİNE GÖRE.

$$F_{4\Sigma}: F/n. \Delta 4 \quad \Delta 4: I + 6 \frac{6+I-8}{36-I} \frac{2}{2}: 0.83$$

$$F_{4\Sigma}: I/6 \times 0.83: 0.14 \text{ Ton.}$$

... V. ANA KİRİŞ

$$M_{c2}:-M_{c5}:-0.42 \text{ Tm.} \quad F_{5M}:-0.09 \text{ Ton.}$$

$$F_{5\Sigma}: I/6 - 0.09: 0.08 \text{ Ton.}$$

... COURBON YÖNTEMİNE GÖRE.

$$F_{5\Sigma}: F/n. \Delta 5 \quad \Delta 5: I + 6 \frac{6+I-2 \times 5}{36-I} \frac{2}{2}: 0.49$$

$$F_{5\Sigma}: I/6 \times 0.49: 0.08 \text{ Ton.}$$

... VI. ANA KİRİŞ

$$M_{c1}:-M_{c6}:-0.71 \text{ Tm.} \quad F_{6M}:-0.14 \text{ Ton.}$$

$$F_{6\Sigma}: I/6 - 0.14: 0.03 \text{ Ton.}$$

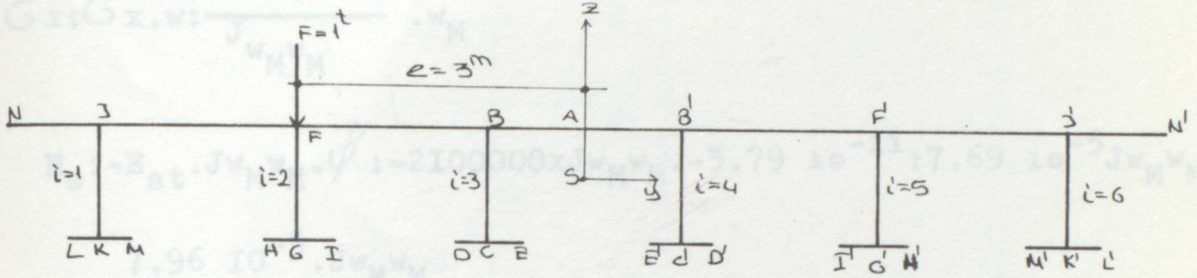
...COURBON YÖNTEMİNE GÖRE.

$$F_{6\Sigma}: F/n. \Delta 6 \quad \Delta 6: I + 6 \frac{6+I-12}{36-I} \frac{2}{2}: 0.14$$

$$F_{6\Sigma}: I/6 \times 0.14: 0.03 \text{ Ton.}$$

3.4.c- III. YÜKLEME

M: Fxe: Ix3: "3tm "



Dönme açıları

$$\varphi' = \frac{3 \cdot 10^5}{810000 \cdot 6336} \left(0.50 - \frac{0.036033}{0.072113} \cdot 1.00 \right) : 1900 \cdot 10^{-8} \text{ cm}^{-1}$$

$$\varphi'' = \frac{-3 \cdot 10^5 \times 0.036033^2 \times 3.603 \cdot 10^{-5}}{810000 \times 0.072113 \times 6336} : -3.79 \cdot 10^{-11} \text{ cm}^{-2}$$

$$\varphi''' = \frac{-3 \cdot 10^5 \times 0.036033 \times 3.603 \cdot 10^{-5})^2 \times 1.00}{810000 \times 6336 \times 0.072113} : -3.79 \cdot 10^{-14} \text{ cm}^{-3}$$

... St.Venant burulma momenti. (M_t):

x:0 için.

$$M_t : G_{st} \cdot J_t \cdot \varphi' : 810000 \times 6336 \times 1.9 \cdot 10^{-8} : 9.55 \cdot 10^{-4} \text{ Tm.}$$

x:10 m. (Açıklık ortası için)

$\varphi : 0$, $M : 0$ (Simetriden dolayı)

... Çarpılma burulması (M_z):

x:0 için.

$$M_z : -E_{st} \cdot J_{wM} \cdot \varphi'' : -2100000 \times 1.88 \cdot 10^{12} \times 3.79 \cdot 10^{-11} : 1.49 \text{ Tm.}$$

x:10 m. (Tüm kesit tesirleri burulma momenti çarpılma

burulmasıdır.) $M_z : 1.50 \text{ Tm.}$

... AÇIKLIK ORTASINDA NORMAL GERİLMELER. (σ_x):

$$\sigma_x: \sigma_{x.w} = \frac{M_w}{J_w w_M} \cdot w_M$$

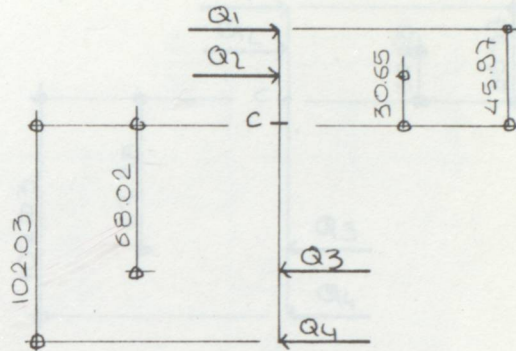
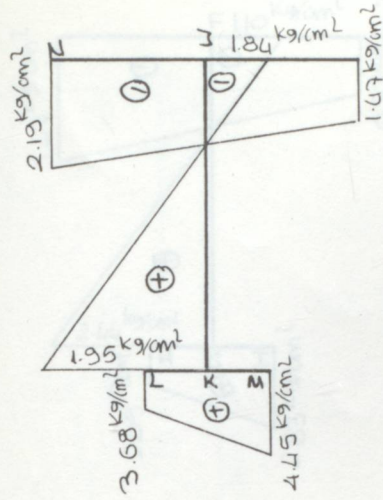
$$M_w: -E_{st} \cdot J_w w_M \cdot \psi'' : -2100000 \times J_w w_M \cdot -3.79 \cdot 10^{-11} : 7.69 \cdot 10^{-5} J_w w_M.$$

$$\sigma_x: \frac{7.96 \cdot 10^{-5} \cdot J_w w_M}{J_w w_M} \cdot w_M : 7.96 \cdot 10^{-5} x w_M$$

$$\sigma_{xA}: 0 \quad (w_{MA}: 0)$$

σ_{xB}	$7.69 \cdot 10^{-5}$	x- 4586	: -0.37	Kg/cm ²	: - σ_{xB}
σ_{xC}	" "	x 10214	: 0.81	" "	: - σ_{xC}
σ_{xD}	" "	x 5367	: 0.43	" "	: - σ_{xD}
σ_{xE}	" "	x 15060	: 1.20	" "	: - σ_{xE}
σ_{xF}	" "	x-13758	: -1,10	" "	: - σ_{xF}
σ_{xG}	" "	x 30642	: 2.44	" "	: - σ_{xG}
σ_{xH}	" "	x 25795	: 2.05	" "	: - σ_{xH}
σ_{xI}	" "	x35488	: 2.83	" "	: - σ_{xI}
σ_{xJ}	" "	x-22940	: -1.84	" "	: - σ_{xJ}
σ_{xK}	" "	x 51070	: 4.07	" "	: - σ_{xK}
σ_{xL}	" "	x 46223	: 3.68	" "	: - σ_{xL}
σ_{xM}	" "	x 55916	: 4.45	" "	: - σ_{xM}
σ_{xN}	" "	x-27516	: -2.19	" "	: - σ_{xN}

... I. ANA KİRİŞ



$$Q_1: \frac{2.19 + 1.47}{2} \times 2 \times 200 : 731.2 \text{ Kg.}$$

$$Q_2: \frac{46.04 \times 1.84}{2} \times 2 : 84.53 \text{ Kg.}$$

$$Q_3: \frac{4.07 \times 10 \times 1.95}{2} \times 2 : 414.43 \text{ Kg.}$$

$$Q_4: \frac{3.68 + 4.45}{2} \times 2 \times 50 : 406.45 \text{ Kg.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_c: 731.2 \times 45.97 + 84.53 \times 30.65 + 414.43 \times 68.02 + 406.45 \times 102.03 : 1.06 \text{ Tm.}$$

$$M_c: F_{IM} \cdot \eta \quad 1.06: F_{IM} \cdot 5 \quad F_{IM}: 0.21 \text{ Ton.}$$

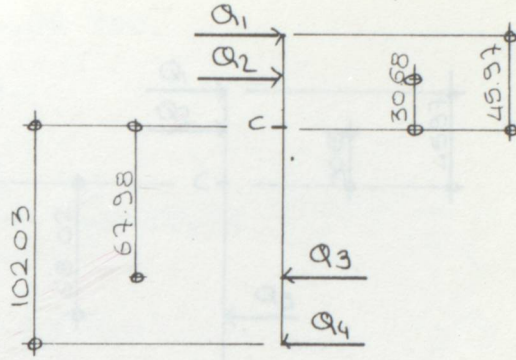
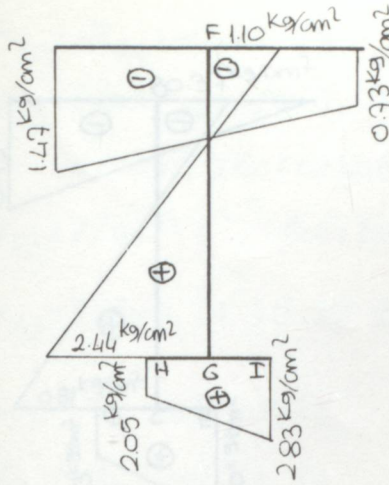
$$F_{I\Sigma}: F/n + F_{IM}: 1/6 + 0.21: 0.38 \text{ Ton.}$$

Courbon yöntemine göre

$$F_{I\Sigma}: F/n \cdot \Delta_1 \quad \Delta_1: 1 + 6 \frac{6 + 1 - 2}{36 - 1} \frac{3}{2} : 2.29$$

$$F_{I\Sigma}: 1/6 \times 2.29: 0.38 \text{ Ton.}$$

... II. ANA KIRIŞ



$$Q_1 = \frac{1.47 + 0.73}{2} \times 2 \times 200 = 439.20 \text{ Kğ.}$$

$$Q_2 = \frac{1.10 \times 45.97}{2} \times 2 = 50.34 \text{ Kğ.}$$

$$Q_3 = \frac{102.03 \times 2.44}{2} \times 2 = 248.85 \text{ Kğ.}$$

$$Q_4 = \frac{2.05 + 2.83}{2} \times 2 \times 50 = 244 \text{ Kğ.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_{2c} = 439.2 \times 45.97 + 50.34 \times 30.68 + 67.98 \times 248.85 + 244 \times 102.03 = 0.64 \text{ Tm.}$$

$$M_{2c} = F_{2M} \cdot \eta \quad 0.64 = F_{2M} \cdot 5 \quad F_{2M} = 0.13 \text{ Ton.}$$

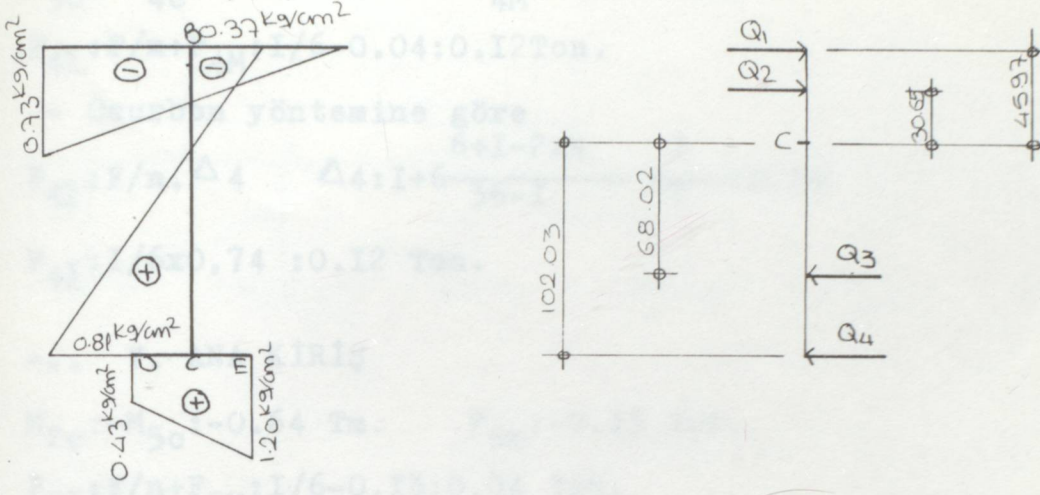
$$F_{2\Sigma} = 1/6 + 0.13 = 0.294 \text{ Ton.}$$

... Courbon yöntemine göre.

