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**ÇOK AÇIKLIKLI KÖPRÜ KİRİŞLERİNDE
MESNET OTURMALARININ EĞİLME
MOMENTLERİNE ETKİSİ**

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TEŐEKKÜR

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ÖZET

Çok açıklıklı köprü kirişlerinde mesnet oturmalarının eğilme momentlerine etkisinin araştırılması konulu bu tezde esas olarak 3 açıklıklı bir köprü kirişi dikkate alınmıştır.

Giriş bölümünde hiperstatik sistemlerin çözümünde kullanılan kuvvet metodu ve tezin ileri konularında faydalanılan redüksiyon teoremi ve courbon yönteminden bahsedilmiştir.

İkinci bölümde öncelikle her bir mesnedin ayrı ayrı ΔA , ΔB , ΔC , ΔD deplasmanı yapmaları halinde kesit tesirleri hesaplanmıştır. Daha sonra aynı köprü kirişi üzerinde muhtelif yükleme halleri için (g sabit yük hali, 1.açıklık ortasında F tekil yük hali, 2.açıklık ortasında F tekil yük hali, 3.açıklık ortasında F tekil yük hali, 1.açıklıkta q yayılı yük hali, 2.açıklıkta q yayılı yük hali, 3.açıklıkta q yayılı yük hali) kesit tesirleri hesaplanmıştır. Redüksiyon teoremi kullanılarak A,B,C,D kesitlerindeki maksimum yer değiştirmeler yani mesnetlerin özelliğini kaybettiği sınır değerler yukarıdaki muhtelif yükleme halleri için hesaplanmıştır. Ardından aynı yükleme halleri için B ve C mesnet eğilme momentlerinin A ve B mesnetlerindeki maksimum mesnet hareketlerine bağlı değişimleri ayrı ayrı incelenmiş ve aralarındaki bağıntı bulunmuştur. Köprü enkesit özellikleri, giriş atalet momenti ve elverişsiz şerit sayısı hesaplanıp son olarak kenar ana kirişin B,5,15 kesitlerinde eğilme momentleri, bu moment değerlerini maksimum yapan yüklemeler için ayrı ayrı hesaplanmıştır. Bu yükleme halleri için ΔA , ΔB , ΔC , ΔD deplasmanları durumlarında $\Delta A_{MAX\Sigma} = \Delta A_{MAXg}, \Delta A_{MAXq1}, \Delta A_{MAXq2}, \Delta A_{MAXF1}, \Delta A_{MAXF2}$ ve benzer şekilde $\Delta B_{MAX\Sigma}, \Delta C_{MAX\Sigma}, \Delta D_{MAX\Sigma}$ ve $M_{MAX\Sigma}$ değerleri bulunur. Bulunan değerler tablo değerleri ile desteklenmiş ve kontrol edilmiştir.

Betonarme karayolu köprülerinin boyutlandırılmasında aşağıda gösterilen yük ve etkilerden varolanlar dikkate alınmalı her yük veya etki altında bulunacak tesirler ayrı ayrı hesaba katılmalıdır. Genel olarak yükler, A grubu yükler (zati yük, hareketli yükler, boyuna kuvvetler, mesnet şartlarındaki değişme, merkezkaç kuvveti, rüzgar yükü, ısı tesiri, kar yükü, rötre, sünme, zemin itkisi, suyun kaldırma kuvveti, su akıntısının etkisi, buz itkisi, atalet etkisi, öngerilme etkisi) ve B grubu yükler (yapım safhalarından ötürü etkiler, deprem etkisi, çarpma) olarak 2 çeşittir. Mesnet şartlarındaki değişme temel zeminindeki hareketten ötürü mesnetlerde meydana gelebilecek öteleme ve dönmeler, beklenen büyüklükleri ile gözönüne alınmalıdır. Ancak, yapı rijit mesnetlendirilmiş olduğu (kaya üzerine) veya mesnet şartlarındaki değişiklikler az ise bu tetkik yapılmayabilir

Bu inceleme sonucunda 5,15,B kesitlerinde ΔA , ΔB , ΔC , ΔD deplasmanlarının her bir cm.'si için aynı kesitteki eğilme momentlerinin ulaştığı değerler tablo olarak verilmiştir. ΔA_{max} , ΔB_{max} , ΔC_{max} , ΔD_{max} değerlerine karşılık gelen moment değerleri belirlenmiştir.

ABSTRACT

Effect of support settlements on bending moments of bridge beams with many spans has been studied in this thesis and basically bridge beams having three spans are analyzed.

In the introductory part, the energy method which is used for the solution of hyperstatic systems, and in the following parts the reduction theorem and courbon method are both utilized.

In the second chapter of this study, for a certain displacements ΔA , ΔB , ΔC and ΔD of each support, hyperstatic system has been evaluated and moment values have been determined at the critical cross-sections. The same bridge beam has also been solved for various loading conditions and bending moments have been calculated. By using the reduction theorem, maximum displacements of cross-sections A, B, C, D have been evaluated for various loading cases as explained above. Also for the same loading case, variation of support moments at B and C due to maximum deflection at the supports A and B, are studied. Cross-sectional features of the bridge, inertia moment of the beam are determined. Finally, at the cross-sections B, 5, 15 of side main beams, bending moments are calculated for the loading conditions in which these moment values reach maximum. For these loading cases and displacements ΔA , ΔB , ΔC , ΔD are $\Delta A_{\max\Sigma} = \Delta A_{\max g} + \Delta A_{\max q1} + \Delta A_{\max q2} + \Delta A_{\max F1} + \Delta A_{\max F2}$ and similarly $\Delta B_{\max\Sigma}$, $\Delta C_{\max\Sigma}$, $\Delta D_{\max\Sigma}$ and $M_{\max\Sigma}$ values are determined. These values are checked from the tables.

When calculating the dimensions of reinforced concrete highway bridges, loads and effects which the bridge is suffering are shown below and subsequent calculations should be made for each loading case. The loads can be grouped into two categories. The first category covers the dead load, live load, variation in support conditions, wind load, centrifugal forces, effect of temperature, creep and shrinkage, etc. The second category are the loading conditions during construction, earthquake loads. Variation in the support conditions, displacements and rotations of supports because of base ground motion should be considered. However, if the structure rigidly supported on a rocky ground, then this method may not be utilized.

At the end of this study bending moment values at the cross-sections B, 5, 15 of side main beams for 1 cm. displacement for ΔA , ΔB , ΔC , ΔD are presented in tables.

1. GİRİŞ

1.1. HİPERSTATİK SİSTEMLERİN ÇÖZÜMÜNDE KUVVET METODU

Hiperstatiklik derecesi n olan bir sistemde denge denklemleri ile hesaplanamayan kuvvetlerin sayısı n tanedir. O halde n . dereceden hiperstatik bir sistemin çözümü için n tane daha denkleme ihtiyaç vardır. Sistem uygun yerlerine mafsallar koyularak ve bunlara ait süreklilik şartları yazılarak izostatik hale getirilir. Mafsal koyulan kesitler, hakiki sisteme nazaran süreklilik şartları bozulduğundan mafsalların iki tarafındaki dış yüklerin etkisiyle dönebilmektedir. Bozulan süreklilik şartlarını sağlamak için bu mafsallara kuvvet çifti etkidiği düşünülür.

1.1.1. İzostatik esas sistem ve hiperstatik bilinmeyenler

Hiperstatik sistem uygun yerlerine mafsallar takarak veya mesnet bağlarından bazılarını kaldırarak izostatik hale getirilir. Bu sisteme kuvvet metodunda izostatik esas sistem denir. Hiperstatik sistemi izostatik hale getirmek için kaldırılan iç kuvvetler veya mesnet reaksiyonlarına hiperstatik bilinmeyenler denir.

1.1.2. Sıfır yükleme ve yükleme terimleri

İzostatik esas sistemin bütün hiperstatik bilinmeyenlerini sıfır kabul ederek sistemin sadece dış tesirlerle (dış yük, mesnet hareketi, sıcaklık farkı) yüklenmesine sıfır yükleme denir. Hiperstatik bilinmeyenlerin tatbik noktaları ve doğrultularında meydana gelen yer değiştirmeler ise yük terimi olarak adlandırılırlar.

yükleme	kesit tesirleri	yük terimleri
dış yükler	M_0, N_0, Q_0	δ_{i0}

δ_{i0} : X_i 'nin tatbik noktası ve doğrultusundaki dış yüklerin sebep olduğu yer değiştirme

1.1.3. Birim yüklemeler ve sistem terimleri

Hiperstatik bilinmeyenlere birim değerler verilerek izostatik esas sistemin bunlarla teker teker yüklenmesine birim yükleme denir. Kaç tane hiperstatik bilinmeyen varsa o kadar birim yükleme yapılır. Birim yüklemelerden dolayı hiperstatik bilinmeyenlerin tatbik noktası ve doğrultusundaki yer değiştirmeler sistem terimi olarak adlandırılırlar.

yükleme	kesit tesirleri	yük terimleri
$X_k = 1$	M_k, N_k, Q_k	δ_{ik}

δ_{ik} : X_i 'nin tatbik noktası ve doğrultusunda $X_k = 1$ birim yüklemesinden meydana gelen yer değiştirme

1.1.4. Süreklilik ve süperpozisyon denklemleri

İzostatik esas sistemde bozulan süreklilik şartlarının gerçekleşebilmesi için X_1, X_2, \dots, X_n hiperstatik bilinmeyenleri öyle değerler olmalıdır ki $\delta = 0, \delta_2 = 0, \dots, \delta_i = 0, \dots, \delta_n = 0$ olmalıdır. δ_1, δ_2 sırasıyla X_1, X_2 'nin tatbik noktası ve doğrultusundaki deformasyonları ifade eder.

İzostatik esas sistemde X_i 'nin tatbik noktası ve doğrultusunda meydana gelen yer değiştirmeler: Dış yüklerden dolayı (δ_{i0}), $X_k = 1$ birim yüklemesinden dolayı (δ_{ik}), X_k yüklemesinden dolayı ($\delta_{ik} \cdot X_k$) şeklinde ifade edilebilir.

Toplam yer değiştirme $\delta_i = \delta_{i0} + \sum \delta_{ik} \cdot X_k$ bağıntısıyla bulunur. Süreklilik şartına göre $\delta_i = \delta_{i0} + \sum \delta_{ik} \cdot X_k = 0$ olmalıdır. O halde n. dereceden hiperstatik bir sistem için n adet süreklilik denklemleri yazılır. Aşağıdaki süreklilik denklemleri çözülerek $X_1, X_2, \dots, X_i, \dots, X_n$ hiperstatik bilinmeyenleri bulunur.

$$\begin{aligned}
 \delta_{10} + \delta_{11} \cdot X_1 + \delta_{12} \cdot X_2 + \dots + \delta_{1n} \cdot X_n &= \delta_1 = 0 \\
 \delta_{20} + \delta_{21} \cdot X_1 + \delta_{22} \cdot X_2 + \dots + \delta_{2n} \cdot X_n &= \delta_2 = 0 \\
 \dots & \\
 \delta_{i0} + \delta_{i1} \cdot X_1 + \delta_{i2} \cdot X_2 + \dots + \delta_{in} \cdot X_n &= \delta_i = 0 \\
 \dots & \\
 \delta_{n0} + \delta_{n1} \cdot X_1 + \delta_{n2} \cdot X_2 + \dots + \delta_{nn} \cdot X_n &= \delta_n = 0
 \end{aligned} \tag{1.1}$$

Hiperstatik sistemin kesit tesirleri sıfır yüklemesi ve birim yüklemelerden elde edilen kesit tesirlerinin süperpozisyonu ile bulunur.

Dış yüklerden doğan kesit tesirleri $S_0(M_0, N_0, Q_0)$

$X_k = 1$ yüklemesinden doğan kesit tesirleri $S_k(M_k, N_k, Q_k)$

X_k yüklemesinden doğan kesit tesirleri $S_k \cdot X_k$

Herhangi bir kesitteki kesit tesirleri $S = S_0 + \sum_{k=1}^n S_k \cdot X_k$ bağıntısıyla bulunur.

Süperpozisyon denklemleri aşağıda verilmiştir.

$$M = M_0 + M_1 \cdot X_1 + M_2 \cdot X_2 + \dots + M_n \cdot X_n \quad (\text{kNm})$$

$$N = N_0 + N_1 \cdot X_1 + N_2 \cdot X_2 + \dots + N_n \cdot X_n \quad (\text{kN})$$

$$Q = Q_0 + Q_1 \cdot X_1 + Q_2 \cdot X_2 + \dots + Q_n \cdot X_n \quad (\text{kN}) \quad (1.2.)$$

1.1.5. Sistem terimleri (δ_{ik}) hesabı

δ_{ik} , izostatik esas sistemin i kesitinde $X_k = 1$ yüklemesinden dolayı X_i hiperstatik bilinmeyeninin tatbik noktası ve doğrultusundaki yer deęiřtirmedir. Bu yer deęiřtirmenin virtüel iş denklemleri ile hesaplanabilmesi için $X_i = 1$ yüklemesi yapılır.

$$\delta_{ik} = \int M_i \cdot M_k \cdot \frac{dx}{EI} + \int N_i \cdot N_k \cdot \frac{dx}{EA} + \int Q_i \cdot Q_k \cdot \frac{dx}{GA} + \sum M_{Li} \cdot \frac{M_{Lk}}{C_{LM}} + \sum N_{Li} \cdot \frac{N_{Lk}}{C_{LN}} \quad (1.3.)$$

M_{Li}, N_{Li} : L mesnedinde $X_i = 1$ yüklemesinden meydana gelen reaksiyon kuvveti (kNm, kN)

M_{Lk}, N_{Lk} : L mesnedinde $X_k = 1$ yüklemesinden meydana gelen reaksiyon kuvveti

C_{LM}, C_{LN} : L mesnedinde moment ve normal kuvvet yay katsayıları

1.1.6. Yük terimi (δ_{i0}) hesabı

1.1.6.1. Sabit dış yük

δ_{i0} , izostatik esas sistemin i kesitinde sıfır yüklemesinden dolayı X_i hiperstatik bilinmeyeninin tatbik noktası ve doğrultusundaki yer deęiřtirmedir.

$$\delta_{i0} = \int M_i \cdot M_0 \cdot \frac{dx}{EI} + \int N_i \cdot N_0 \cdot \frac{dx}{EA} + \int Q_i \cdot Q_0 \cdot \frac{dx}{GA} + \sum M_{Li} \cdot \frac{M_{L0}}{C_{LM}} + \sum N_{Li} \cdot \frac{N_{L0}}{C_{LN}} \quad (1.4.)$$

Şekil deęiřtirme etkileri az ise bu denklemlerdeki normal kuvvet ve kesme kuvveti terimleri ihmal edilebilirler.

1.1.6.2. Sıcaklık farkı

δ_{it} , izostatik esas sistemin i kesitinde, sıcaklık farkından dolayı X_i hiperstatik bilinmeyeninin tatbik noktası ve doğrultusundaki yer deęiřtirmedir.

$$\delta_{i0} = \delta_{it}$$

İç kuvvetler olmayacağından $M_0 = N_0 = Q_0 = 0$

$$\text{Üniform sıcaklık hali } \delta_{it} = \int \alpha_t \cdot N_i \cdot t^0 \cdot dx \quad (1.5.)$$

$$\text{Üniform olmayan sıcaklık hali } \delta_{it} = \int \alpha_t \cdot \frac{M_i \cdot \Delta t^0}{h} \cdot dx \quad (1.6.)$$

α_t : sıcaklıkla ilgili bir katsayı ($\frac{1}{^{\circ}C}$)

1.1.6.3. Mesnet hareketleri

δ_{iw} , izostatik esas sistemin i kesitinde, mesnet hareketlerinden dolayı X_i hiperstatik bilinmeyeninin tatbik noktası ve doğrultusundaki yer deęiřtirmedir.

$$\delta_{i0} = \delta_{iw}$$

$$\delta_{iw} = -\sum (M_{Li} \cdot \Delta \varphi_L + V_{Li} \cdot \Delta W_L + H_{Li} \cdot \Delta U_L) \quad (1.7.)$$

M_{Li}, V_{Li}, H_{Li} : L elastik mesnedinde $X_i = 1$ yüklemesinden meydana gelen mesnet reaksiyonları (kNm, kN, kN)

$\Delta \varphi_L, \Delta W_L, \Delta U_L$: L elastik mesnedindeki mesnet deplasmanları (m)

1.2. Courbon yöntemi

Bu yöntem köprü boyu eninin 2 katından fazlaysa uygun sonuçlar verir. Yöntemde ana kiriřlerin ve enleme kiriřlerin burulma rijitlikleri dikkate alınmamıştır. Ana kiriřler sonsuz rijit kabul edilmiştir. Böylelikle deformatsiyondan sonra da doğrusal kalmaktadırlar. Ana kiriřler enleme kiriřler için yaylı mesnet olarak kabul edilmişlerdir. Böylelikle ana kiriřlere gelen yükler yaylı mesnet reaksiyonları olarak elde edilmektedir. Öncelikle enleme kiriř üzerindeki bir tekil yük için elde edilecek olan yöntem enleme kiriř dışındaki yükler için de doğru kabul edilecektir. Ancak köprü mesnetlerindeki enlemeler için courbon yöntemi

geçersizdir. Zira bu enlemeler köprü mesnetleri üzerinde olduğundan mesnet deplasmanları oluşmaz.

$$F_i = F \cdot \frac{J_i}{\sum J_i} \cdot \Delta_i$$

$$\Delta_i = \left[1 + \frac{\sum J_i}{\sum J_i \cdot \rho_i^2} \cdot e \cdot \rho_i \right]$$

$$F_i = F \cdot \frac{J_i}{\sum J_i} \cdot \left[1 + \frac{\sum J_i}{\sum J_i \cdot \rho_i^2} \cdot e \cdot \rho_i \right] \quad (1.8.)$$

Courbon yöntemi atalet momentleri birbirine eşit ve eşit aralıklı ana kirişler için aşağıdaki şekli alır.

$$\Delta_i = 1 + 6 \cdot \frac{n+1-2i}{n^2-1} \cdot \frac{e}{\lambda}$$

$$F_i = F \cdot \frac{J_i}{\sum J_i} \cdot \Delta_i$$

$$F_i = F \cdot \frac{1}{n} \cdot \left[1 + 6 \cdot \frac{n+1-2i}{n^2-1} \cdot \frac{e}{\lambda} \right] \quad (1.9.)$$

F_i : i. kirişe gelen yük (kN)

F : köprü üzerine etkiyen yük (kN)

Δ_i : i. kirişin yük eksantriklik katsayısı

J_i : i. kirişin atalet momenti (m^4)

e : yükün etki ettiği noktanın köprü simetri eksenine olan uzaklığı (m)

ρ_i : i. kirişin köprü simetri eksenine olan uzaklığı (m)

n : ana kiriş sayısı

i : incelenen kirişin numarası

λ : köprü kirişleri arası uzaklık (m)

1.3. Redüksiyon teoremi

Hiperstatik sistemlerde sistemin herhangi bir noktasındaki yer deęiřtirmenin hesabı için virtüel iř denklemini kullanılabilir. Hiperstatik sisteme ait sonuç moment diyagramı ile yer deęiřtirmesinin hesabı istenen noktaya virtüel yükleme yapılması sonucu oluşan moment diyagramının çarpılması suretiyle istenen noktalardaki yer deęiřtirmeler bulunur. Redüksiyon teoremine göre dıř yükler veya virtüel yüklemeler izostatik esas sisteme yapılabilir.

$$\delta_{AF} = \int M_{DISYÜK}^1 \cdot M_1^0 \cdot \frac{dx}{EI} \quad (1.10)$$

δ_{AF} : Hiperstatik sistemin A kesitinde F dıř yükü etkisinde oluşan yer deęiřtirme

$M_{DISYÜK}^1$: Hiperstatik sistemde dıř yük etkisinde oluşan sonuç eğilme momenti diyagramı

M_1^0 : İzostatik esas sistemde virtüel yükleme sonucu oluşan eğilme momenti diyagramı

$$\delta_{AF} = \int M_{DISYÜK}^1 \cdot M_1^0 \cdot \frac{dx}{EI} = \int M_{DISYÜK}^0 \cdot M_1^1 \cdot \frac{dx}{EI}$$

Yukarıdaki teoremin tersi de doğrudur, izostatik esas sistemin dıř yük ile yüklenmesiyle oluşan eğilme momenti diyagramıyla hiperstatik sistemde virtüel yükleme yapılmasıyla elde edilen sonuç moment diyagramının çarpılması da adı geçen kesitteki yer deęiřtirmeyi verir.

$M_{DISYÜK}^0$: İzostatik esas sistemde dıř yük etkisinde oluşan eğilme momenti diyagramı

M_1^1 : Hiperstatik sistemde virtüel yükleme sonucu oluşan eğilme momenti diyagramı

2. ÇOK AÇIKLIKLI KÖPRÜ KİRİŞLERİNDE MESNET OTURMALARININ EĞİLME MOMENTLERİNE ETKİSİNİN ARAŞTIRILMASI

2.1. Üç açıklıklı köprü kirişlerinde mesnetlerin deplasmanları halinde eğilme momentleri

2.1.1. Üç açıklıklı köprü kirişlerinde A mesnet deplasmanı halinde eğilme momentleri

2.1.2. Üç açıklıklı köprü kirişlerinde B mesnet deplasmanı halinde eğilme momentleri

2.1.3. Üç açıklıklı köprü kirişlerinde C mesnet deplasmanı halinde eğilme momentleri

2.1.4. Üç açıklıklı köprü kirişlerinde D mesnet deplasmanı halinde eğilme momentleri

2.2. Üç açıklıklı köprü kirişlerinde çeşitli yükleme durumlarında eğilme momentleri

2.2.1. g sabit yük hali

2.2.2. 1. açıklık ortasında F tekil yük hali

2.2.3. 2. açıklık ortasında F tekil yük hali

2.2.4. 3. açıklık ortasında F tekil yük hali

2.2.5. 1. açıklıkta q yayılı yük hali

2.2.6. 2. açıklıkta q yayılı yük hali

2.2.7. 3. açıklıkta q yayılı yük hali

2.3. Üç açıklıklı köprü kirişlerinde çeşitli yükleme durumlarında maksimum yer değiştirmelerin hesabı

2.3.1. A kesitindeki maksimum yer değiştirmenin hesabı

2.3.1.1. g sabit yük hali

2.3.1.2. 1. açıklık ortasında F_1 tekil yük hali

2.3.1.3. 2. açıklık ortasında F_2 tekil yük hali

2.3.1.4. 3. açıklık ortasında F_3 tekil yük hali

2.3.1.5. 1. açıklıkta q_1 yayılı yük hali

- 2.3.1.6. 2. açıklıkta q_2 yayılı yük hali
- 2.3.1.7. 3. açıklıkta q_3 yayılı yük hali
- 2.3.2. B kesitindeki maksimum yer değiştirmenin hesabı
 - 2.3.2.1. g sabit yük hali
 - 2.3.2.2. 1. açıklık ortasında F_1 tekil yük hali
 - 2.3.2.3. 2. açıklık ortasında F_2 tekil yük hali
 - 2.3.2.4. 3. açıklık ortasında F_3 tekil yük hali
 - 2.3.2.5. 1. açıklıkta q_1 yayılı yük hali
 - 2.3.2.6. 2. açıklıkta q_2 yayılı yük hali
 - 2.3.2.7. 3. açıklıkta q_3 yayılı yük hali

2.4. Üç açıklıklı köprü girişlerinde çeşitli yükleme durumlarında mesnet momentlerinin maksimum mesnet hareketlerine bağlı değişimi

- 2.4.1. B mesnet momentinin A mesnedindeki maksimum mesnet hareketine bağlı değişimi
 - 2.4.1.1. g sabit yük hali
 - 2.4.1.2. 1. açıklık ortasında F_1 tekil yük hali
 - 2.4.1.3. 2. açıklık ortasında F_2 tekil yük hali
 - 2.4.1.4. 3. açıklık ortasında F_3 tekil yük hali
 - 2.4.1.5. 1. açıklıkta q_1 yayılı yük hali
 - 2.4.1.6. 2. açıklıkta q_2 yayılı yük hali
 - 2.4.1.7. 3. açıklıkta q_3 yayılı yük hali
- 2.4.2. B mesnet momentinin B mesnedindeki maksimum mesnet hareketine bağlı değişimi
 - 2.4.2.1. g sabit yük hali
 - 2.4.2.2. 1. açıklık ortasında F_1 tekil yük hali
 - 2.4.2.3. 2. açıklık ortasında F_2 tekil yük hali
 - 2.4.2.4. 3. açıklık ortasında F_3 tekil yük hali
 - 2.4.2.5. 1. açıklıkta q_1 yayılı yük hali