$$F_{2\Sigma} = F/n \cdot \Delta 2 \quad \Delta 2 = 1 + 6 \frac{6+1-4}{36-1} \frac{3}{2} = 1.77$$

$$F_{2\Sigma} = 1/6 \times 1.77 = 0.295 \text{ Ton.}$$

... III. ANA KİRİŞ



$$Q_I = \frac{0.73 \times 200}{2} \times 2 \quad : 146 \text{ Kg.}$$

$$Q_2 = \frac{0.37 \times 45.97}{2} \times 2 \quad : 16.78 \text{ Kg.}$$

$$Q_3 = \frac{0.81 \times 102.03}{2} \times 2 \quad : 82.64 \text{ Kg.}$$

$$Q_4 = \frac{0.43 + 1.20}{2} \times 2 \times 50 \quad : 81.45 \text{ Kg.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_{3c} : 146 \times 45.97 + 16.78 \times 30.65 + 82.64 \times 68.02 + 81.45 \times 102.03 : 0.21 \text{ Tm.}$$

$$M_{3c} : F_{3M} \cdot \rho \quad 0.21 : F_{3M} \cdot 5 \quad F_{3M} : 0.04 \text{ Ton.}$$

$$F_{3\Sigma} : F/n + F_{3M} : 1/6 + 0.04 : 0.21 \text{ Ton.}$$

- Courbon yöntemine göre

$$F_{3\Sigma} : F/n \cdot \Delta_3 \quad \Delta_3 : 1 + 6 \frac{6 + 1 - 2 \times 3}{36 - 1} \frac{3}{2} : 1.26$$

$$F_{3\Sigma} : 1/6 \times 1.26 : 0.21 \text{ Ton.}$$

-... IV. ANA KIRIŞ

$$M_{3c}:-M_{4c}:-0.21 \text{ Tm} \quad F_{4M}:-0.04 \text{ Ton.}$$

$$F_{4\Sigma}:F/n+F_{4M}:I/6-0.04:0.12 \text{ Ton.}$$

- Courbon yöntemine göre

$$F_{4\Sigma}:F/n. \Delta 4 \quad \Delta 4:I+6 \frac{6+I-2x4}{36-I} \frac{3}{2}:0.74$$

$$F_{4\Sigma}:I/6x0,74 :0.12 \text{ Ton.}$$

-... V. ANA KIRIŞ

$$M_{2c}:-M_{5c}:-0.64 \text{ Tm.} \quad F_{5M}:-0.13 \text{ Ton.}$$

$$F_{5\Sigma}:F/n+F_{5M}:I/6-0.13:0.04 \text{ Ton.}$$

- Courbon yöntemine göre

$$F_{5\Sigma}:F/n. \Delta 5 \quad \Delta 5:I+6 \frac{6+I-2x5}{36-I} \frac{3}{2}:0.23$$

$$F_{5\Sigma}:I/6x0,23:0.04 \text{ Ton.}$$

-... VI. ANA KIRIŞ

$$M_{1c}:-M_{6c}:-1.06 \text{ Tm.} \quad F_{6M}:-0.21 \text{ Ton.}$$

$$F_{6\Sigma}:F/n+F_{6M}:I/6-0.21+0.05 \text{ Ton.}$$

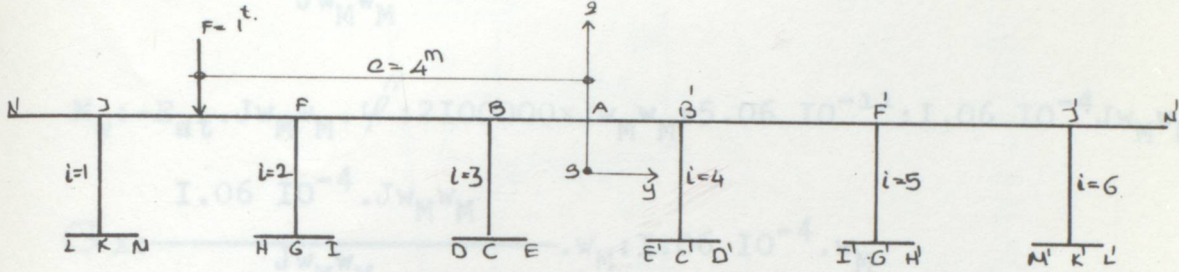
- Courbon yöntemine göre.

$$F_{6\Sigma}:F/n. \Delta 6 \quad \Delta 6:I+6 \frac{6+I-2x6}{36-I} \frac{3}{2}:-0.29$$

$$F_{6\Sigma}:I/6x0.29 :-0.05 \text{ Ton.}$$

3.4.d- IV. YÜKLEME NORMAL GERİLMELER (σ_x):

M: $Fxe: Ix4:4$ Tm.



Dönme açıları.

$$\phi' : \frac{4 \cdot 10^5}{810000 \cdot 6336} \left(0.50 - \frac{0.036033}{0.072113} \cdot 1.00 \right) : 2.53 \cdot 10^{-8} \text{ cm}^{-1}.$$

$$\phi'' : \frac{-4 \cdot 10^5 \cdot 0.036033^2 \cdot 3.603 \cdot 10^{-5}}{810000 \cdot 6336 \cdot 0.072113} : -5.06 \cdot 10^{-11} \text{ cm}^{-2}.$$

$$\phi''' : \frac{-4 \cdot 10^5 \cdot 0.036033 \cdot (3.603 \cdot 10^{-5})^2}{810000 \cdot 6336 \cdot 0.072113} : -5.06 \cdot 10^{-14} \text{ cm}^{-3}$$

-.. St.Venant burulma momenti (M_t):

x:0 için.

$$M_t : G_{st} \cdot J_t \cdot \phi' : 810000 \cdot 6336 \cdot 2.53 \cdot 10^{-8} : 0.0013 \text{ Tm.}$$

x:10 m. Açıklık ortası için)

$$\phi : 0, \quad M_t : 0 \text{ (simetriden dolayı)}$$

-.. Çarpılma burulması (M_z):

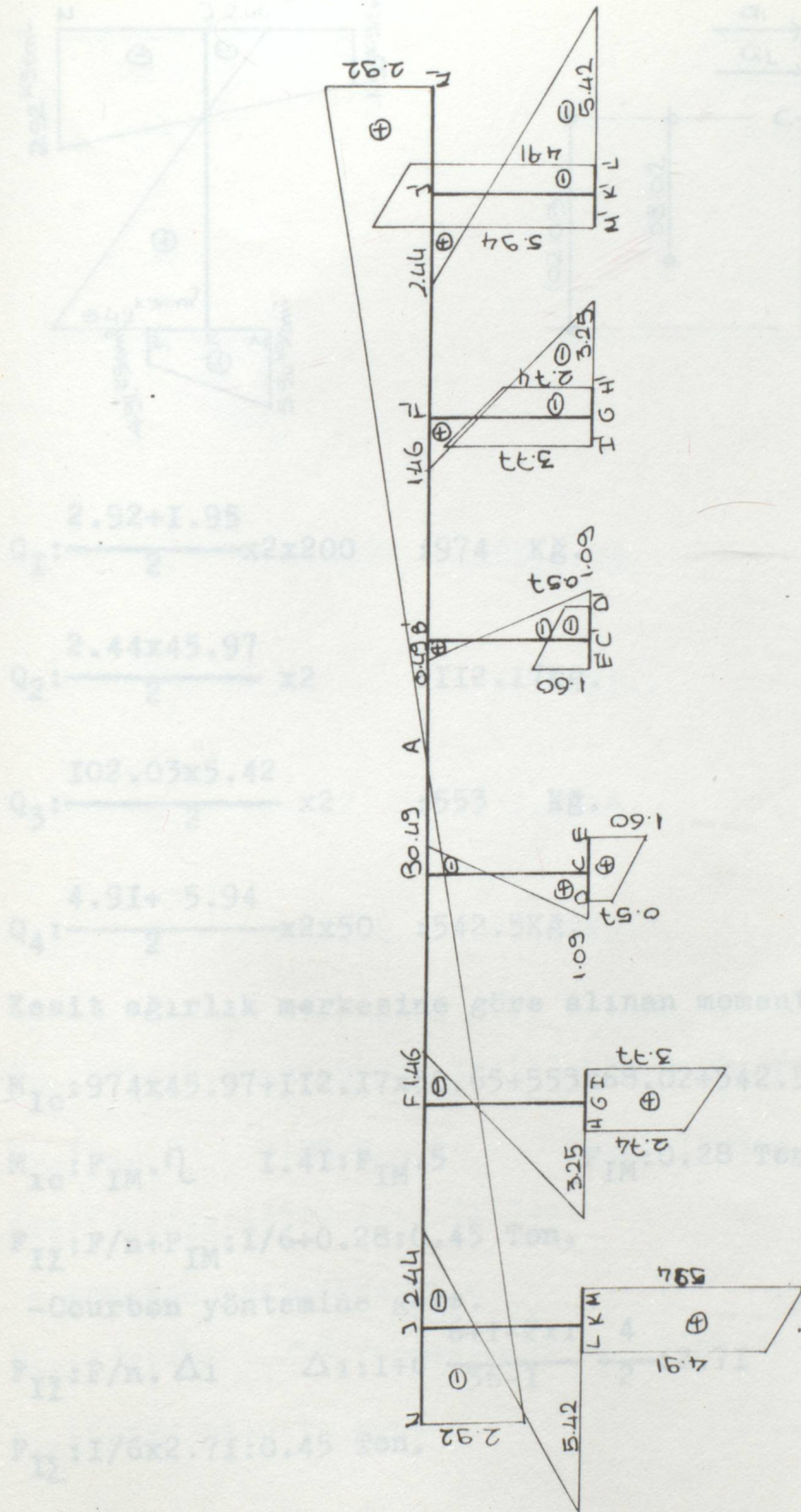
x:0 için.

$$M_z : -E_{st} \cdot J_w \cdot M \cdot \phi''' : 2100000 \cdot 1.88 \cdot 10^{12} \cdot 5.06 \cdot 10^{-14} : 1.99 \text{ Tm.}$$

x:10 m. (Tüm kesit tesirleri burulma momenti çarpılma

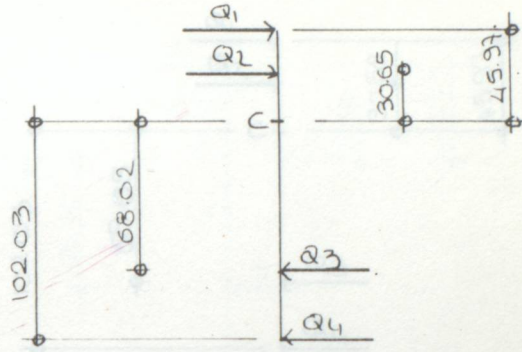
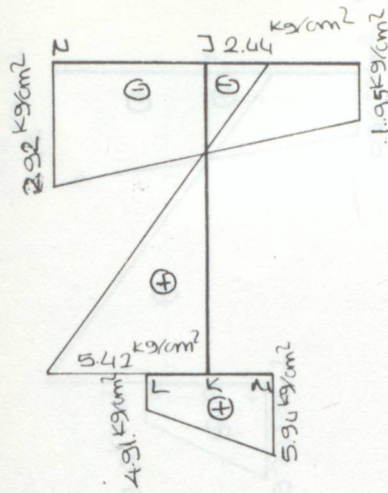
burulmasıdır. $M_z : 2.00 \text{ Tm.}$

... 1. ANA KIRIŞ



IV. YÜKLEME NORMAL GERİLME DİYAGRAMI (G_x) $\ddot{O} = 1/2 - 1/67$

... I. ANA KIRIŞ



$$Q_1 = \frac{2.92 + 1.95}{2} \times 2 \times 200 = 974 \text{ Kg.}$$

$$Q_2 = \frac{2.44 \times 45.97}{2} \times 2 = 112.17 \text{ Kg.}$$

$$Q_3 = \frac{102.03 \times 5.42}{2} \times 2 = 553 \text{ Kg.}$$

$$Q_4 = \frac{4.91 + 5.94}{2} \times 2 \times 50 = 542.5 \text{ Kg.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_{Ic} = 974 \times 45.97 + 112.17 \times 30.65 + 553 \times 68.02 + 542.5 \times 102.03 = 1.41 \text{ Tm.}$$

$$M_{Ic} = F_{IM} \cdot \eta \quad 1.41 = F_{IM} \cdot 5 \quad F_{IM} = 0.28 \text{ Ton.}$$

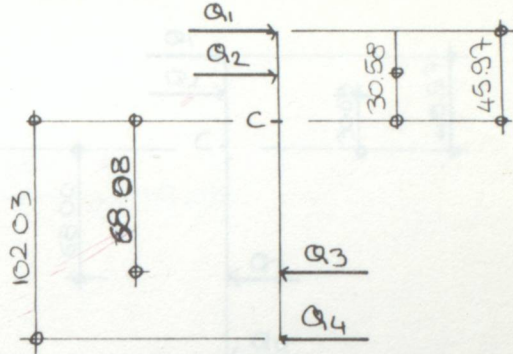
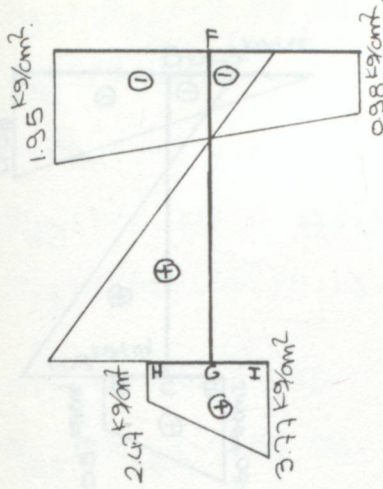
$$F_{Iz} = F/n + F_{IM} = 1/6 + 0.28 = 0.45 \text{ Ton.}$$