2.4.2.6. 2. açıklıkta q_2 yayılı yük hali

2.4.2.7. 3. açıklıkta q_3 yayılı yük hali

2.4.3. C mesnet momentinin A mesnedindeki maksimum mesnet hareketine bağlı değişimi

2.4.3.1. g sabit yük hali

2.4.3.2. 1. açıklık ortasında F_1 tekil yük hali

2.4.3.3. 2. açıklık ortasında F_2 tekil yük hali

2.4.3.4. 3. açıklık ortasında F_3 tekil yük hali

2.4.3.5. 1. açıklıkta q_1 yayılı yük hali

2.4.3.6. 2. açıklıkta q_2 yayılı yük hali

2.4.3.7. 3. açıklıkta q_3 yayılı yük hali

2.4.4. C mesnet momentinin B mesnedindeki maksimum mesnet hareketine bağlı değişimi

2.4.4.1. g sabit yük hali

2.4.4.2. 1. açıklık ortasında F_1 tekil yük hali

2.4.4.3. 2. açıklık ortasında F_2 tekil yük hali

2.4.4.4. 3. açıklık ortasında F_3 tekil yük hali

2.4.4.5. 1. açıklıkta q_1 yayılı yük hali

2.4.4.6. 2. açıklıkta q_2 yayılı yük hali

2.4.4.7. 3. açıklıkta q_3 yayılı yük hali

2.5. Köprü en kesit özellikleri

2.6. Kenar ana kiriş atalet momenti ve elverişsiz şerit sayısı

2.7. Üç açıklıklı köprü kirişlerinde kenar ana kirişin muhtelif kesitlerinde eğilme momentlerinin mesnet deplasmanlarına bağlı değişimi

2.7.1. Kenar ana kiriş B mesnet kesiti eğilme momenti

2.7.1.1. Kenar ana kiriş B mesnet kesiti eğilme momentinin ΔA mesnet deplasmanına göre değişimi

2.7.1.2. Kenar ana kiriş B mesnet kesiti eğilme momentinin ΔB mesnet deplasmanına göre değişimi

2.7.1.3. Kenar ana kiriş B mesnet kesiti eğilme momentinin ΔC mesnet deplasmanına göre değişimi

2.7.1.4. Kenar ana kiriş B mesnet kesiti eğilme momentinin ΔD mesnet deplasmanına göre değişimi

2.7.2. Kenar ana kiriş 5 kesiti eğilme momenti

2.7.2.1. Kenar ana kiriş 5 kesiti eğilme momentinin ΔA mesnet deplasmanına göre değişimi

2.7.2.2. Kenar ana kiriş 5 kesiti eğilme momentinin ΔB mesnet deplasmanına göre değişimi

2.7.2.3. Kenar ana kiriş 5 kesiti eğilme momentinin ΔC mesnet deplasmanına göre değişimi

2.7.2.4. Kenar ana kiriş 5 kesiti eğilme momentinin ΔD mesnet deplasmanına göre değişimi

2.7.3. Kenar ana kiriş 15 kesiti eğilme momenti

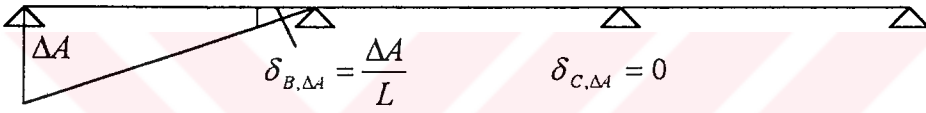
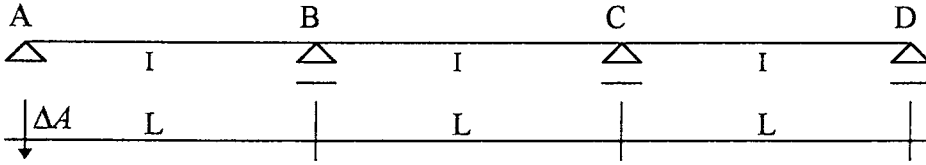
2.7.3.1. Kenar ana kiriş 15 kesiti eğilme momentinin ΔA mesnet deplasmanına göre değişimi

2.7.3.2. Kenar ana kiriş 15 kesiti eğilme momentinin ΔB mesnet deplasmanına göre değişimi

2. ÇOK AÇIKLIKLI KÖPRÜ KİRİŞLERİNDE MESNET OTURMALARININ EĞİLME MOMENTLERİNE ETKİSİNİN ARAŞTIRILMASI

2.1. Üç açıklıklı köprü kirişlerinde mesnetlerin deplasmanları halinde eğilme momentleri

2.1.1. Üç açıklıklı köprü kirişlerinde A mesnet deplasmanı halinde eğilme momentleri

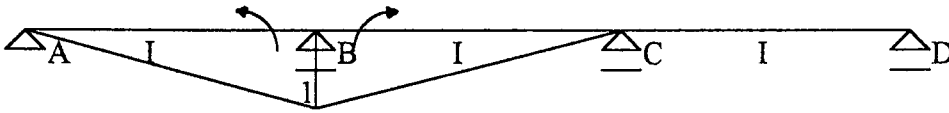


$$\delta_{BB} \cdot X_B + \delta_{BC} \cdot X_C + \delta_{B,\Delta A} = 0$$

$$\delta_{CB} \cdot X_B + \delta_{CC} \cdot X_C + \delta_{C,\Delta A} = 0$$

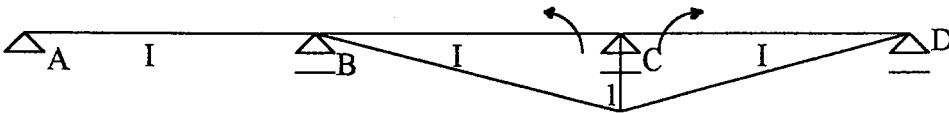
$$\text{Birim yüklemeler : } X_B = 1$$

M_B



$$X_C = 1$$

M_C



$$\delta_{BB} = \int M_B \cdot M_B \cdot \frac{dx}{EI} = \frac{1}{3} \cdot L \cdot 1 \cdot \frac{1}{EI} + \frac{1}{3} \cdot L \cdot 1 \cdot \frac{1}{EI} = \frac{2L}{3EI} = \delta_{CC}$$

$$\delta_{BC} = \int M_B \cdot M_C \cdot \frac{dx}{EI} = \frac{1}{6} \cdot L \cdot 1 \cdot 1 \cdot \frac{1}{EI} = \frac{L}{6EI} = \delta_{CB}$$

$$\frac{2L}{3EI} \cdot X_B + \frac{L}{6EI} \cdot X_C = \frac{-\Delta A}{L}$$

$$\frac{L}{6EI} \cdot X_B + \frac{2L}{3EI} \cdot X_C = 0 \quad (.-4)$$

$$\frac{2L}{3EI} \cdot X_B + \frac{L}{6EI} \cdot X_C = \frac{-\Delta A}{L}$$

$$+ \frac{-4L}{6EI} \cdot X_B + \frac{-8L}{3EI} \cdot X_C = 0$$

$$\frac{-15L}{6EI} \cdot X_C = \frac{-\Delta A}{L}$$

$$X_C = M_C = \frac{2}{5} \cdot \frac{\Delta A}{L^2} \cdot EI$$

$$\frac{2L}{3EI} \cdot X_B + \frac{L}{6EI} \cdot X_C = \frac{-\Delta A}{L} \quad (.-4)$$

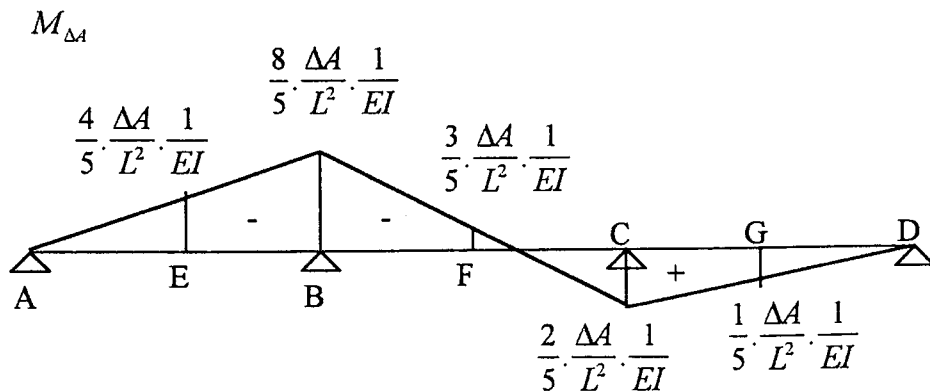
$$\frac{L}{6EI} \cdot X_B + \frac{2L}{3EI} \cdot X_C = 0$$

$$\frac{-8L}{3EI} \cdot X_B + \frac{-4L}{6EI} \cdot X_C = \frac{4\Delta A}{L}$$

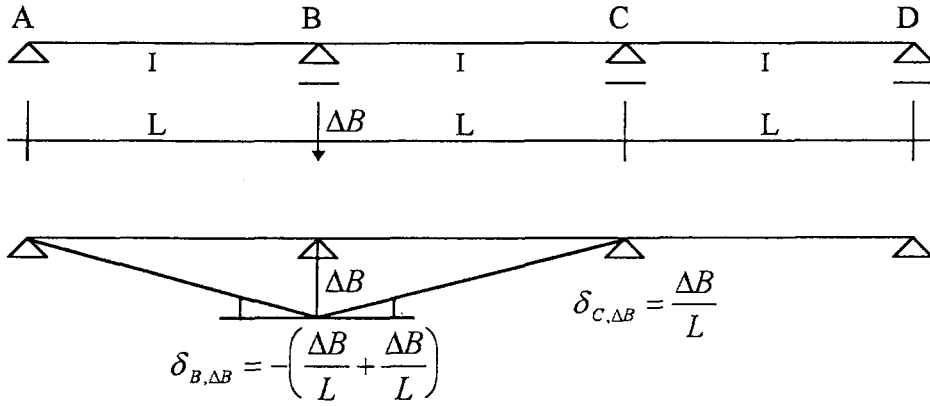
$$+ \frac{L}{6EI} \cdot X_B + \frac{2L}{3EI} \cdot X_C = 0$$

$$\frac{-15L}{6EI} \cdot X_B = \frac{4\Delta A}{L}$$

$$X_B = M_B = \frac{-8}{5} \cdot \frac{\Delta A}{L^2} \cdot \frac{1}{EI}$$



2.1.2. Üç açıklıklı köprü kirişlerinde B mesnet deplasmanı halinde eğilme momentleri



$$\delta_{BB} \cdot X_B + \delta_{BC} \cdot X_C + \delta_{B,\Delta B} = 0$$

$$\delta_{CB} \cdot X_B + \delta_{CC} \cdot X_C + \delta_{C,\Delta B} = 0$$

$$\frac{2L}{3EI} \cdot X_B + \frac{L}{6EI} \cdot X_C = \frac{2\Delta B}{L} \quad (.-4)$$

$$\frac{L}{6EI} \cdot X_B + \frac{2L}{3EI} \cdot X_C = \frac{-\Delta B}{L}$$

$$\frac{-8L}{3EI} \cdot X_B + \frac{-4L}{6EI} \cdot X_C = \frac{-8\Delta B}{L}$$

$$+ \frac{L}{6EI} \cdot X_B + \frac{2L}{3EI} \cdot X_C = \frac{-\Delta B}{L}$$

$$\frac{-15L}{6EI} \cdot X_B = \frac{-9\Delta B}{L}$$

$$X_B = M_B = \frac{18}{5} \cdot \frac{\Delta B}{L^2} \cdot \frac{1}{EI}$$

$$\frac{2L}{3EI} \cdot X_B + \frac{L}{6EI} \cdot X_C = \frac{2\Delta B}{L}$$

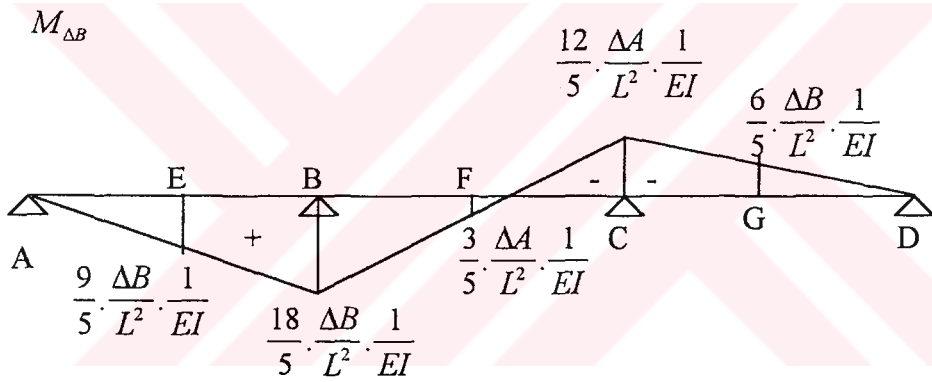
$$\frac{L}{6EI} \cdot X_B + \frac{2L}{3EI} \cdot X_C = \frac{-\Delta B}{L} \quad (.4)$$

$$\frac{2L}{3EI} \cdot X_B + \frac{L}{6EI} \cdot X_C = \frac{2\Delta B}{L}$$

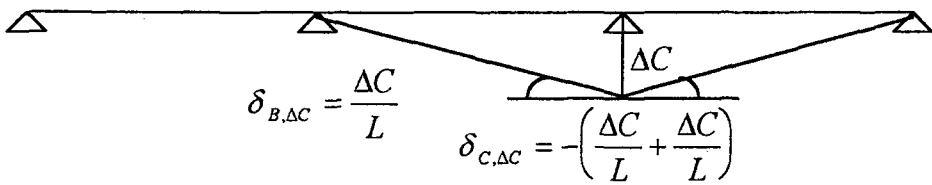
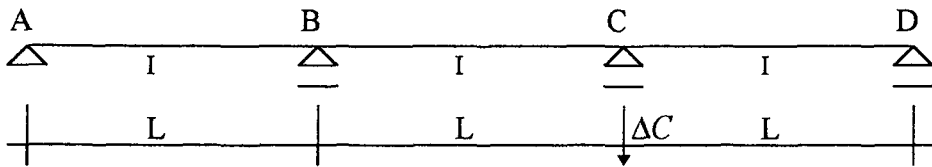
$$+ \frac{-4L}{6EI} \cdot X_B + \frac{-8L}{3EI} \cdot X_C = \frac{4\Delta B}{L}$$

$$\frac{-15L}{6EI} \cdot X_C = \frac{6\Delta B}{L}$$

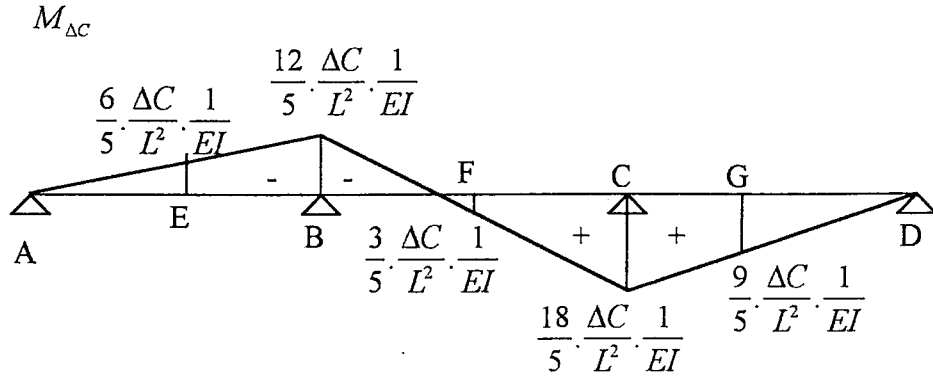
$$X_C = M_C = \frac{-12}{5} \cdot \frac{\Delta B}{L^2} \cdot \frac{1}{EI}$$



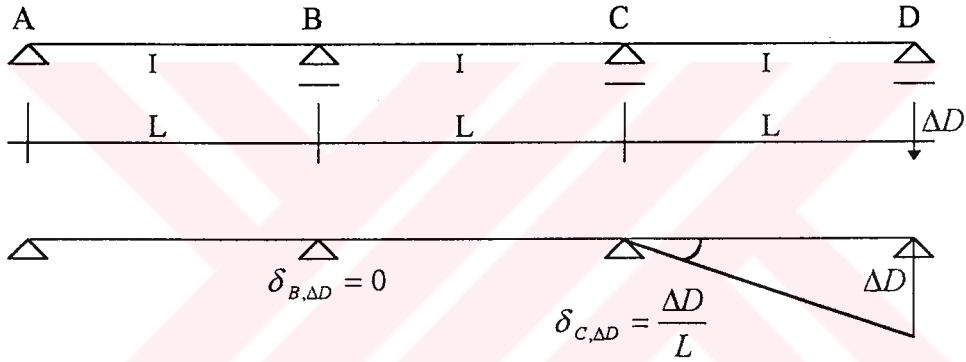
2.1.3. Üç açıklıklı köprü kirişlerinde C mesnet deplasmanı halinde kesit tesirleri



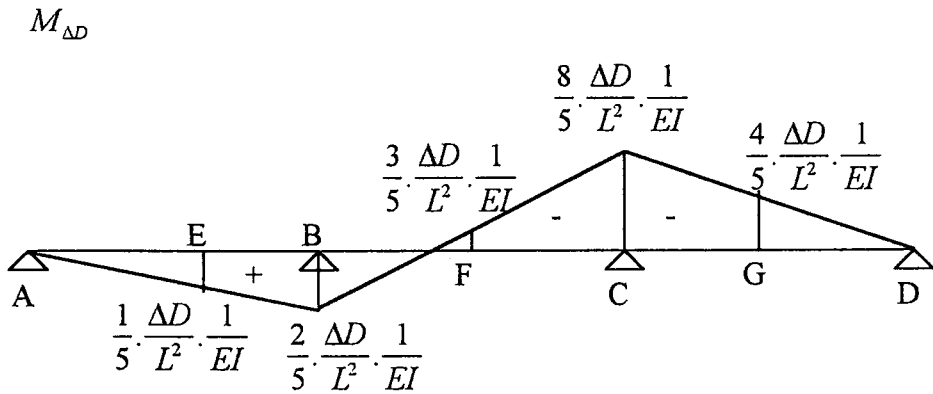
sistem simetrisinden $M_{\Delta C}$ $M_{\Delta B}$ nin simetriğidir.



2.1.4. Üç açıklıklı köprü kirişlerinde D mesnet deplasmanı halinde kesit tesirleri

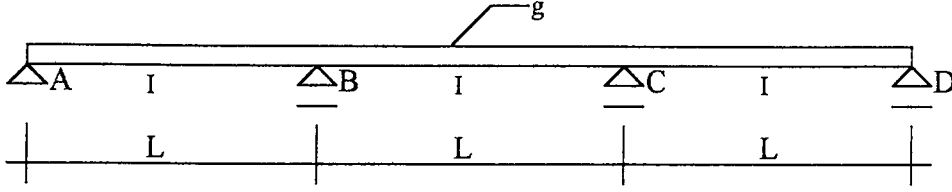


sistem simetrisinden $M_{\Delta D}$ $M_{\Delta A}$ nin simetriğidir.



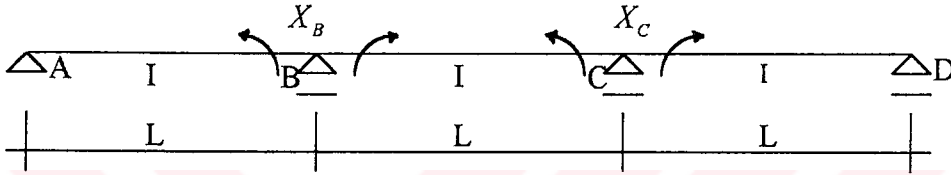
2.2. Üç açıklıklı köprü kirişlerinde çeşitli yükleme durumlarında eğilme momentleri

2.2.1. g sabit yük hali

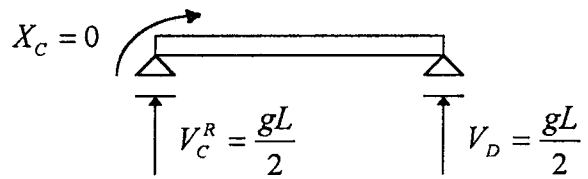
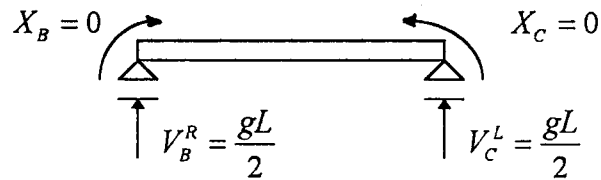
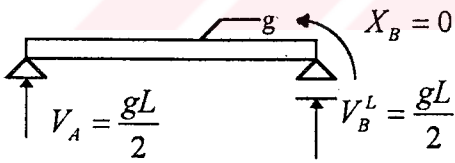
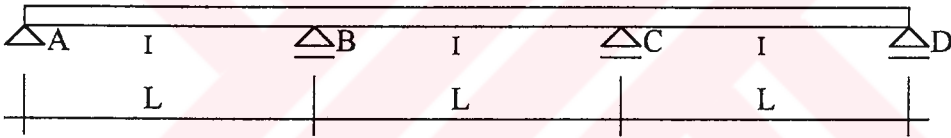


a) 2. dereceden hiperstatik

b) İzostatik esas sistem seçilmesi : İzostatik esas sistem ve hiperstatik bilinmeyenler

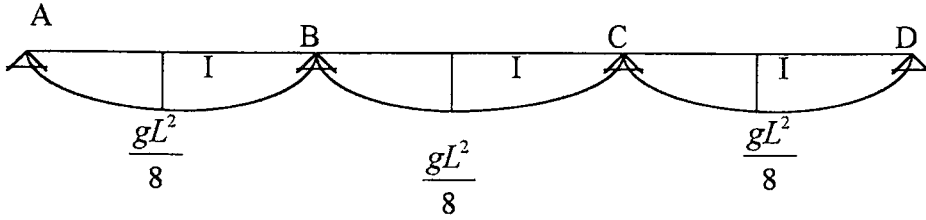


c) Sıfır yüklemesi : $X_i = 0$ ($X_B = X_C = 0$)



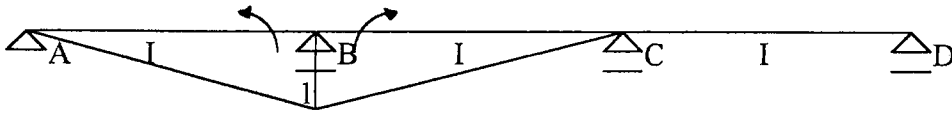
$$M_{MAX} = V_A \cdot \frac{L}{2} - \frac{gL}{2} \cdot \frac{L}{4} = \frac{gL^2}{8}$$

M_0



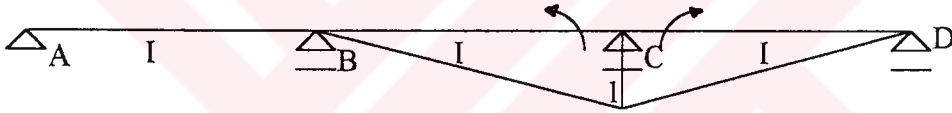
d) Birim yüklemeler : $X_B = 1$

M_B



$X_C = 1$

M_C



$$\delta_{BO} = \int M_B \cdot M_0 \cdot \frac{dx}{EI} = \frac{1}{3} \cdot L \cdot 1 \cdot \frac{gL^2}{8} \cdot 2 \cdot \frac{1}{EI} = \frac{gL^3}{12} = \delta_{CO}$$