-Courbon yöntemine göre.

$$F_{Iz} = F/n \cdot \Delta_1 \quad \Delta_1 = 1 + 6 \frac{6 + 1 - 2 \times 1}{36 - 1} \frac{4}{2} = 2.71$$

$$F_{Iz} = 1/6 \times 2.71 = 0.45 \text{ Ton.}$$

... II. ANA KIRIŞ



$$Q_I = \frac{1.95 + 0.98}{2} \times 2 \times 200 : 585 \text{ Kg.}$$

$$Q_2 = \frac{1.46 \times 45.87}{2} \times 2 : 66.97 \text{ Kg.}$$

$$Q_3 = \frac{3.25 \times 102.13}{2} \times 2 : 331.93 \text{ Kg.}$$

$$Q_4 = \frac{2.74 + 3.77}{2} \times 2 \times 50 : 325.50 \text{ Kg.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_{2c} : 585 \times 45.97 + 66.97 \times 30.58 + 331.93 \times 68.09 + 325.5 \times 102.03 : 0.85 \text{ Tm.}$$

$$M_{2c} : F_{2M} \cdot \Omega \quad 0.85 : F_{2M} \cdot 5 \quad F_{2M} : 0.17 \text{ Ton.}$$

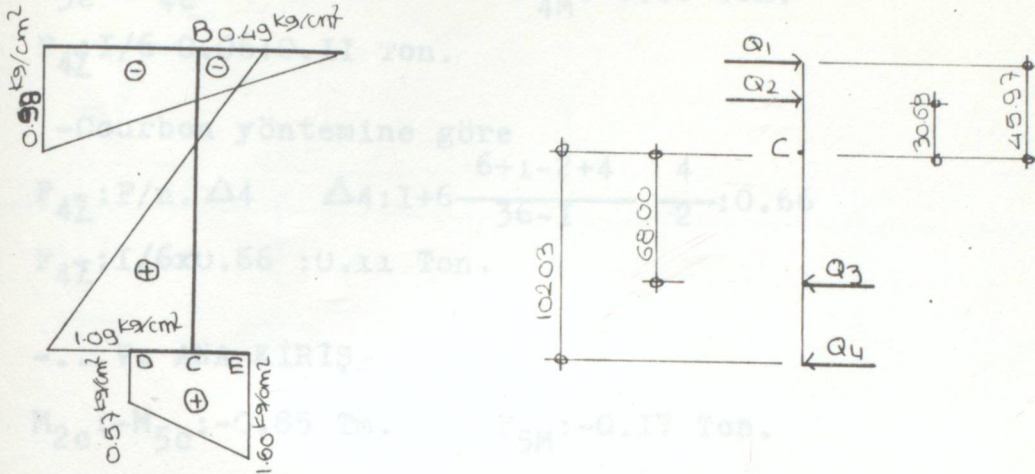
$$F_{2\Sigma} : F/n + F_{2M} : 1/6 + 0.17 : 0.34 \text{ Ton.}$$

- Courbon yöntemine göre

$$F_{2\Sigma} : F/n \cdot \Delta^2 \quad \Delta^2 : 1 + 6 \frac{6 + 1 - 2 \times 2}{36 - 1} \frac{4}{2} : 2.03$$

$$F_{2\Sigma} : 1/6 \times 2.03 : 0.34 \text{ Ton.}$$

... III. ANA KIRIŞ



$$Q_1 = \frac{0.98 \times 200}{2} \times 2 = 195 \text{ Kğ.}$$

$$Q_2 = \frac{0.49 \times 45.97}{2} \times 2 = 22.53 \text{ Kğ.}$$

$$Q_3 = \frac{1.09 \times 102.03}{2} \times 2 = 110.70 \text{ Kğ.}$$

$$Q_4 = \frac{0.57 + 1.60}{2} \times 2 \times 50 = 108.50 \text{ Kğ.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_{3c} = 195 \times 45.97 + 22.53 \times 30.69 + 110.70 \times 67.97 + 102.03 \times 108.5 = 0.29 \text{ Tm.}$$

$$M_{3c} = F_{3M} \cdot \Delta_3 \quad 0.29 = F_{3M} \cdot 5 \quad F_{3M} = 0.06 \text{ Ton.}$$

$$F_{3\Sigma} = F/n + F_{3M} = 1/6 + 0.06 = 0.22 \text{ Ton.}$$

- Courbon yöntemine göre

$$F_{3\Sigma} = F/n \cdot \Delta_3 \quad \Delta_3 = 1 + 6 \frac{6 + 1 - 2 \times 3}{36 - 1} \frac{4}{2} = 1.34$$

$$F_{3\Sigma} = 1/6 \times 1.34 = 0.22 \text{ Ton.}$$

-.. IV. ANA KIRIŞ

$$M_{3c}:-M_{4c}:-0.29 \text{ Tm.} \quad F_{4M}:-0.06 \text{ Ton.}$$

$$F_{4Z}:I/6-0.06:0.11 \text{ Ton.}$$

-Courbon yöntemine göre

$$F_{4Z}:F/n.\Delta 4 \quad \Delta 4:I+6\frac{6+1-2+4}{36-1} \frac{4}{2}:0.66$$

$$F_{4Z}:I/6x0.66 :0.11 \text{ Ton.}$$

-.. V. ANA KIRIŞ

$$M_{2c}:-M_{5c}:-0.85 \text{ Tm.} \quad F_{5M}:-0.17 \text{ Ton.}$$

$$F_{5Z}:F/n+F_{5M}:I/6-0.17:-0.003 \text{ Ton.}$$

- Courbon yöntemine göre

$$F_{5Z}:F/n.\Delta 5 \quad \Delta 5:I+6\frac{6+1-2x5}{36-1} \frac{4}{2}:-0.03$$

$$F_{5Z}:I/6x0.03 :-0.004 \text{ Ton.}$$

-.. VI. ANA KIRIŞ

$$M_{1c}:-M_{6c}:-1.41 \text{ Tm.} \quad F_{6M}:-0.28$$

$$F_{6Z}:F/n+F_{6M}:I/6+0.28 :-0.12 \text{ Ton.}$$

- Courbon yöntemine göre

$$F_{6Z}:F/n.\Delta 6 \quad \Delta 6:I+6\frac{6+1-2x6}{36-1} \frac{4}{2}:-0.71$$

$$F_{6Z}:I/6x(-0.71):-0.12 \text{ Ton.}$$

...Çarpılma burulması(M_z):

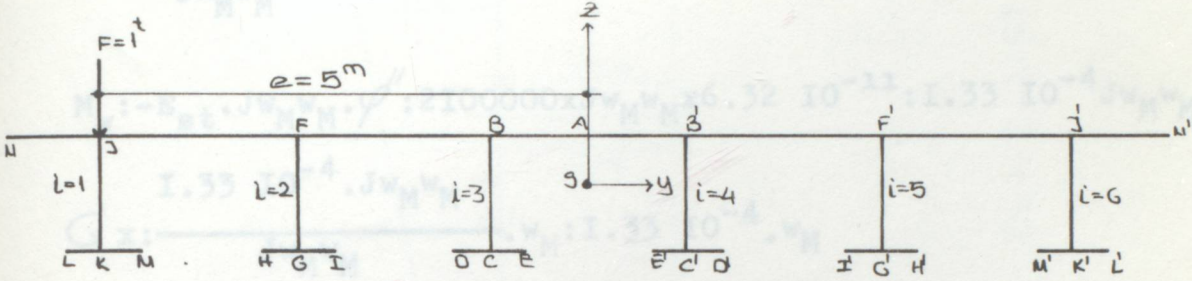
$$M_z=I \cdot \sigma_{max} = 2100000 \times 1.88 \cdot 10^{-12} \times 6.32 \cdot 10^{-14} = 2.50 \text{ Tm.}$$

x:10 m. (Bu kesit teatirleri burulma momenti çarpılma burulmasıdır.)

$$M_z:2.5 \text{ Tm.}$$

3.4.e- V. YÜKLEME

M:Fxe:Ix5:5 tm.



Dönme açıları.

$$\varphi' = \frac{5 \cdot 10^5}{810000 \cdot 6336} \left(0.50 - \frac{0.036033}{0.072113} \cdot 1.00 \right) : 3.16 \cdot 10^{-8} \text{ cm}^{-1}.$$

$$\varphi'' = \frac{-5 \cdot 10^5 \times 0.036033^2 \times 3.603 \cdot 10^{-5}}{810000 \times 6336 \times 0.072113} : -6.32 \cdot 10^{-8} \text{ cm}^{-2}$$

$$\varphi''' = \frac{-5 \cdot 10^5 \times 0.036033 \times (3.603 \cdot 10^{-5})^2}{810000 \times 6336 \times 0.072113} : -6.32 \cdot 10^{-14} \text{ cm}^{-3}.$$

... St.Venant burulma momenti (M_t):

x:0 için

$$M_t = G_{st} \cdot J_t \cdot \varphi' : 810000 \times 6336 \times 3.16 \cdot 10^{-8} : 0.0016 \text{ tm.}$$

x:10 m. (Açıklık ortası için)

$$\varphi : 0, \quad M_t : 0 \quad (\text{Simetriden dolayı.})$$

...Çarpılma burulması (M_z):

$$M_z = -E_{st} \cdot J_w \cdot M \cdot \varphi''' : 2100000 \times 1.88 \cdot 10^{12} \times 6.32 \cdot 10^{-14} : 2.50 \text{ Tm.}$$

x:10 m. (Tüm kesit tesirleri burulma momenti çarpılma

burulmasıdır.)

$$M_z : 2,5 \text{ Tm.}$$

... AÇIKLIK ORTASINDA NORMAL GERİLMELER(σ_x):

$$\sigma_x = \frac{M_w}{J_w w_M} \cdot w_M$$

$$M_w = -E_{st} \cdot J_w w_M \cdot \varphi'' = 2100000 \times J_w w_M \times 6.32 \cdot 10^{-11} = 1.33 \cdot 10^{-4} J_w w_M$$

$$\sigma_x = \frac{1.33 \cdot 10^{-4} \cdot J_w w_M}{J_w w_M} \cdot w_M = 1.33 \cdot 10^{-4} \cdot w_M$$

$$\sigma_{xA}: 0 \quad (w_{MA}: 0)$$

$$\sigma_{xB}: 1.33 \cdot 10^{-4} \times -4586 : -0.61 \text{ Kg/cm}^2 : -\sigma_{xB}'$$

$$\sigma_{xC}: \quad " \quad " \quad \times 10214 : 1.36 \quad " \quad " : -\sigma_{xC}'$$

$$\sigma_{xD}: \quad " \quad " \quad \times 5367 : 0.71 \quad " \quad " : -\sigma_{xD}'$$

$$\sigma_{xE}: \quad " \quad " \quad \times 15060 : 2.00 \quad " \quad " : -\sigma_{xE}'$$

$$\sigma_{xF}: \quad " \quad " \quad \times -13758 : -1.83 \quad " \quad " : -\sigma_{xF}'$$

$$\sigma_{xG}: \quad " \quad " \quad \times 30642 : 4.07 \quad " \quad " : -\sigma_{xG}'$$

$$\sigma_{xH}: \quad " \quad " \quad \times 25795 : 3.42 \quad " \quad " : -\sigma_{xH}'$$

$$\sigma_{xI}: \quad " \quad " \quad \times 35488 : 4.71 \quad " \quad " : -\sigma_{xI}'$$

$$\sigma_{xJ}: \quad " \quad " \quad \times -22940 : -3.05 \quad " \quad " : -\sigma_{xJ}'$$

$$\sigma_{xK}: \quad " \quad " \quad \times 51070 : 6.78 \quad " \quad " : -\sigma_{xK}'$$