Süreklilik denklemleri:

$$\delta_{BB} \cdot X_B + \delta_{BC} \cdot X_C + \delta_{BO} = 0$$

$$\delta_{CB} \cdot X_B + \delta_{CC} \cdot X_C + \delta_{CO} = 0$$

$$\frac{2L}{3EI} \cdot X_B + \frac{L}{6EI} \cdot X_C = \frac{-gL^3}{12EI}$$

$$+ \frac{L}{6EI} \cdot X_B + \frac{2L}{3EI} \cdot X_C = \frac{-gL^3}{12EI} \quad (.4)$$

$$\frac{-15L}{6EI} \cdot X_C = \frac{3gL^3}{12EI}$$

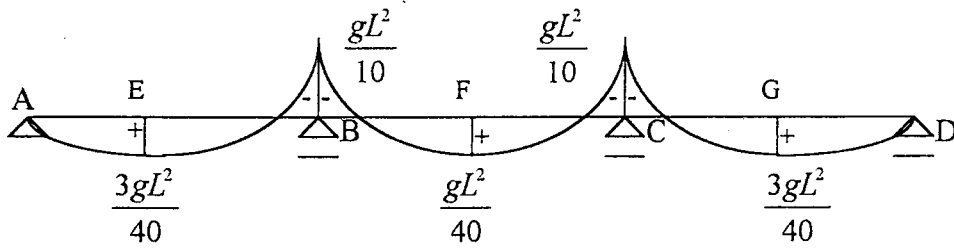
$$X_C = X_B = \frac{-gL^3}{10} = M_C = M_B$$

$$M_{\text{sonuç}} = M_0 + M_B \cdot X_B + M_C \cdot X_C$$

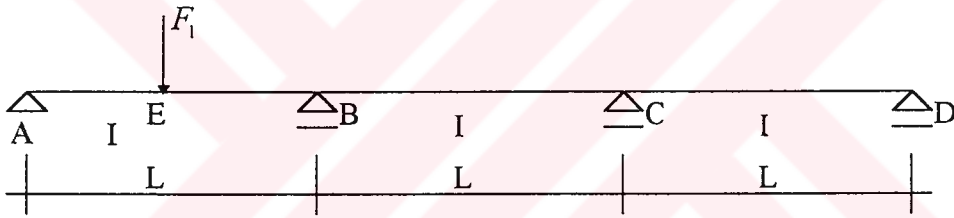
$$M_E = M_{0E} + M_{BE} \cdot X_B + M_{CE} \cdot X_C = \frac{gL^2}{8} + \frac{1}{2} \cdot \frac{-gL^2}{10} + 0 \cdot \frac{-gL^2}{10} = \frac{3gL^2}{40} = M_G$$

$$M_F = M_{0F} + M_{BF} \cdot X_B + M_{CF} \cdot X_C = \frac{gL^2}{8} + \frac{1}{2} \cdot \frac{-gL^2}{10} + \frac{1}{2} \cdot \frac{-gL^2}{10} = \frac{gL^2}{40}$$

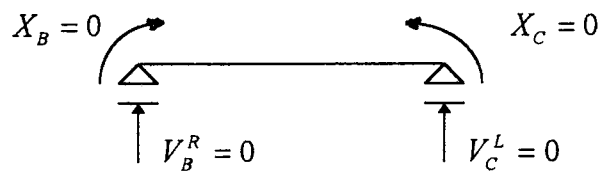
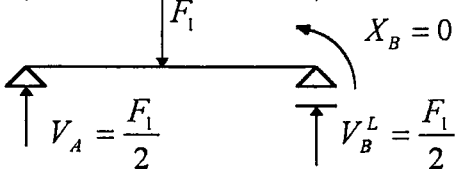
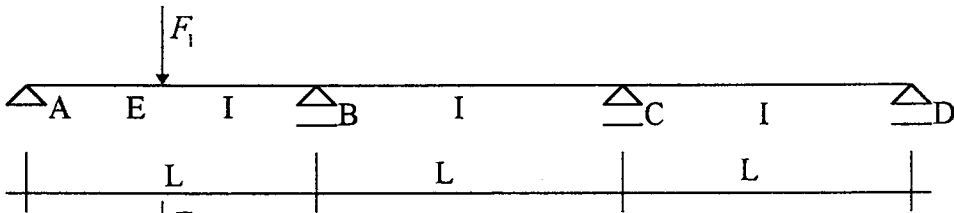
$M_{\text{sonuç}}$



2.2.2. 1. açıklık ortasında F_1 tekil yük hali

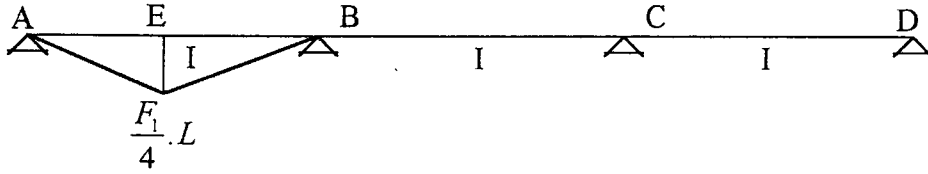


Sıfır yükleme : $X_i = 0$ ($X_B = X_C = 0$)

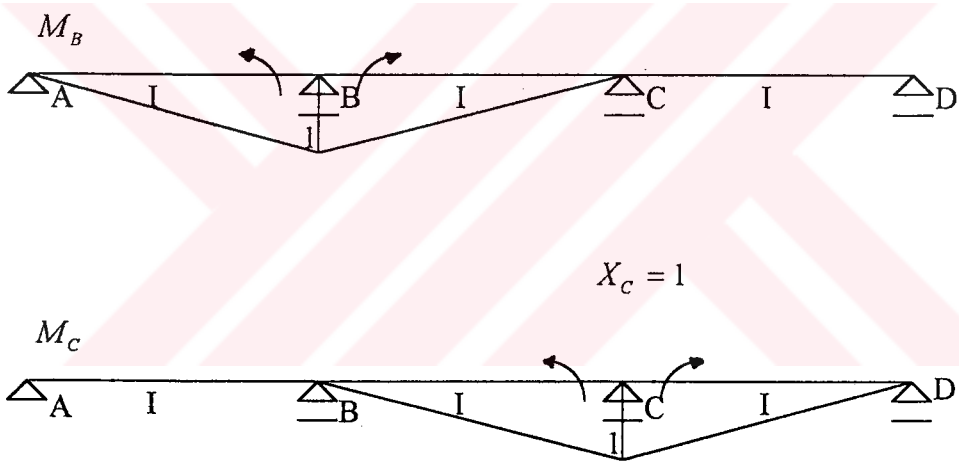


$$M_{MAX} = \frac{F_1}{2} \cdot \frac{L}{2} = \frac{FL}{4}$$

M_0



Birim yüklemeler : $X_B = 1$



$$\delta_{B0} = \int M_B \cdot M_0 \cdot \frac{dx}{EI} = \frac{1}{6} \cdot L \cdot (1 + \alpha) \cdot i \cdot k = \frac{1}{6} \cdot L \cdot (1 + \frac{1}{2}) \cdot 1 \cdot \frac{F_1}{4} \cdot L = \frac{F_1}{16} \cdot \frac{L^2}{EI}$$

$$\delta_{C0} = 0$$

Süreklilik denklemleri:

$$\delta_{BB} \cdot X_B + \delta_{BC} \cdot X_C + \delta_{B0} = 0$$

$$\delta_{CB} \cdot X_B + \delta_{CC} \cdot X_C + \delta_{C0} = 0$$

$$\frac{2L}{3EI} \cdot X_B + \frac{L}{6EI} \cdot X_C = \frac{-FL^2}{16EI} \quad (. -4)$$

$$\frac{L}{6EI} \cdot X_B + \frac{2L}{3EI} \cdot X_C = 0$$

$$\frac{-8L}{3EI} \cdot X_B + \frac{-4L}{6EI} \cdot X_C = \frac{4FL^2}{16EI}$$

$$+ \frac{L}{6EI} \cdot X_B + \frac{2L}{3EI} \cdot X_C = 0$$

$$\frac{-15L}{6EI} \cdot X_B = \frac{4FL^2}{16EI}$$

$$X_B = M_B = \frac{-FL}{10}$$

$$\frac{2L}{3EI} \cdot X_B + \frac{L}{6EI} \cdot X_C = \frac{-FL^2}{16EI}$$

$$\frac{L}{6EI} \cdot X_B + \frac{2L}{3EI} \cdot X_C = 0 \quad (. -4)$$

$$\frac{2L}{3EI} \cdot X_B + \frac{L}{6EI} \cdot X_C = \frac{-FL^2}{16EI}$$

$$+ \frac{-4L}{6EI} \cdot X_B + \frac{-8L}{3EI} \cdot X_C = 0$$

$$\frac{-15L}{6EI} \cdot X_C = \frac{-FL^2}{16EI}$$

$$X_C = M_C = \frac{FL}{40}$$

$$M_{somuç} = M_0 + M_B \cdot X_B + M_C \cdot X_C$$

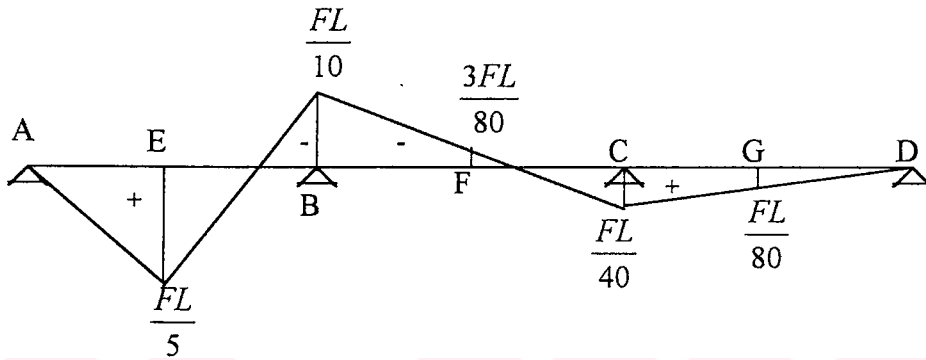
$$M_E = M_{0E} + M_{BE} \cdot X_B + M_{CE} \cdot X_C = \frac{FL}{4} + \frac{1}{2} \cdot \frac{-FL}{10} + 0 \cdot \frac{FL}{40} = \frac{FL}{5}$$

$$M_B = M_{0B} + M_{BB} \cdot X_B + M_{CB} \cdot X_C = 0 + 1 \cdot \frac{-FL}{10} + 0 \cdot \frac{FL}{40} = \frac{-FL}{10}$$

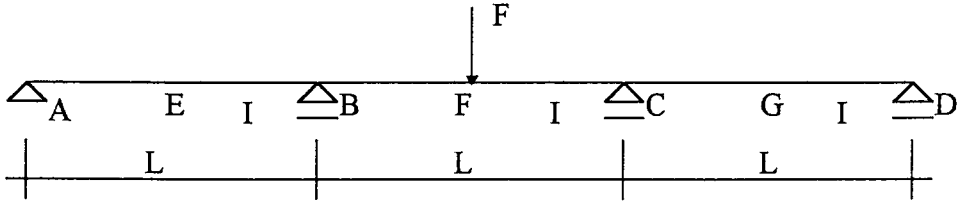
$$M_C = M_{0C} + M_{BC} \cdot X_B + M_{CC} \cdot X_C = 0 + 0 \cdot \frac{-FL}{10} + 1 \cdot \frac{FL}{40} = \frac{FL}{40}$$

$$M_F = M_{0F} + M_{BF} \cdot X_B + M_{CF} \cdot X_C = 0 + \frac{1}{2} \cdot \frac{-FL}{10} + \frac{1}{2} \cdot \frac{FL}{40} = \frac{-3FL}{80}$$

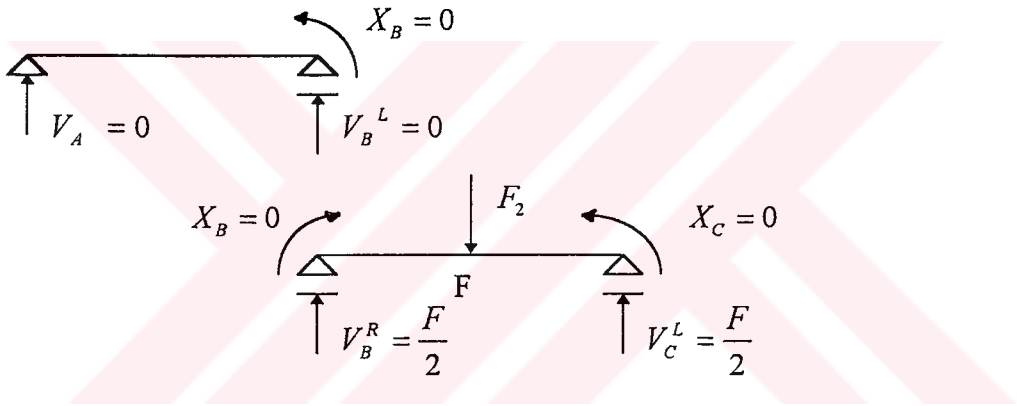
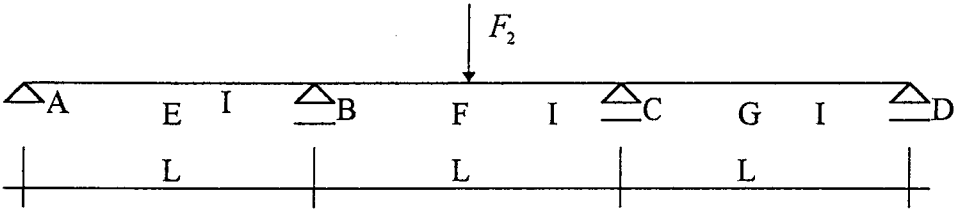
$$M_G = M_{0G} + M_{BG} \cdot X_B + M_{CG} \cdot X_C = 0 + 0 \cdot \frac{-FL}{10} + \frac{1}{2} \cdot \frac{FL}{40} = \frac{FL}{80}$$