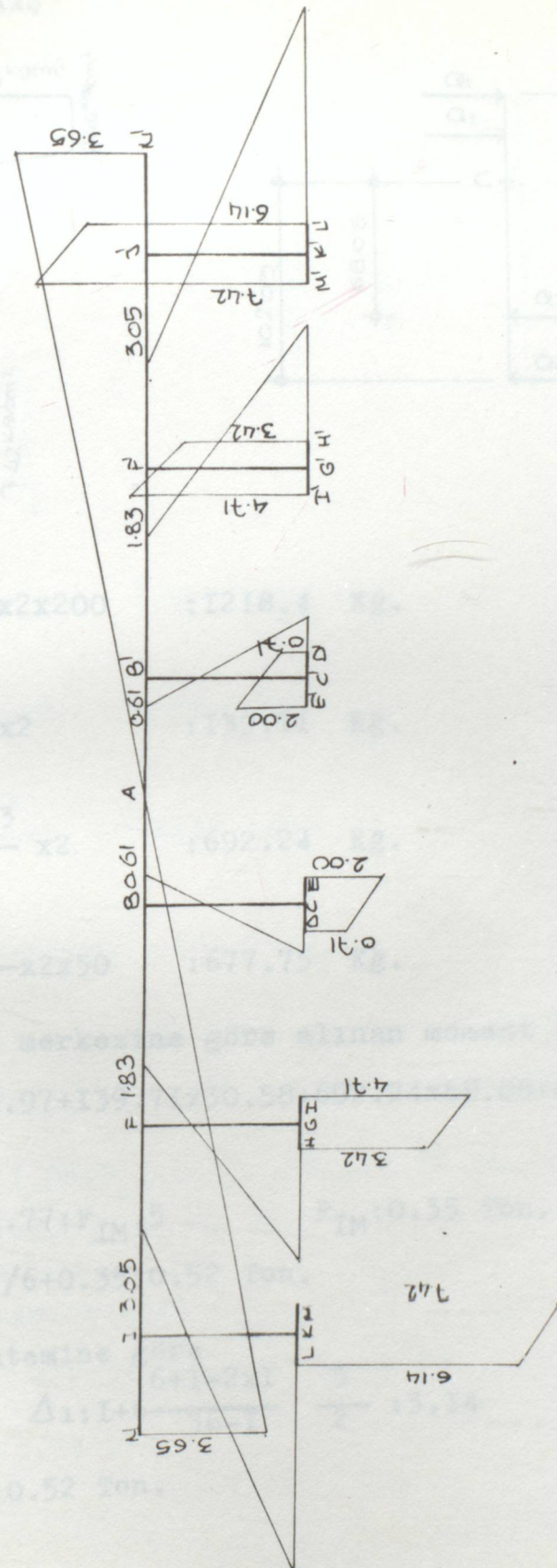
$$\sigma_{xL}: \quad " \quad " \quad \times 46223 : 6.14 \quad " \quad " : -\sigma_{xL}'$$

$$\sigma_{xM}: \quad " \quad " \quad \times 55916 : 7.42 \quad " \quad " : -\sigma_{xM}'$$

$$\sigma_{xN}: \quad " \quad " \quad \times -27516 : -3.65 \quad " \quad " : -\sigma_{xN}'$$

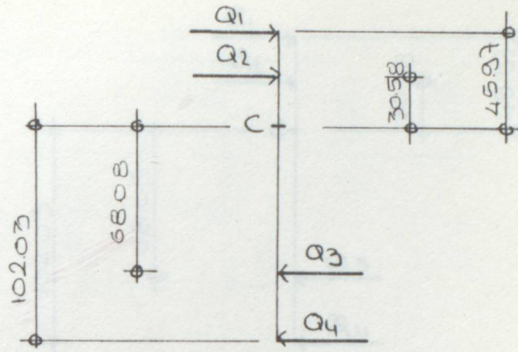
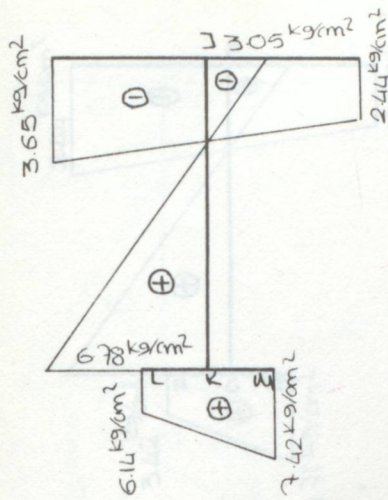
... I. ANA KIRIS

$Q_1 = \frac{3.65 + 2.44}{2} \times 2 \times 200 = 1218.4$
 $Q_2 = \frac{3.05 \times 45.88}{2} \times 2 = 139.7$
 $Q_3 = \frac{6.70 \times 102.13}{2} \times 2 = 684.9$
 $Q_4 = \frac{6.14 + 7.42}{2} \times 2 \times 250 = 1377.5$
 $M_{10} = 1218.4 \times 45.97 + 139.7 \times 22.985 = 57717.7$
 $M_{10} = P_{10} \times \eta = 1.77 \times P_{10}$
 $P_{12} = P/n + P_{10} \times 1/6 + 0.52$
 $P_{12} = P/n + \Delta_1$
 $P_{12} = 1/6 \times 3.14 = 0.52 \text{ Ton.}$



V. YÜKLEME · NORMAL GERİLME DİYAGRAMI (G_x) Ö=1/2 - 1/67

-... I. ANA KIRIŞ



$$Q_1 = \frac{3.65 + 2.44}{2} \times 2 \times 200 : 1218.4 \text{ Kğ.}$$

$$Q_2 = \frac{3.05 \times 45.88}{2} \times 2 : 139.71 \text{ Kğ.}$$

$$Q_3 = \frac{6.78 \times 102.13}{2} \times 2 : 692.24 \text{ Kğ.}$$

$$Q_4 = \frac{6.14 + 7.42}{2} \times 2 \times 50 : 677.75 \text{ Kğ.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_{1c} : 1218.4 \times 45.97 + 139.71 \times 30.58 + 692.24 \times 68.08 + 677.75 \times 102.03 :$$

$$: 1.77 \text{ Tm.}$$

$$M_{1c} : F_{IM} \cdot \Omega \quad 1.77 : F_{IM} \cdot 5 \quad F_{IM} : 0.35 \text{ Ton.}$$

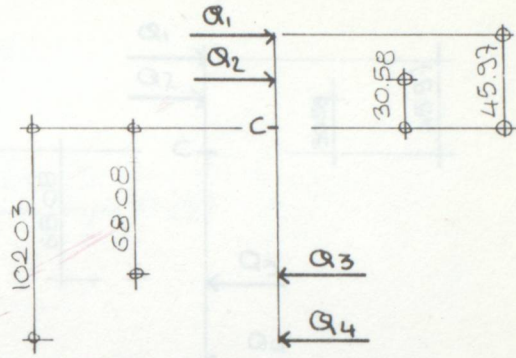
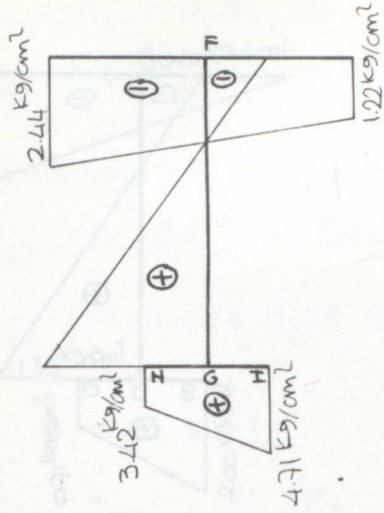
$$F_{I\Sigma} : F/n + F_{IM} : 1/6 + 0.35 : 0.52 \text{ Ton.}$$

-Courbon yöntemine göre

$$F_{I\Sigma} : F/n \cdot \Delta_1 \quad \Delta_1 : 1 + 6 \frac{6 + 1 - 2 \times 1}{36 - 1} \frac{5}{2} : 3.14$$

$$F_{I\Sigma} : 1/6 \times 3,14 : 0.52 \text{ Ton.}$$

... II. ANA KİRİŞ



$$Q_1: \frac{2.44 + 1.22}{2} \times 2 \times 200 : 732 \text{ Kğ.}$$

$$Q_2: \frac{1.83 \times 45.88}{2} \times 2 : 83.78 \text{ Kğ.}$$

$$Q_3: \frac{4.07 \times 102.13}{2} \times 2 : 415.36 \text{ Kğ.}$$

$$Q_4: \frac{4.71 + 3.42}{2} \times 2 \times 50 : 406.7 \text{ Kğ.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_{2c}: 732 \times 45.97 + 83.78 \times 30.58 + 415.36 \times 68.08 + 406.7 \times 102.03 : 1.06 \text{ Tm.}$$

$$M_{2c} : F_{2M} \cdot \eta \quad 1.06 : F_{2M} \cdot 5 \quad F_{2M} : 0.21 \text{ Ton.}$$

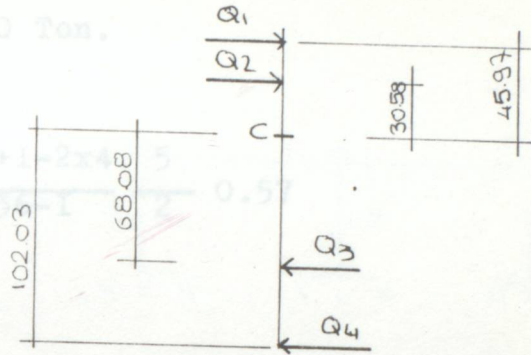
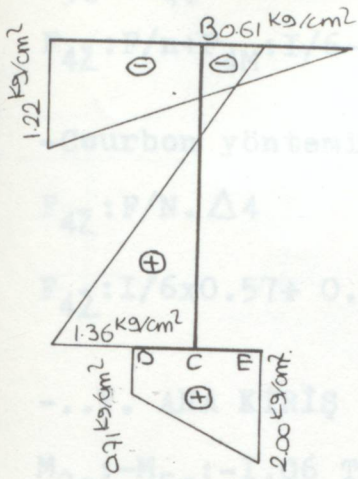
$$F_{2\Sigma} : F/n + F_{2M} : 1/6 + 0.21 : 0.38 \text{ Ton.}$$

-Courbon yöntemine göre

$$F_{2\Sigma} : F/n \cdot \Delta_2 \quad \Delta_2 : 1 + 6 \frac{6 + 1 - 2 \times 2}{36 - 1} \frac{5}{2} : 2.29$$

$$F_{2\Sigma} : 1/6 \times 2.29 : 0.38 \text{ Ton.}$$

... III. ANA KIRIŞ



$$Q_1: \frac{1.22 \times 200}{2} \times 2 : 244 \text{ Kg.}$$

$$Q_2: \frac{0.6 \times 45.97}{2} \times 2 : 28 \text{ Kg.}$$

$$Q_3: \frac{1.36 \times 102.13}{2} \times 2 : 138.5 \text{ Kg.}$$

$$Q_4: \frac{0.71 \times 2.00}{2} \times 2 \times 50 : 135.45 \text{ Kg.}$$

Kesit ağırlık merkezine göre alınan moment/(M_c):

$$M_{3c}: 244 \times 45.97 + 28 \times 30.58 + 138.5 \times 68.08 + 135.45 \times 102.03 : 0.35 \text{ Tm.}$$

$$M_{3c}: F_{3M} \cdot \rho \quad 0.35 : F_{3M} \cdot 5 \quad F_{3M} : 0.07 \text{ Ton.}$$

$$F_{3\Sigma}: F/n + F_{3M} : 1/6 + 0.07 : 0.23 \text{ Ton.}$$

-Courbon yöntemine göre

$$F_{3\Sigma}: F/n \cdot \Delta_3 \quad \Delta_3: 1 + 6 \frac{6 + 1 - 2 \times 3}{36 - 1} - \frac{5}{2} : 1.43$$

$$F_{3Z}: 1/6 \times 1.43 : 0.24 \text{ Ton.}$$

-.. IV. ANA KİRİŞ

$$M_{3c}:-M_{4c}:-0.35 \text{ Tm.} \quad F_{4M}:-0.07 \text{ Ton.}$$

$$F_{4\bar{\Sigma}}:F/n+F_{4M}:I/6-0.07:0.10 \text{ Ton.}$$

-Courbon yöntemine göre.

$$F_{4\bar{\Sigma}}:F/n.\Delta 4 \quad \Delta 4:I+6\frac{6+I-2x4}{36-I}\frac{5}{2} 0.57$$

$$F_{4\bar{\Sigma}}:I/6x0.57+ 0.10 \text{ Ton.}$$

-..V. ANA KİRİŞ

$$M_{2c}:-M_{5c}:-1.06 \text{ TM.} \quad F_{5M}:-0.21 \text{ Ton.}$$

$$F_{5\bar{\Sigma}}:F/n+F_{5M}:I/6-0.21:0.05 \text{ Ton.}$$

- Courbon yöntemine göre

$$F_{5\bar{\Sigma}}:F/n.\Delta 5 \quad \Delta 5:I+6\frac{6+I-2x5}{36-I}\frac{5}{2}:-0.29$$

$$F_{5\bar{\Sigma}}:I/6x(-0.29):-0.05 \text{ Ton.}$$

-.. VI. ANA KİRİŞ

$$M_{1c}:-M_{6c}:-1.77 \text{ Tm.} \quad F_{6M}:-0.35 \text{ Ton.}$$

$$F_{6\bar{\Sigma}}:F/n+F_{6M}:I/6-0.35:-0.19 \text{ Ton.}$$

- Courbon yöntemine göre

$$F_{6\bar{\Sigma}}:F/n.\Delta 6 \quad \Delta 6:I+6\frac{6+I-2x6}{36-I}\frac{5}{2}:-1.14$$

$$F_{6\bar{\Sigma}}:I/6x(-1.14):-0.19 \text{ Ton.}$$

-..Çarpılma burulması (M_p):

x:10 için.

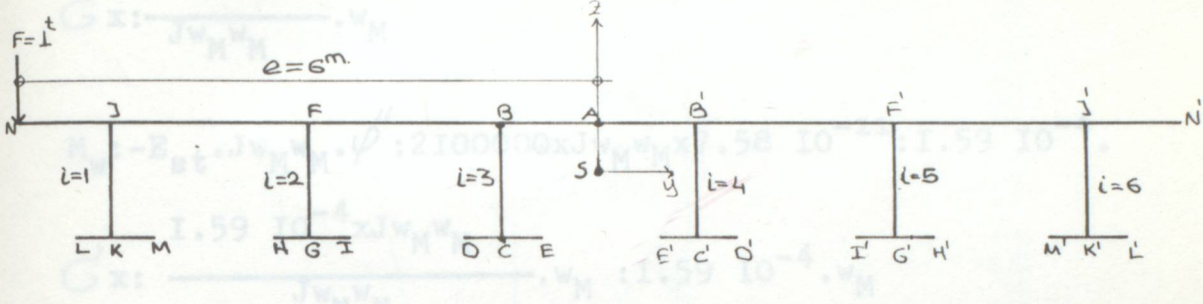
$$M_{2i}-E_{2i}\cdot J_{2i}\cdot \omega_{2i} \cdot \sqrt{21000000x1.88 \cdot 10^{12} \cdot x7.58 \cdot 10^{-14}}:2.99 \text{ Tm.}$$

x:10 n. (Tüm kesit tasvirleri burulma momenti çarpılma

burulmasıdır.) $M_p:3.00 \text{ Tm.}$

3.4.f- VI. Yükleme

M:Fxe:Ix6:6 Tm.



Dönme açıları.

$$\varphi' = \frac{6 \cdot 10^5}{810000 \cdot 6336} \left(0.50 - \frac{0.036033}{0.072113} \cdot 1.00 \right) : 3.83 \cdot 10^{-8} \text{ cm}^{-1}.$$

$$\varphi'' = \frac{-6 \cdot 10^5 \cdot 0.036033^2 \cdot 3.603 \cdot 10^{-5}}{810000 \cdot 6336 \cdot 0.072113} : 7.58 \cdot 10^{-11} \text{ cm}^{-2}.$$

$$\varphi''' = \frac{-6 \cdot 10^5 \cdot 0.036033 \cdot 3.603 \cdot 10^{-5} \cdot 2}{810000 \cdot 6336 \cdot 0.072113} : 7.58 \cdot 10^{-14} \text{ cm}^{-3}.$$

... St. Venant burulma momenti (M_t):

x:0 için.

$$M_t = G_{st} \cdot J_t \cdot \varphi' : 810000 \cdot 6336 \cdot 3.83 \cdot 10^{-8} : 0.002 \text{ Tm.}$$

x:10 m. (Açıklık ortası için)

$$\varphi' : 0, M_t : 0 \text{ (Simetriden dolayı)}$$

...Çarpılma burulması (M_z):

x:0 için.

$$M_z = -E_{st} \cdot J_w \cdot \varphi''' : 2100000 \cdot 1.88 \cdot 10^{12} \cdot 7.58 \cdot 10^{-14} : 2.99 \text{ Tm.}$$

x:10 m. (Tüm kesit tesirleri burulma momenti çarpılma

burulmasıdır.) $M_z : 3.00 \text{ Tm.}$

-.. AÇIKLIK ORTOSINDA NORMAL GERİLMELER (σ_x):

$$\sigma_x = \frac{M_w}{J_w w_M} \cdot w_M$$

$$M_w = -E_{st} \cdot J_w w_M \cdot \varphi'' : 2100000 \times J_w w_M \times 7.58 \cdot 10^{-11} : 1.59 \cdot 10^{-4}$$

$$\sigma_x = \frac{1.59 \cdot 10^{-4} \times J_w w_M}{J_w w_M} \cdot w_M : 1.59 \cdot 10^{-4} \cdot w_M$$

$$\sigma_{xA} : 0 \quad (w_{MA} : 0)$$

$$\sigma_{xB} : 1.59 \cdot 10^{-4} \times -4586 : -0.73 \text{ Kg/cm}^2 : -\sigma_{xB}'$$

$$\sigma_{xC} : \quad " \quad " \times 10214 : 1.63 \quad " \quad " : -\sigma_{xC}'$$

$$\sigma_{xD} : \quad " \quad " \times 5367 : 0.85 \quad " \quad " : -\sigma_{xD}'$$

$$\sigma_{xE} : \quad " \quad " \times 15060 : 2.40 \quad " \quad " : -\sigma_{xE}'$$

$$\sigma_{xF} : \quad " \quad " \times -13758 : -2.19 \quad " \quad " : -\sigma_{xF}'$$

$$\sigma_{xG} : \quad " \quad " \times 30642 : 4.88 \quad " \quad " : -\sigma_{xG}'$$

$$\sigma_{xH} : \quad " \quad " \times 25795 : 4.11 \quad " \quad " : -\sigma_{xH}'$$

$$\sigma_{xI} : \quad " \quad " \times 35488 : 5.65 \quad " \quad " : -\sigma_{xI}'$$

$$\sigma_{xJ} : \quad " \quad " \times -22940 : -3.65 \quad " \quad " : -\sigma_{xJ}'$$

$$\sigma_{xK} : \quad " \quad " \times 51070 : 8.13 \quad " \quad " : -\sigma_{xK}'$$

$$\sigma_{xL} : \quad " \quad " \times 46223 : 7.36 \quad " \quad " : -\sigma_{xL}'$$

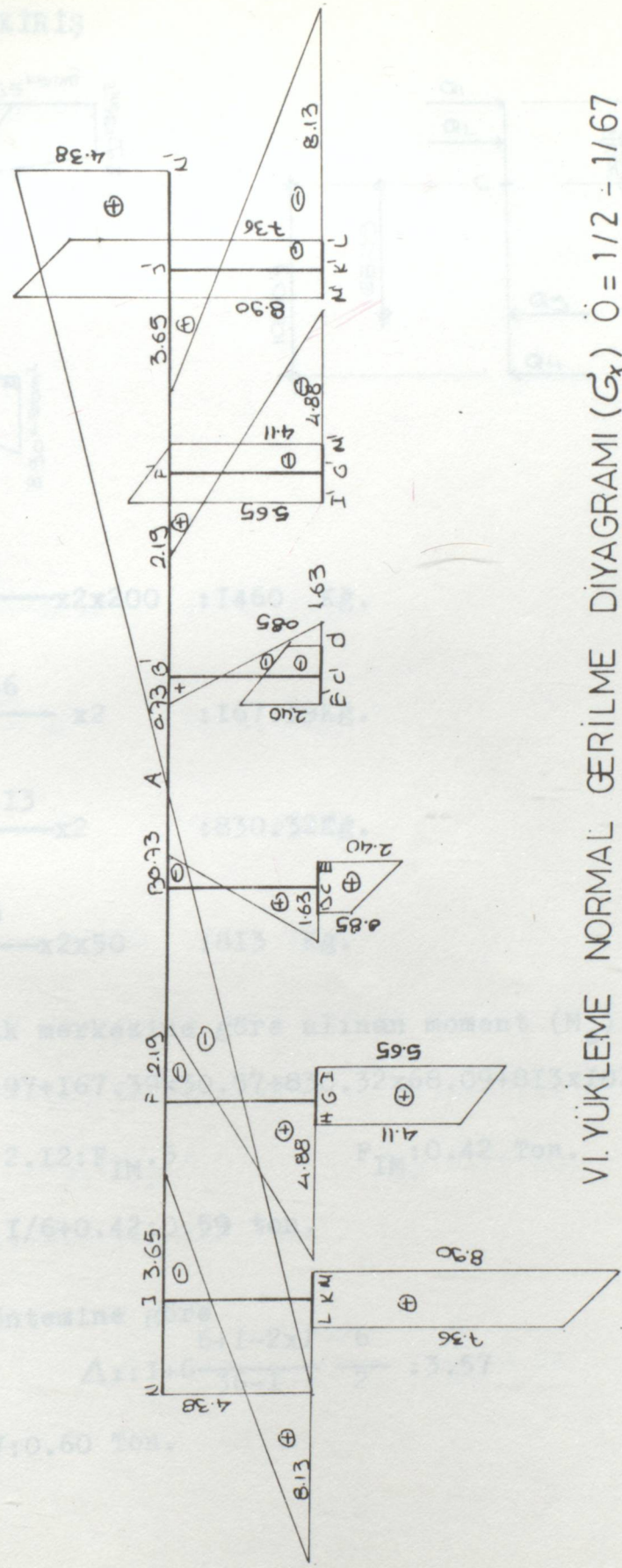
$$\sigma_{xM} : \quad " \quad " \times 55916 : 8.90 \quad " \quad " : -\sigma_{xM}'$$

$$\sigma_{xN} : \quad " \quad " \times -27516 : 4.38 \quad " \quad " : -\sigma_{xN}'$$

1. ANA KIRIŞ

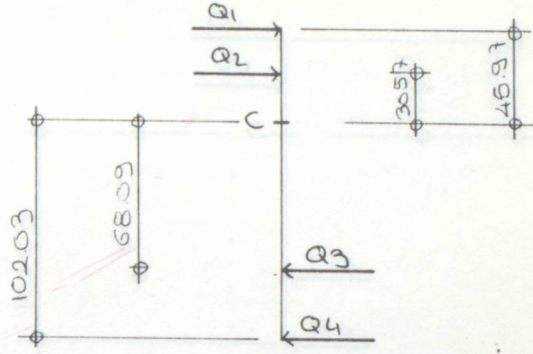
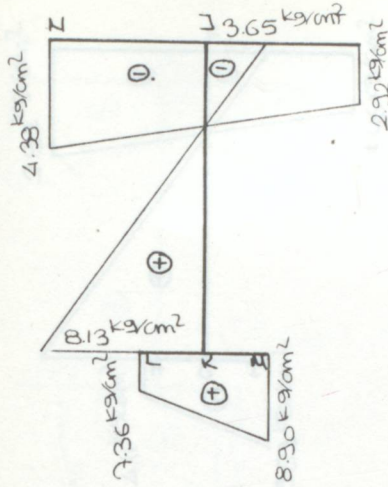
$Q_1 = \frac{4.38 + 2.92}{2} \times 2 \times 200 = 1460$
 $Q_2 = \frac{3.65 \times 45.86}{2} \times 2 = 1670$
 $Q_3 = \frac{8.13 \times 102.13}{2} \times 2 = 830.525$
 $Q_4 = \frac{7.56 + 8.90}{2} \times 2 \times 50 = 813$

$M_{10} = 1460 \times 45.97 + 1670 \times 2.12 = 72500.34$
 $M_{11} = 1460 \times 2.12 + 1670 \times 45.97 = 81300.34$
 $F_{12} = \frac{P}{\alpha} + F_{1N} = \frac{1}{6} + 0.42 = 0.59$
 $F_{13} = \frac{P}{\alpha} \Delta_1$
 $F_{14} = \frac{1}{6} \times 3.57 = 0.60$



VI. YÜKLEME NORMAL GERİLME DİYAGRAMI (G_x) $\bar{\sigma} = 1/2 - 1/67$

... I. ANA KIRIŞ



$$Q_1: \frac{4.38+2.92}{2} \times 2 \times 200 : 1460 \text{ Kğ.}$$

$$Q_2: \frac{3.65 \times 45.86}{2} \times 2 : 167.39 \text{ Kğ.}$$

$$Q_3: \frac{8.13 \times 102.13}{2} \times 2 : 830.32 \text{ Kğ.}$$

$$Q_4: \frac{7.36+8.90}{2} \times 2 \times 50 : 813 \text{ Kğ.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_{1c}: 1460 \times 45.97 + 167.39 \times 30.57 + 830.32 \times 68.09 + 813 \times 102.03 : 2.12 \text{ Tm.}$$

$$M_{1c}: F_{IM} \cdot \eta \quad 2.12: F_{IM} \cdot 5 \quad F_{IM}: 0.42 \text{ Ton.}$$

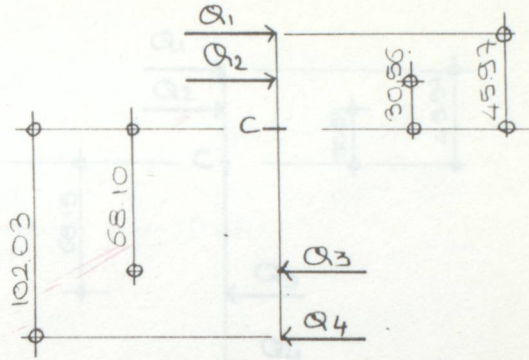
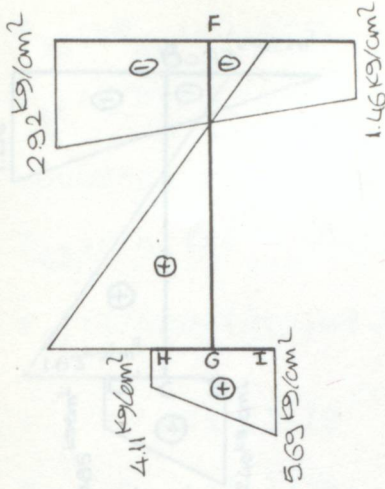
$$F_{I\bar{2}}: F/n + F_{IM}: 1/6 + 0.42: 0.59 \text{ ton.}$$