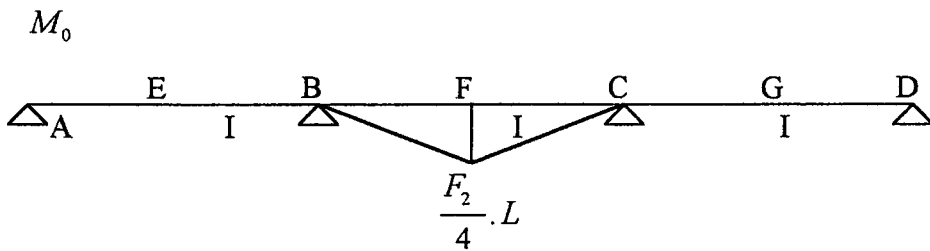
2.2.3. 2. Açıklık ortasında F_2 tekil yük hali



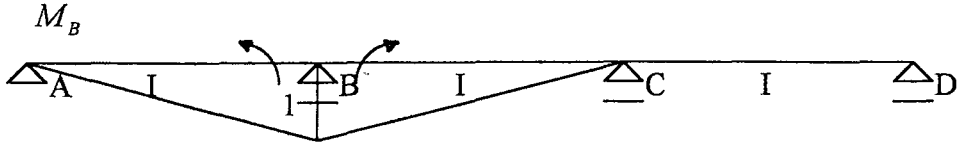
Sıfır yükleme : $X_i = 0$ ($X_B = X_C = 0$)



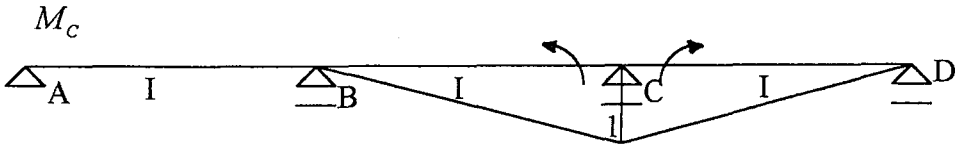
$$M_{MAX} = \frac{F_2}{2} \cdot \frac{L}{2} = \frac{FL}{4}$$



Birim yüklemeler : $X_B = 1$



$X_C = 1$



$$\delta_{B0} = \int M_B \cdot M_0 \cdot \frac{dx}{EI} = \frac{1}{6} \cdot L \cdot (1 + \beta) \cdot i \cdot k = \frac{1}{6} \cdot L \cdot \left(1 + \frac{1}{2}\right) \cdot 1 \cdot \frac{F_2}{4} \cdot L = \frac{F_2}{16} \cdot \frac{L^2}{EI}$$

Süreklilik denklemleri:

$$\delta_{BB} \cdot X_B + \delta_{BC} \cdot X_C + \delta_{B0} = 0$$

$$\delta_{CB} \cdot X_B + \delta_{CC} \cdot X_C + \delta_{C0} = 0$$

$$\frac{2L}{3EI} \cdot X_B + \frac{L}{6EI} \cdot X_C = \frac{-FL^2}{16EI} \quad (. -4)$$

$$\frac{L}{6EI} \cdot X_B + \frac{2L}{3EI} \cdot X_C = \frac{-FL^2}{16EI}$$

$$\frac{-8L}{3EI} \cdot X_B + \frac{-4L}{6EI} \cdot X_C = \frac{4FL^2}{16EI}$$

$$+ \frac{L}{6EI} \cdot X_B + \frac{2L}{3EI} \cdot X_C = \frac{-FL^2}{16EI}$$

$$\frac{-15L}{6EI} \cdot X_B = \frac{3FL^2}{16EI}$$

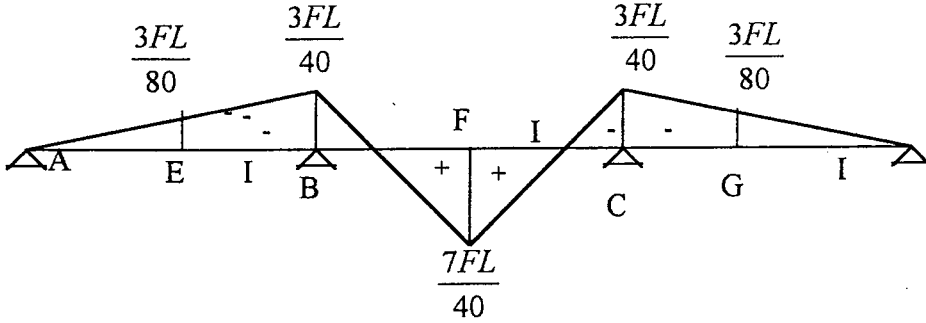
$$X_B = M_B = \frac{-3FL}{40}$$

$$X_C = M_C = \frac{-3FL}{40}$$

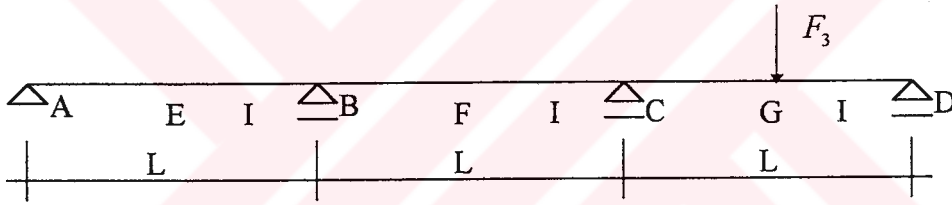
$$M_{\text{sonuç}} = M_0 + M_B \cdot X_B + M_C \cdot X_C$$

$$M_E = M_{0E} + M_{BE} \cdot X_B + M_{CE} \cdot X_C = 0 + \frac{1}{2} \cdot \frac{-3FL}{40} + 0 \cdot \frac{-3FL}{40} = \frac{-3FL}{80} = M_G$$

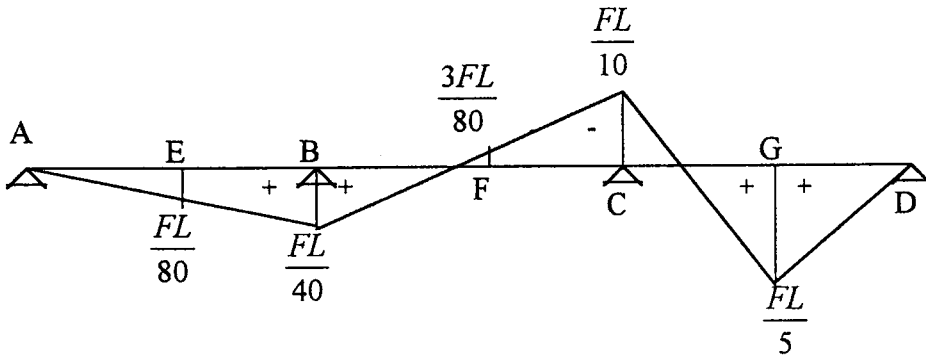
$$M_F = M_{0F} + M_{BF} \cdot X_B + M_{CF} \cdot X_C = \frac{FL}{4} + \frac{1}{2} \cdot \frac{-3FL}{40} + \frac{1}{2} \cdot \frac{-3FL}{40} = \frac{7FL}{40}$$



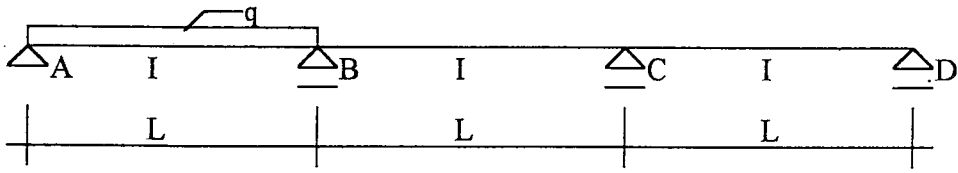
2.2.4. 3. Açıklık ortasında F_3 tekil yük hali



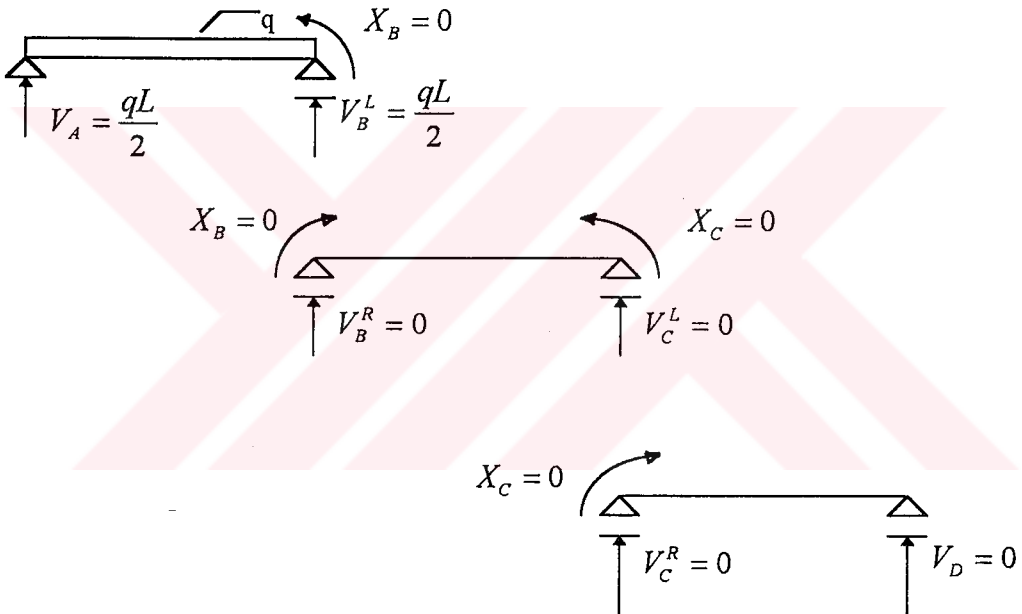
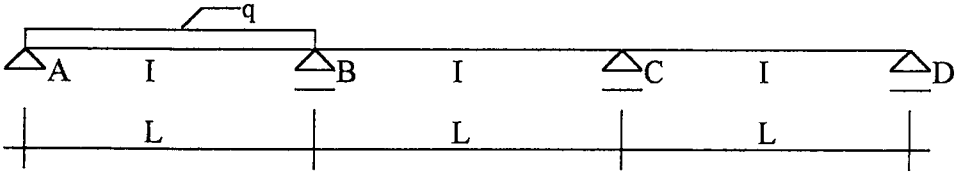
2.2.2. simetrisinden yazılabilir.