- Courbon yöntemine göre

$$F_{I\bar{2}}: F/n \cdot \Delta_1 \quad \Delta_1: 1 + 6 \frac{6+I-2xI}{36-I} \frac{6}{2} : 3.57$$

$$F_{I\bar{2}}: 1/6 \times 3.57: 0.60 \text{ Ton.}$$

... II. ANA KIRIŞ



$$Q_1: \frac{2.92+1.46}{2} \times 2 \times 200 : 876 \text{ Kğ.}$$

$$Q_2: \frac{2.19 \times 45.84}{2} \times 2 : 100.39 \text{ Kğ.}$$

$$Q_3: \frac{4.88 \times 102.15}{2} \times 2 : 498.49 \text{ Kğ.}$$

$$Q_4: \frac{4.11+5.69}{2} \times 2 \times 50 : 490 \text{ Kğ.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_{2c}: 876 \times 45.97 + 100.38 \times 30.56 + 498.46 \times 68.10 + 490 \times 102.03 : 1.27 \text{ Tm.}$$

$$M_{2c}: F_{2M} \cdot \eta \quad M_{2c}: F_{2M} \cdot 5 \quad F_{2M}: 0.26 \text{ Kğ.}$$

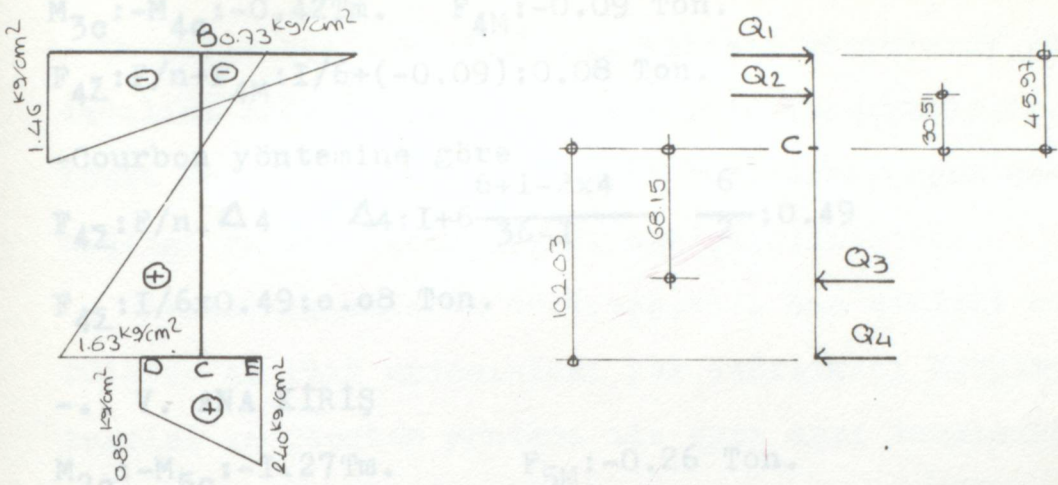
$$F_{2Z}: F/n + F_{2M}: 1/6 + 0.26 : 0.42 \text{ Ton.}$$

- Courbon yöntemine göre.

$$F_{2Z}: F/n \cdot \Delta 2 \quad \Delta 2: 1 + 6 \frac{6+1-2 \times 2}{36-1} \quad \frac{6}{2}: 2.54$$

$$F_{2Z}: 1/6 \times 2.54 : 0.42 \text{ Ton.}$$

... III. ANA KIRIŞ



$$Q_1: \frac{1.46 \times 200}{2} \times 2 : 292 \text{ Kğ.}$$

$$Q_2: \frac{0.73 \times 45.77}{2} \times 2 : 33.41 \text{ Kğ.}$$

$$Q_3: \frac{1.63 \times 102.23}{2} \times 2 : 166.64 \text{ Kğ.}$$

$$Q_4: \frac{0.85 + 2.40}{2} \times 2 \times 50 : 162.50 \text{ Kğ.}$$

Kesit ağırlık merkezine göre alınan moment (M_c):

$$M_{3c}: 292 \times 45.97 + 33.41 \times 30.51 + 166.64 \times 68.15 + 162.5 \times 102.03 : 0.42 \text{ Tm.}$$

$$M_{3c}: F_{3M} \cdot \Omega \quad 0.42 : F_{3M} \cdot 5 \quad F_{3M} : 0.09 \text{ Ton.}$$

$$F_{3\Sigma}: F/n + F_{3M} : 1/6 + 0.09 : 0.25 \text{ Ton.}$$

- Courbon yöntemine göre.

$$F_{3\Sigma}: F/n \cdot \Delta 3 \quad \Delta 3: 1 + 6 \frac{6 + 1 - 2 \times 3}{36 - 1} \frac{6}{2} : 1.51$$

$$F_{3\Sigma}: 1/6 \times 1.51 : 0.25 \text{ Ton.}$$

-... IV. ANA KİRİŞ

$$M_{3c}:-M_{4c}:-0.42\text{tm.} \quad F_{4M}:-0.09 \text{ Ton.}$$

$$F_{4Z}:F/n+F_{4M}:I/6+(-0.09):0.08 \text{ Ton.}$$

-Courbon yöntemine göre

$$F_{4Z}:F/n.\Delta 4 \quad \Delta 4:I+6\frac{6+I-2x4}{36-I} \frac{6}{2}:0.49$$

$$F_{4Z}:I/6x0.49:0.08 \text{ Ton.}$$

-... V. ANA KİRİŞ

$$M_{2c}:-M_{5c}:-I.27\text{tm.} \quad F_{5M}:-0.26 \text{ Ton.}$$

$$F_{5Z}:F/n+F_{5M}:I/6-0.26:-0.09 \text{ Ton.}$$

-Courbon yöntemine göre.

$$F_{5Z}:F/n.\Delta 5 \quad \Delta 5:I+6\frac{6+I-2x5}{36-I} \frac{6}{2}:-0.54$$

$$F_{5Z}:I/6x(-0.54):-0.09 \text{ Ton.}$$

-... VI. ANA KİRİŞ

$$M_{1c}:-M_{6c}:-2.12 \text{ tm.} \quad F_{6M}:-0.42 \text{ Ton.}$$

$$F_{6Z}:F/n+F_{6M}:I/6-0.42:-0.25 \text{ Ton.}$$

-Courbon yöntemine göre.

$$F_{6Z}:I/6x\Delta 6 \quad \Delta 6:I+6\frac{6+I-2x6}{36-I} \frac{6}{2}:I.57$$

$$F_{6Z}:I/6x(-I.57):0.26 \text{ ton.}$$

KIYASLAMA TABLOSU

4-. SONUÇ

Bu çalışmada tek açıklıklı kirişli köprülerde yük dağılımı sadece açıklık ortası için incelenmiştir. Köprü açıklığı (1:20 m.) sabit tutularak, köprü genişliği ve ana kiriş sayısı değiştirilmiştir.

Sayısal örneklerde dört, beş, altı ana kirişli köprülerde açıklık ortasındaki yük dağılımını burulma teorisi ve Courbon yöntemi ile ayrı ayrı incelenmiştir. Bu iki yöntemle bulunan sonuçlar arkadaki sayfada kıyaslama tablosu olarak verilmiştir. Bu tablo incelendiğinde iki yöntemle bulunan sonuçlar virgülden sonra iki rakam alınarak çalışıldığında bir birine son derece yakın çıktığı görülmüştür.

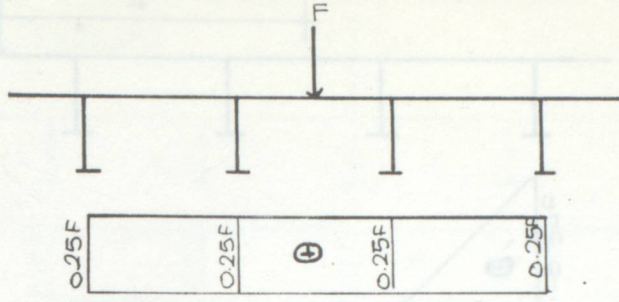
Tek açıklıklı köprülerde yük dağılımını burulma teorisi ile bulmak uzun bir yöntemdir. Aynı iş Courbon yöntemi ile daha kısa ve basittir. Zamanın ve işlemin kısalığı bakımından tek açıklıklı köprülerde yük dağılımını Courbon yöntemi ile bulmak daha avantajlıdır.

4 ANA KİRİŞLİ KÖPRÜDE BURULMA MOMENTİNİN GÖRE YÜK DAĞILIMI
KIYASLAMA TABLOSU

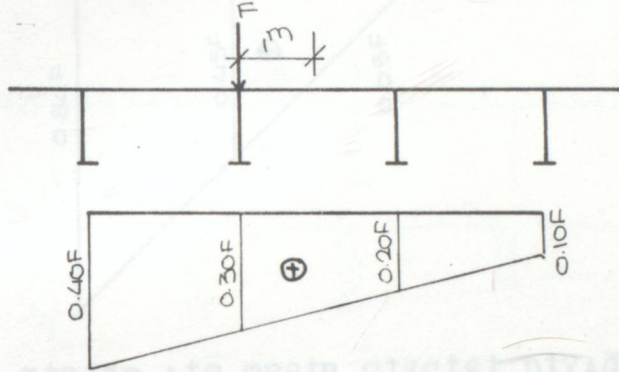
		4 ANA KİRİŞLİ KÖPRÜ		5 ANA KİRİŞLİ KÖPRÜ		6 ANA KİRİŞLİ KÖPRÜ	
		Burulma	Courbon	Burulma	Courbon	Burulma	Courbon
I. YÜKLEME	I	0.40	0.40	0.30	0.30	0.24	0.24
	2	0.30	0.30	0.25	0.25	0.21	0.21
	3	0.20	0.20	0.20	0.20	0.18	0.18
	4	0.10	0.10	0.15	0.15	0.15	0.15
	5	— —	— —	0.10	0.10	0.12	0.12
	6	— —	— —	— —	— —	0.10	0.10
II. YÜKLEME	I	0.54	0.55	0.40	0.40	0.31	0.31
	2	0.35	0.35	0.30	0.30	0.25	0.25
	3	0.15	0.15	0.20	0.20	0.20	0.20
	4	-0.04	-0.05	0.10	0.10	0.14	0.14
	5	— —	— —	-0.00	0.00	0.08	0.08
	6	— —	— —	— —	— —	0.03	0.03
III. YÜKLEME	I	0.69	0.70	0.50	0.50	0.38	0.38
	2	0.40	0.40	0.35	0.35	0.29	0.30
	3	0.10	0.10	0.20	0.20	0.21	0.21
	4	-0.19	-0.20	0.05	0.05	0.12	0.12
	5	— —	— —	-0.10	-0.10	0.04	0.04
	6	— —	— —	— —	— —	-0.05	-0.05
IV. YÜKLEME	I	0.84	0.85	0.59	0.60	0.45	0.45
	2	0.45	0.45	0.40	0.40	0.34	0.34
	3	0.05	0.05	0.20	0.20	0.22	0.22
	4	-0.34	-0.35	0.00	0.00	0.11	0.11
	5	— —	— —	-0.19	-0.20	-0.03	-0.04
	6	— —	— —	— —	— —	-0.12	-0.12
V. YÜKLEME	I	— —	— —	0.69	0.70	0.52	0.52
	2	— —	— —	0.45	0.45	0.38	0.38
	3	— —	— —	0.20	0.20	0.23	0.24
	4	— —	— —	-0.05	-0.05	0.10	0.10
	5	— —	— —	-0.29	-0.30	-0.05	-0.05
	6	— —	— —	— —	— —	-0.19	-0.19
VI. YÜKLEME	I	— —	— —	— —	— —	0.59	0.60
	2	— —	— —	— —	— —	0.42	0.42
	3	— —	— —	— —	— —	0.25	0.25
	4	— —	— —	— —	— —	0.08	0.08
	5	— —	— —	— —	— —	-0.09	-0.09
	6	— —	— —	— —	— —	-0.25	-0.26