2.2.5. 1. Açıklıkta q yayılı yük hali

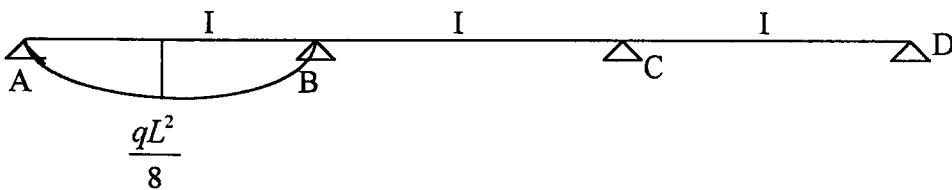


Sıfır yüklemesi : $X_i = 0$ ($X_B = X_C = 0$)

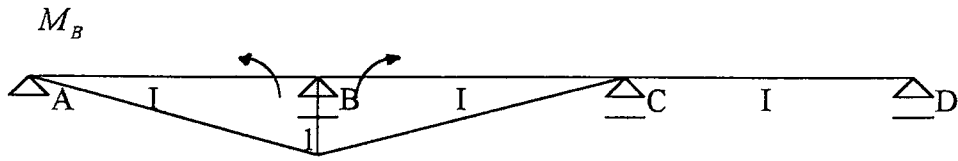


$$M_{MAX} = V_A \cdot \frac{L}{2} - \frac{qL}{2} \cdot \frac{L}{4} = \frac{qL^2}{8}$$

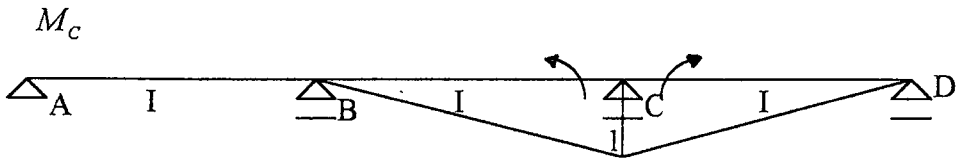
M_0



$$X_B = 1$$



$$X_C = 1$$



$$\delta_{B0} = \int M_B \cdot M_0 \cdot \frac{dx}{EI} = \frac{1}{3} \cdot L \cdot 1 \cdot \frac{qL^2}{8} \cdot \frac{1}{EI} = \frac{qL^3}{24EI}$$

$$\delta_{C0} = 0$$

$$\delta_{BB} \cdot X_B + \delta_{BC} \cdot X_C + \delta_{B0} = 0$$

$$\delta_{CB} \cdot X_B + \delta_{CC} \cdot X_C + \delta_{C0} = 0$$

$$\frac{2L}{3EI} \cdot X_B + \frac{L}{6EI} \cdot X_C = \frac{-qL^3}{24EI}$$

$$\frac{L}{6EI} \cdot X_B + \frac{2L}{3EI} \cdot X_C = 0 \quad (\cdot -4)$$

$$\frac{2L}{3EI} \cdot X_B + \frac{L}{6EI} \cdot X_C = \frac{-qL^3}{24EI}$$

$$\frac{-4L}{6EI} \cdot X_B + \frac{-8L}{3EI} \cdot X_C = 0$$

$$\frac{-15L}{6EI} \cdot X_C = \frac{-qL^3}{24EI}$$

$$X_C = M_C = \frac{qL^2}{60}$$

$$\frac{2L}{3EI} \cdot X_B + \frac{L}{6EI} \cdot X_C = \frac{-qL^3}{24EI} \quad (. -4)$$

$$\frac{L}{6EI} \cdot X_B + \frac{2L}{3EI} \cdot X_C = 0$$

$$\frac{-8L}{3EI} \cdot X_B + \frac{-4L}{6EI} \cdot X_C = -\frac{-4qL^3}{24EI}$$

$$+ \frac{L}{6EI} \cdot X_B + \frac{2L}{3EI} \cdot X_C = 0$$

$$\frac{-15L}{6EI} \cdot X_B = \frac{qL^3}{6EI}$$

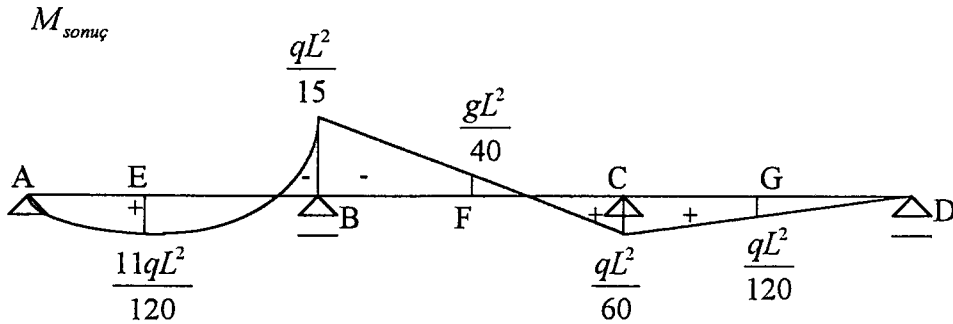
$$X_B = M_B = \frac{-qL^2}{15}$$

$$M_{\text{sonuç}} = M_0 + M_B \cdot X_B + M_C \cdot X_C$$

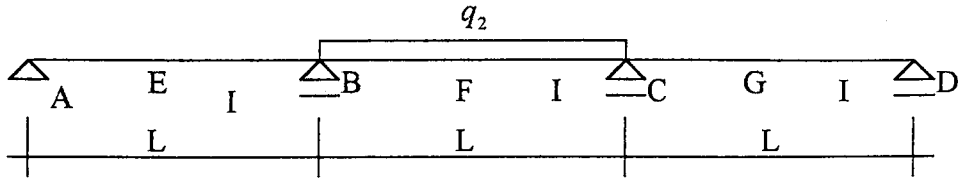
$$M_E = M_{0E} + M_{BE} \cdot X_B + M_{CE} \cdot X_C = \frac{qL^2}{8} + \frac{1}{2} \cdot \frac{-qL^2}{15} + 0 \cdot \frac{qL^2}{60} = \frac{11qL^2}{120}$$

$$M_F = M_{0F} + M_{BF} \cdot X_B + M_{CF} \cdot X_C = 0 + \frac{1}{2} \cdot \frac{-qL^2}{15} + \frac{1}{2} \cdot \frac{qL^2}{60} = \frac{-qL^2}{40}$$

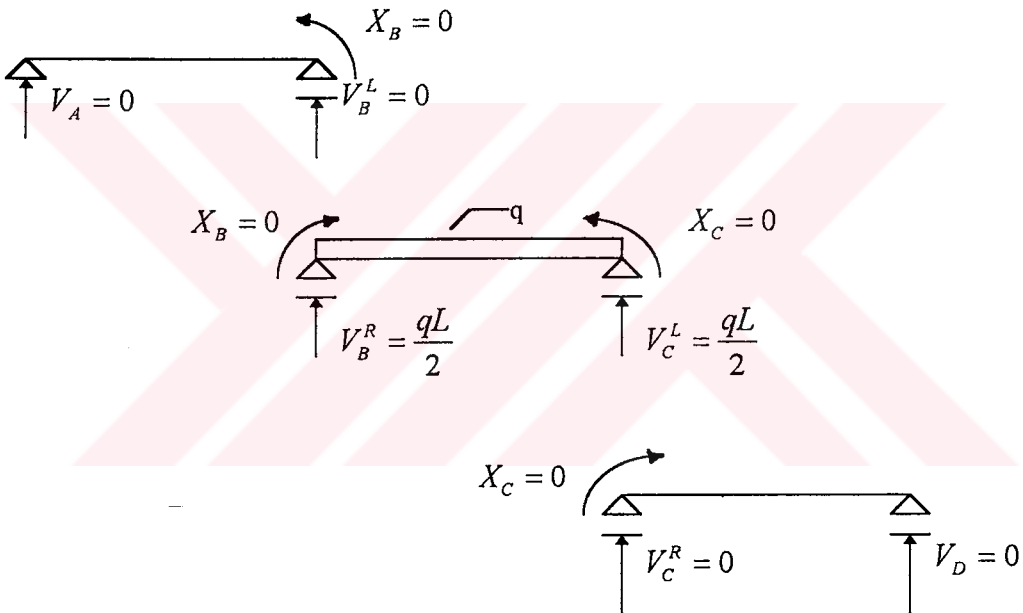
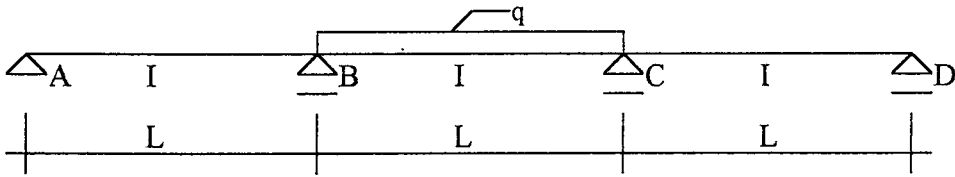
$$M_G = M_{0G} + M_{BG} \cdot X_B + M_{CG} \cdot X_C = 0 + 0 \cdot \frac{-qL^2}{15} + \frac{1}{2} \cdot \frac{qL^2}{60} = \frac{qL^2}{120}$$



2.2.6. 2. Açıklıkta q_2 yayılı yük hali

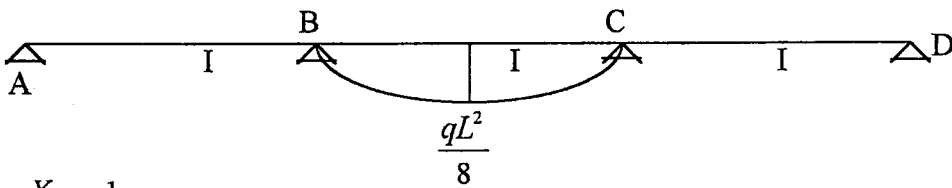


Sıfır yükleme : $X_i = 0$ ($X_B = X_C = 0$)

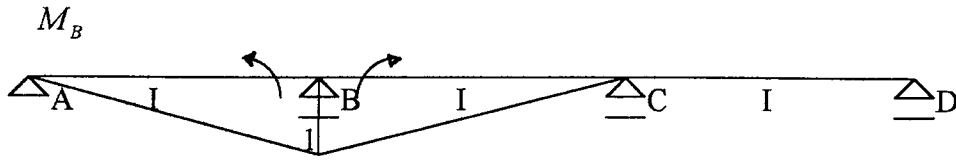


$$M_{MAX} = V_A \cdot \frac{L}{2} - \frac{qL}{2} \cdot \frac{L}{4} = \frac{qL^2}{8}$$

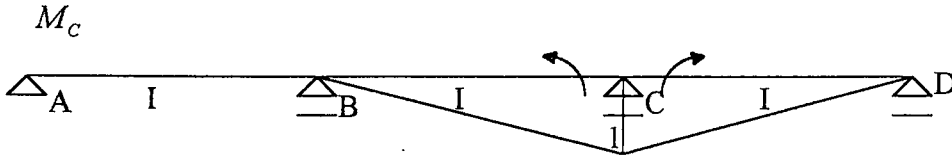
M_0



$X_B = 1$



$$X_C = 1$$



$$\delta_{B0} = \int M_B \cdot M_0 \cdot \frac{dx}{EI} = \frac{1}{3} \cdot L \cdot \frac{qL^2}{8} \cdot \frac{1}{EI} = \frac{qL^3}{24EI}$$

$$\delta_{C0} = \int M_C \cdot M_0 \cdot \frac{dx}{EI} = \frac{1}{3} \cdot L \cdot \frac{qL^2}{8} \cdot \frac{1}{EI} = \frac{qL^3}{24EI}$$

$$\delta_{BB} \cdot X_B + \delta_{BC} \cdot X_C + \delta_{B0} = 0$$

$$\delta_{CB} \cdot X_B + \delta_{CC} \cdot X_C + \delta_{C0} = 0$$

$$\frac{2L}{3EI} \cdot X_B + \frac{L}{6EI} \cdot X_C = \frac{-qL^3}{24EI} \quad (. -4)$$

$$\frac{L}{6EI} \cdot X_B + \frac{2L}{3EI} \cdot X_C = \frac{-qL^3}{24EI}$$

$$\frac{-8L}{3EI} \cdot X_B + \frac{-4L}{6EI} \cdot X_C = \frac{4qL^3}{24EI}$$

$$+ \frac{L}{6EI} \cdot X_B + \frac{2L}{3EI} \cdot X_C = \frac{-qL^3}{24EI}$$

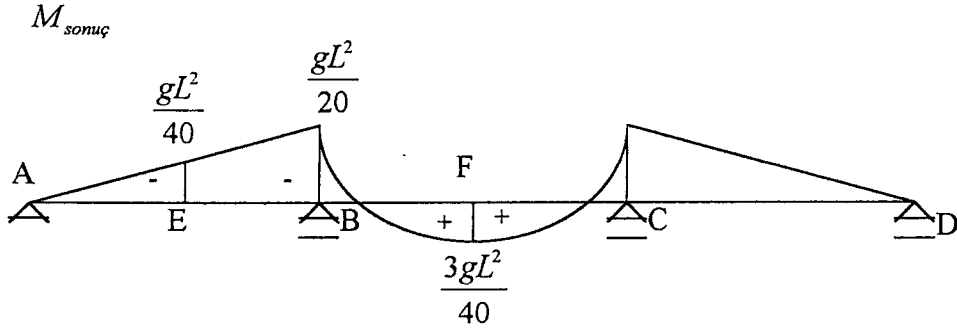
$$\frac{-15L}{6EI} \cdot X_B = \frac{3qL^3}{24EI}$$

$$X_B = M_B = \frac{-qL^2}{20}$$

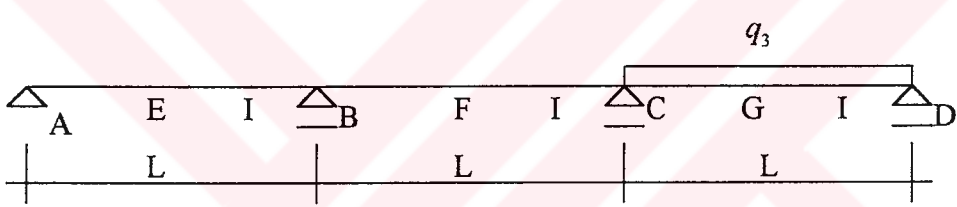
$$M_{\text{somuq}} = M_0 + M_B \cdot X_B + M_C \cdot X_C$$

$$M_E = M_{0E} + M_{BE} \cdot X_B + M_{CE} \cdot X_C = 0 + \frac{1}{2} \cdot \frac{-qL^2}{20} + 0 \cdot \frac{-qL^2}{20} = \frac{-qL^2}{40} = M_G$$