4 ANA KIRIŞLI KÖPRÜDE BURULMA TEORİSİNE GÖRE YÜK DAĞILIMI

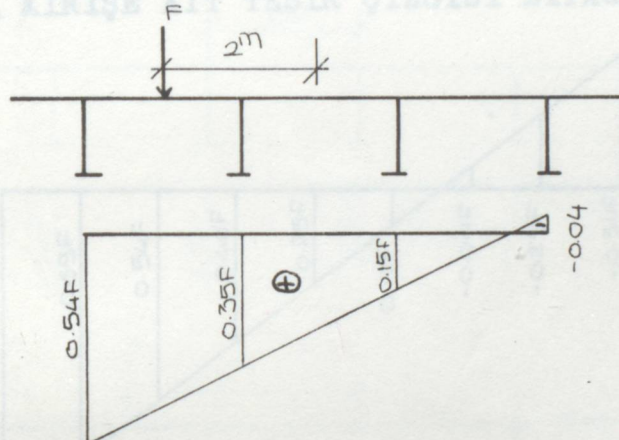
1



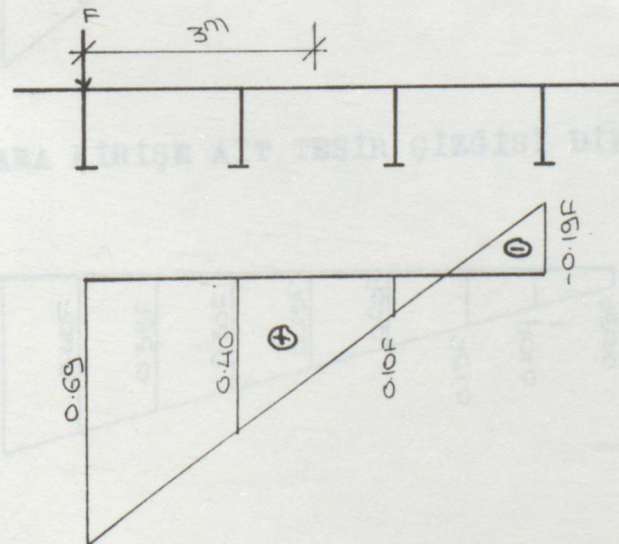
2



3

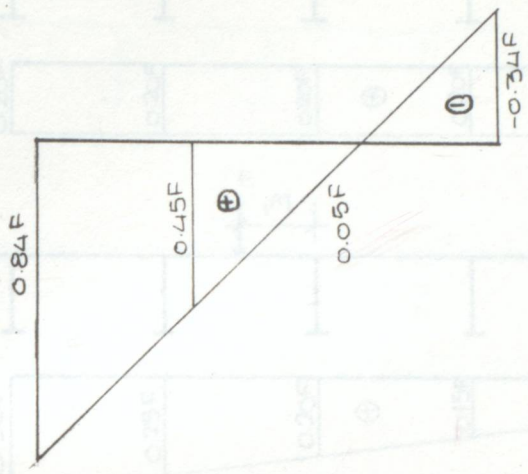
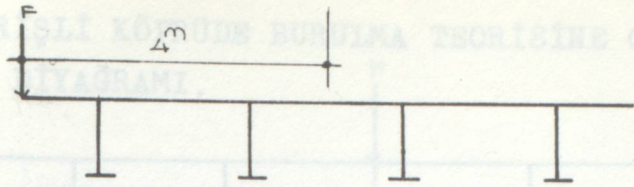


4

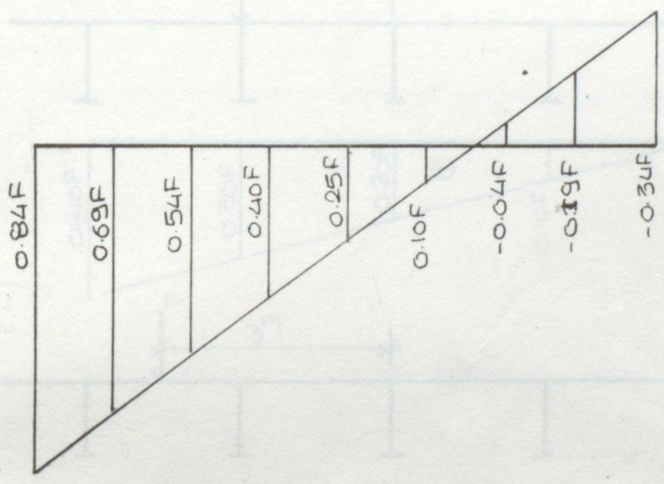


5. ANA KIRIŞLI KÖRÜDE BULUNAN TEORİKİNE GÖRE YÜK
DİĞERİ DİYAGRAMI.

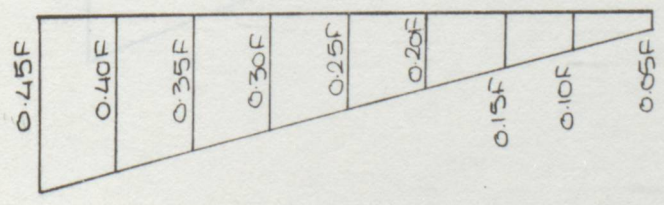
5



I. ANA KIRIŞE AIT TESİR ÇİZGİSİ DİYAGRAMI

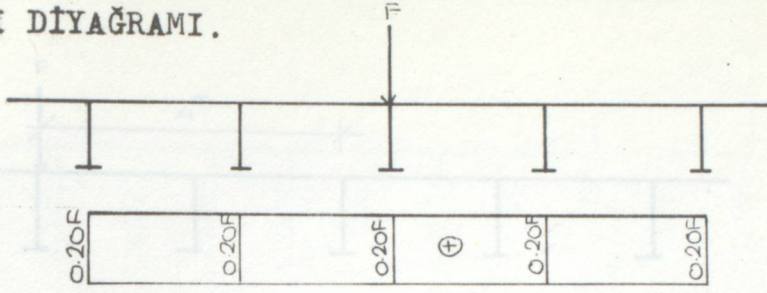


II. ANA KIRIŞE AIT TESİR ÇİZGİSİ DİYAGRAMI.

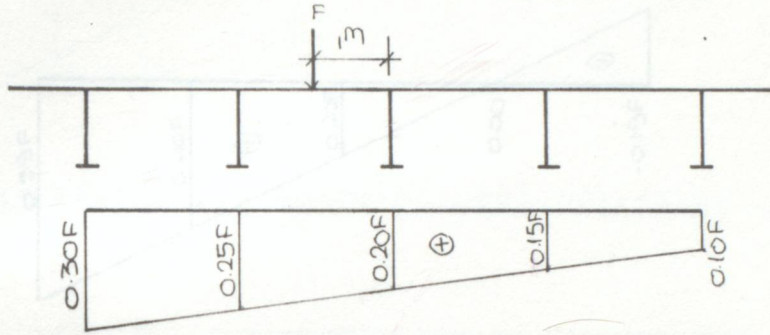


5. ANA KIRIŞLI KÖPRÜDE BURULMA TEORİSİNE GÖRE YÜK DAĞILIMI DİYAĞRAMI.

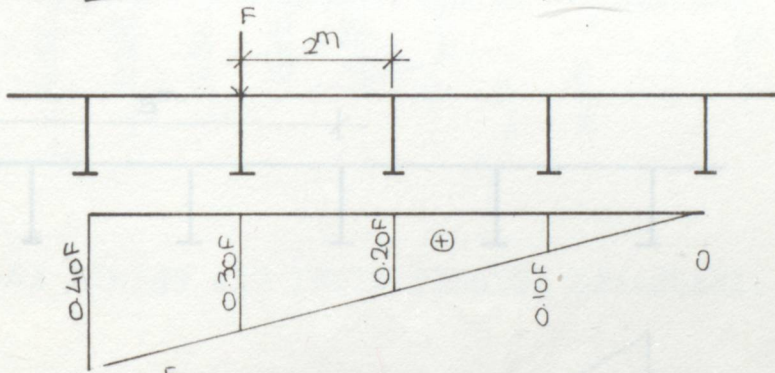
①



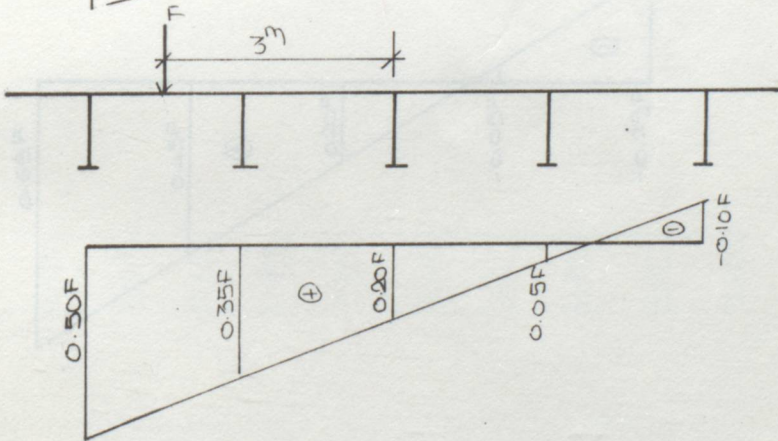
②



③

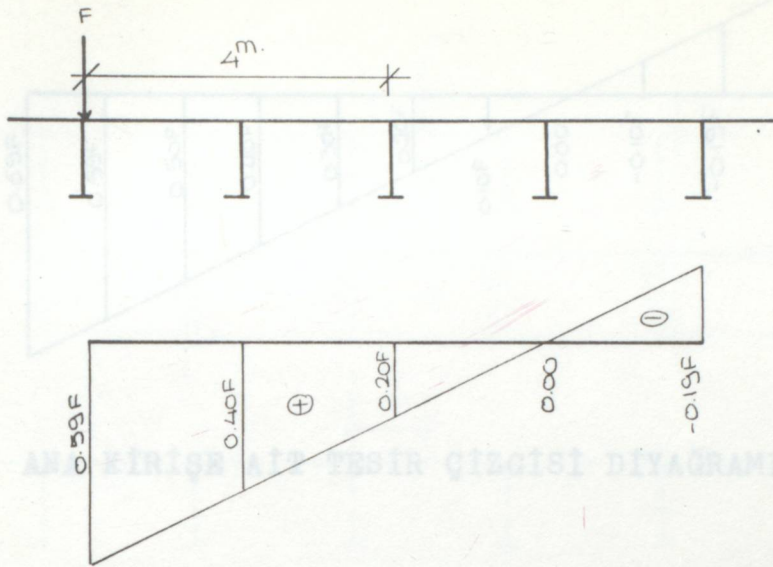


④



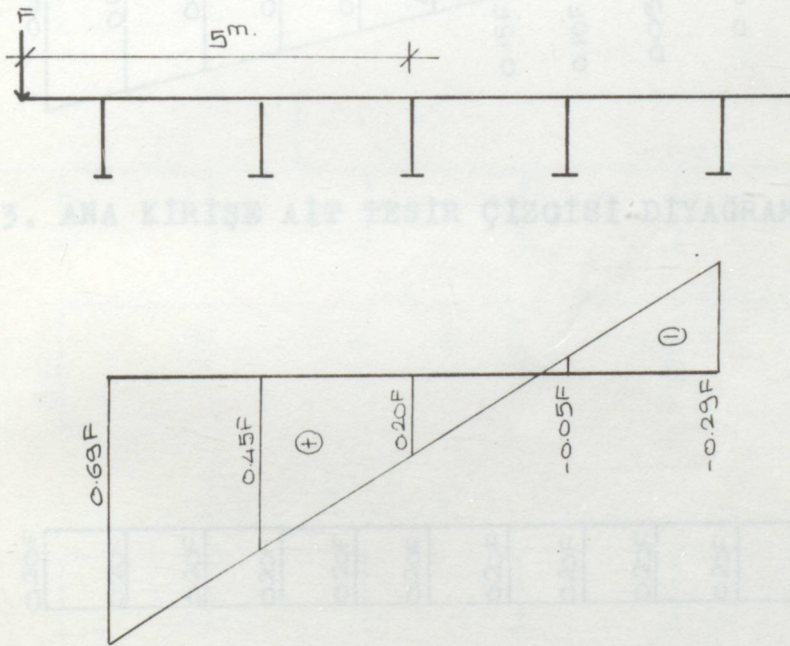
1. ANA KIRIŞA AIT TESİR ÇİZGİSİ DİYAGRAMI.

5



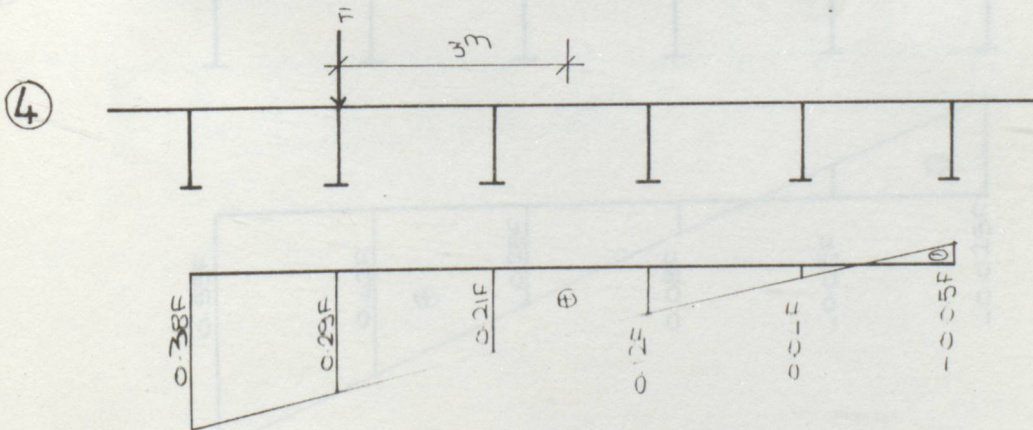
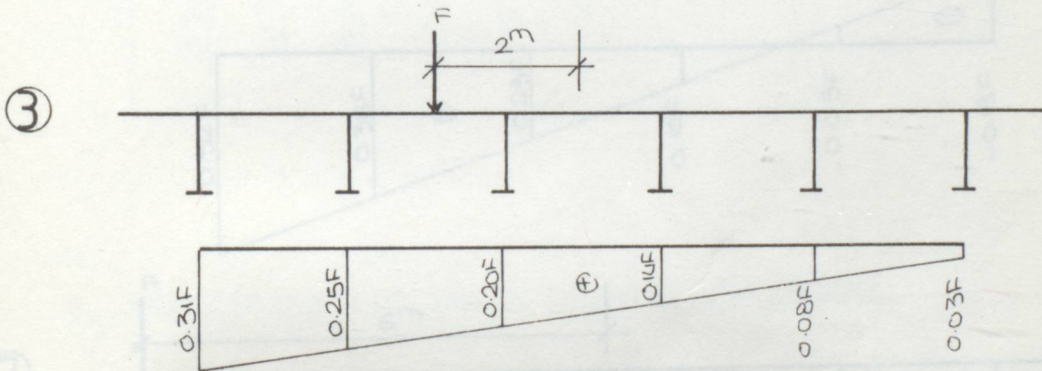
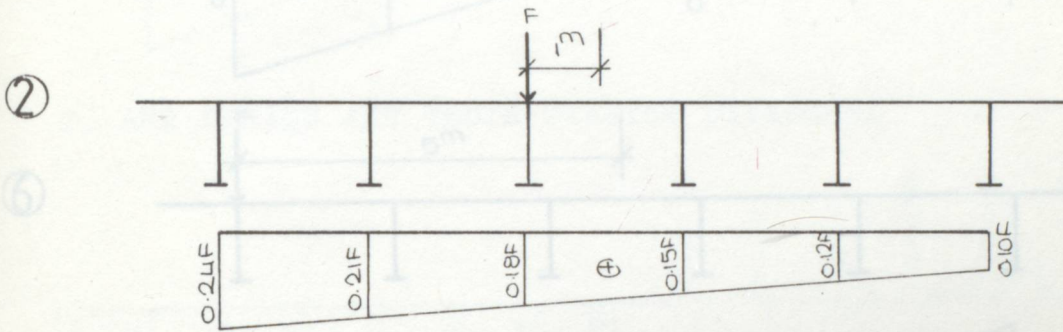
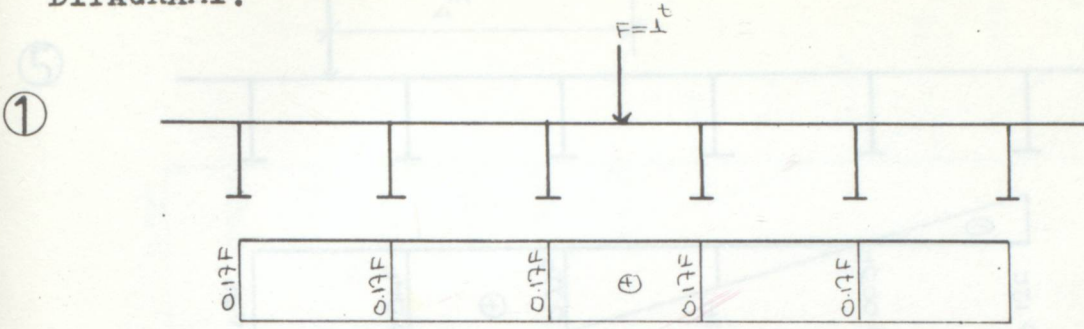
2. ANA KIRIŞA AIT TESİR ÇİZGİSİ DİYAGRAMI

6



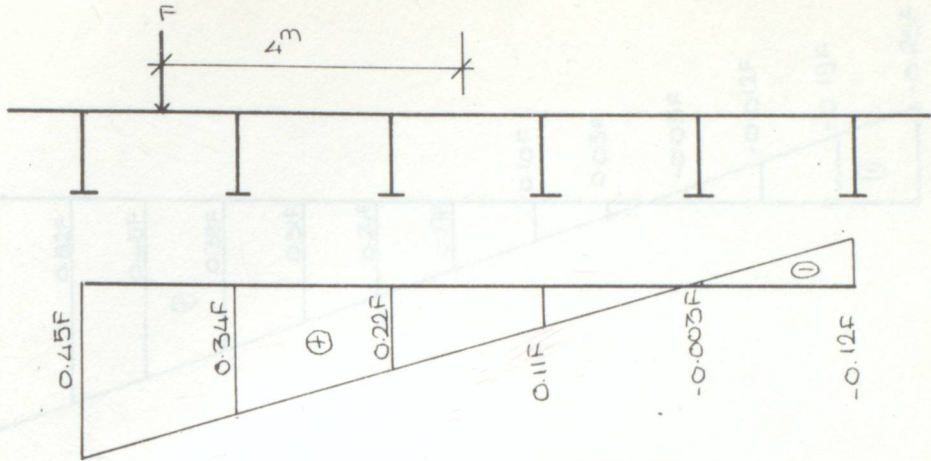
3. ANA KIRIŞA AIT TESİR ÇİZGİSİ DİYAGRAMI.

6 ANA KIRIŞLI KÖPRÜDE BURULMA TEORİSİNE GÖRE YÜK DAĞILIMI DİYAĞRAMI.

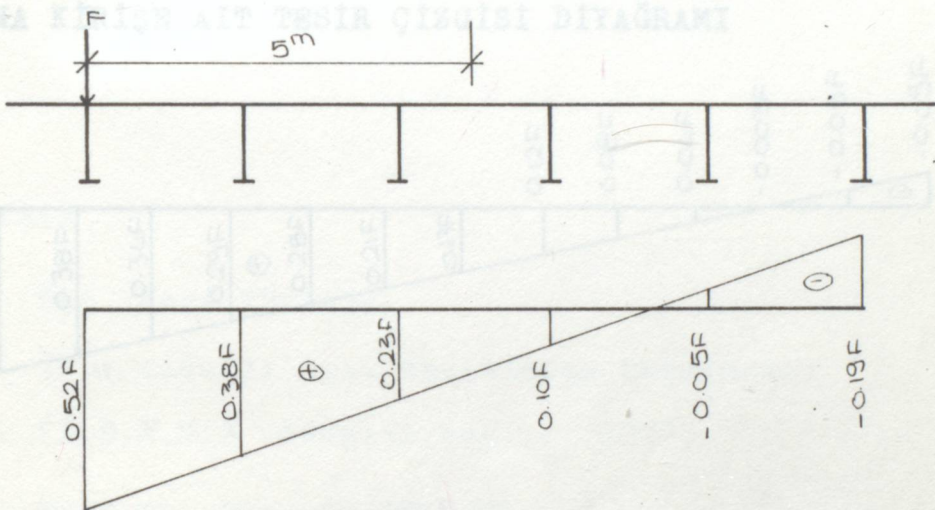


1. ANA KIRIŞE AİT TESİR ÇİZGİSİ DİYAGRAMI.

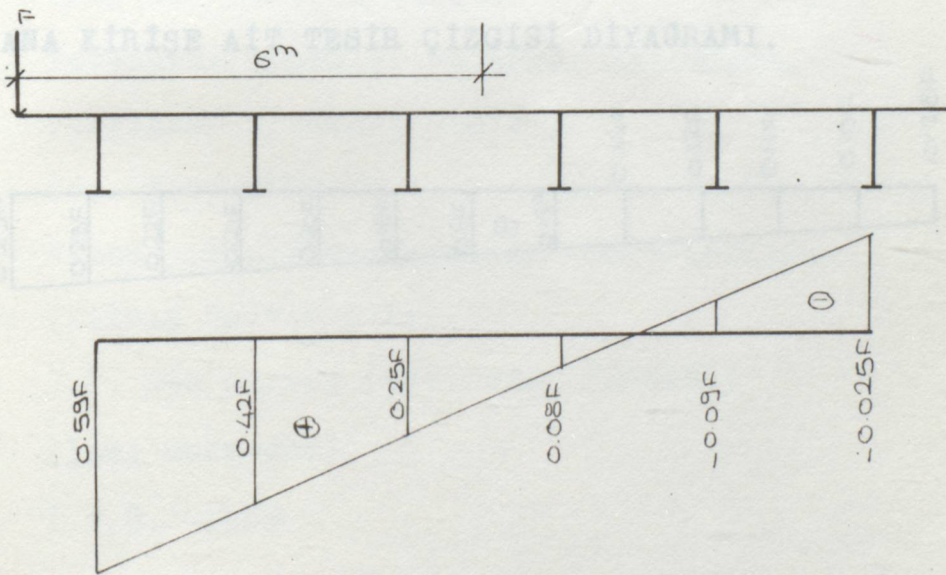
5



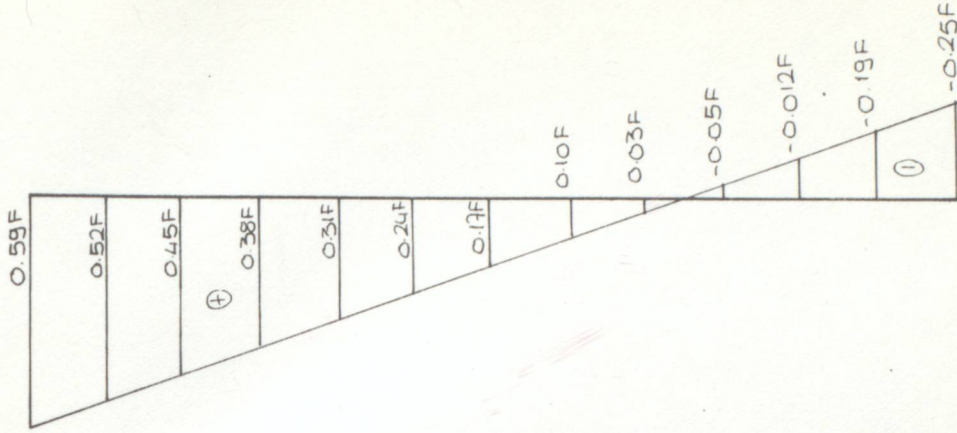
6



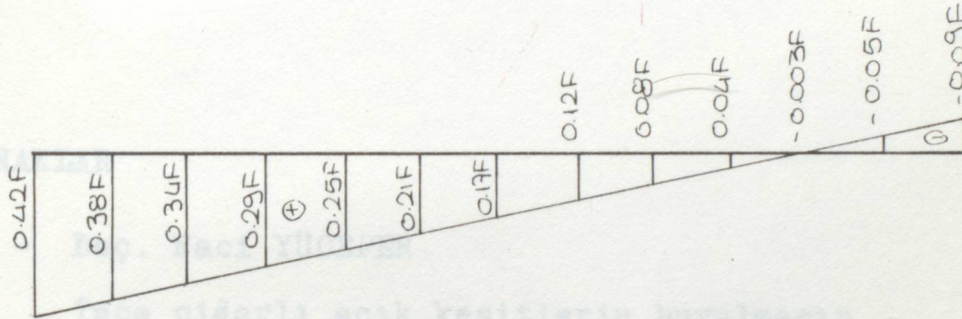
7



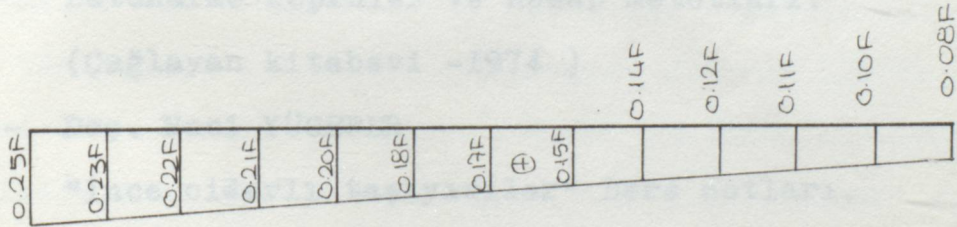
I. ANA KIRIŞE AIT TESİR ÇİZGİSİ DİYAĞRAMI.



2. ANA KIRIŞE AIT TESİR ÇİZGİSİ DİYAĞRAMI



3. ANA KIRIŞE AIT TESİR ÇİZGİSİ DİYAĞRAMI.



KAYNAKLAR

- (1) - Doç. Naci YÜCEFER
İnce cidarlı açık kesitlerin burulması
(İ.D.M.M.A dergisi sayı:1 1977)
- (2) - Prof.Dr. Hüseyin CELASUN
Betonarme köprüler ve hesap metotları.
(Çağlayan kitabevi -1974)
- (3) - Doç. Naci YÜCEFER
"İnce cidarlı taşıyıcılar" Ders notları.
(Yıldız Üniversitesi)
- (4) - J.P. Den Hartog (Çev:Oktay İZMİRLİ)
İleri mukavemet.
İ.T.Ü. -1969

ÖZGEÇMİŞ

Hasan PARLAR, 1959 yılında Malatya 'da doğdu. İlk öğrenimini Bahariye ilk okulunda, Orta öğrenimini Kadıköy orta okulunda ve Haydarpaşa Lisesinde yaptı. Ekim 1979 da Yıldız Üniversitesi Mühendislik Fakültesi İnşaat bölümüne girerek 1983 yılında aynı fakülteden İnşaat Mühendisi olarak mezun oldu.