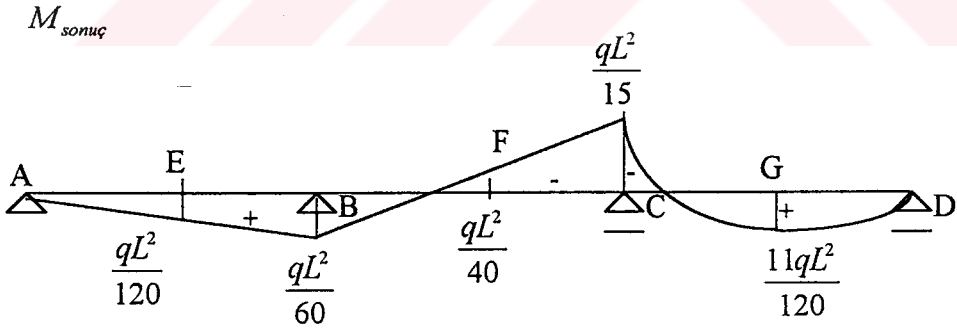
$$M_F = M_{0F} + M_{BF} \cdot X_B + M_{CF} \cdot X_C = \frac{qL^2}{8} + \frac{1}{2} \cdot \frac{-qL^2}{20} + \frac{1}{2} \cdot \frac{-qL^2}{20} = \frac{3qL^2}{40}$$



2.2.7. 3. Açıklıkta q_3 yayılı yük hali



simetriden yazılabilir.



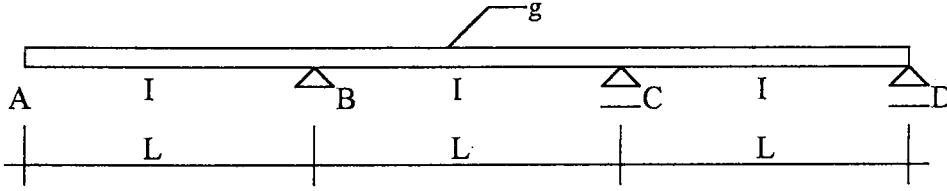
2.3. Üç açıklıklı köprü kirişlerinde çeşitli yükleme durumlarında maksimum yer değiştirmelerin hesabı

2.3.1. A kesitindeki maksimum yer değiştirmenin hesabı (δ_{Ag})

2.3.1.1. g sabit yük hali

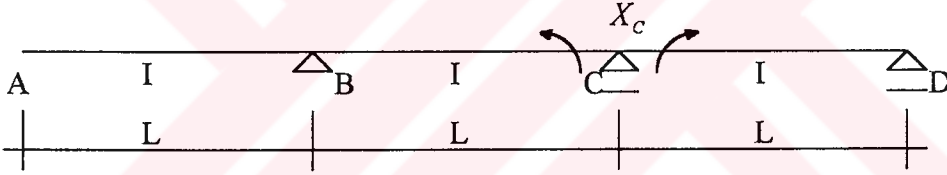
$$\delta_{Ag} = \int M_g^1 \cdot M_1^0 \cdot \frac{dx}{EI}$$

M_g^1 : Hiperstatik sistemde g yüklemesi

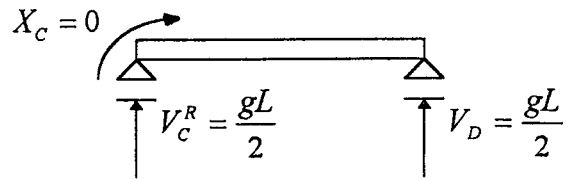
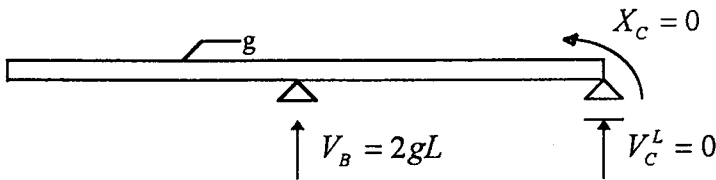
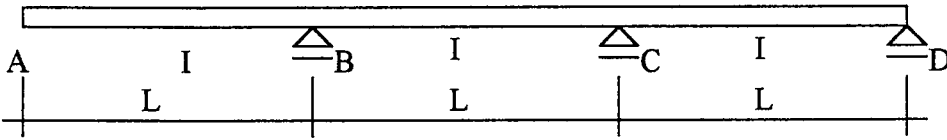


a) 1. dereceden hiperstatik

b) İzostatik esas sistem seçilmesi : İzostatik esas sistem ve hiperstatik bilinmeyenler



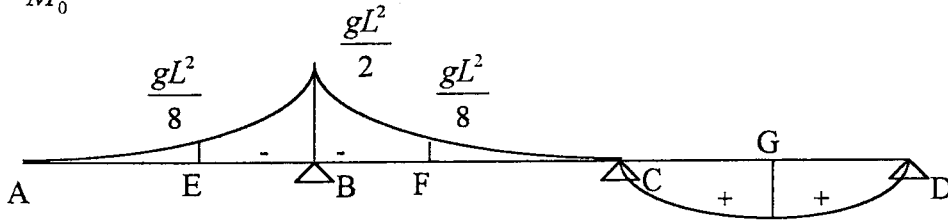
c) Sıfır yüklemesi : $X_i = 0$ ($X_C = 0$)



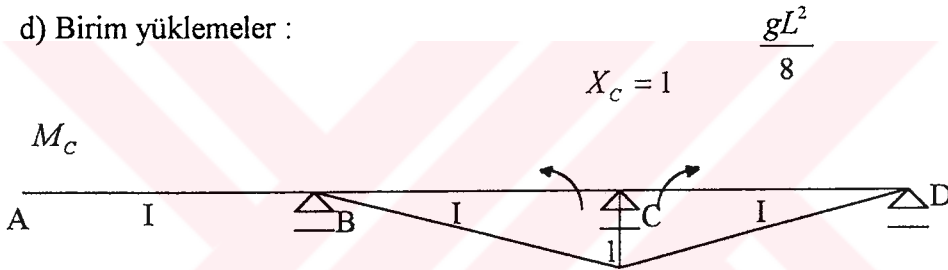
$$\begin{aligned} \sum M_B = 0 \quad V_C^L + g \cdot L \cdot \frac{L}{2} - g \cdot L \cdot \frac{L}{2} &= 0 & V_C^L &= 0 \\ \sum M_C = 0 \quad V_B \cdot L - g \cdot 2L \cdot L &= 0 & V_B &= 2gL \\ \sum M_D = 0 \quad V_C^R \cdot L - g \cdot L \cdot \frac{L}{2} &= 0 & V_C^R = V_D &= \frac{gL}{2} \end{aligned}$$

$$M_{MAXG} = V_A \cdot \frac{L}{2} - \frac{gL}{2} \cdot \frac{L}{4} = \frac{gL^2}{8}$$

M_0



d) Birim yüklemeler :

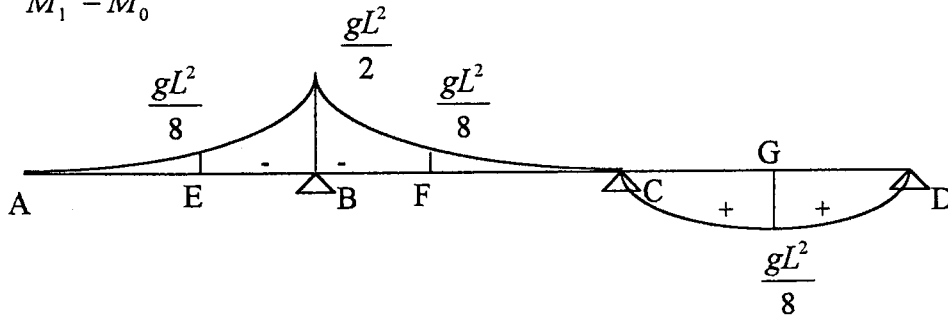


$$\delta_{CC} = \int M_C \cdot M_C \cdot \frac{dx}{EI} = \frac{1}{3} \cdot L \cdot 1 \cdot 1 \cdot \frac{1}{EI} + \frac{1}{3} \cdot L \cdot 1 \cdot 1 \cdot \frac{1}{EI} = \frac{2L}{3EI}$$

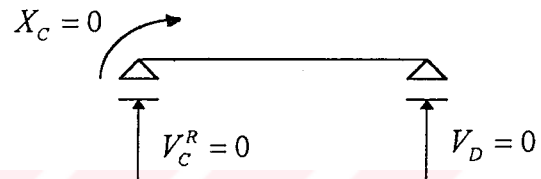
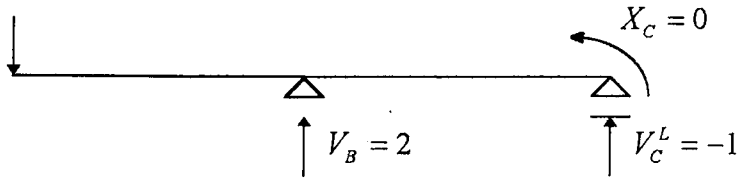
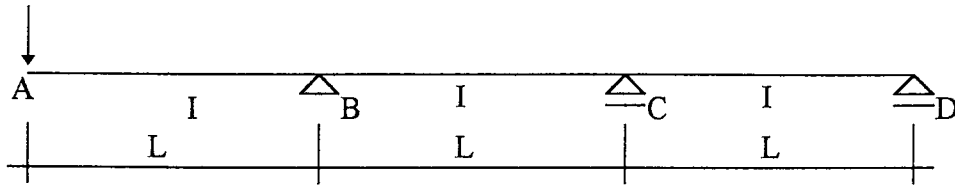
$$\delta_{C0} = \frac{1}{12} \cdot L \cdot \frac{-gL^2}{12} \cdot 1 + \frac{1}{3} \cdot L \cdot 1 \cdot \frac{gL^2}{8} = 0$$

$$\delta_{CC} \cdot X_C + \delta_{C0} = 0 \quad X_C = 0 \text{ izostatik}$$

$$M_1^G = M_0$$



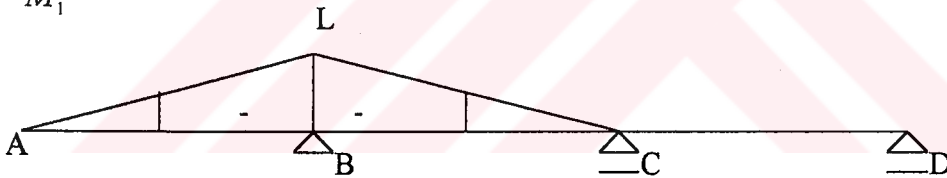
M_1^0 : İzostatik sistemde birim yükleme



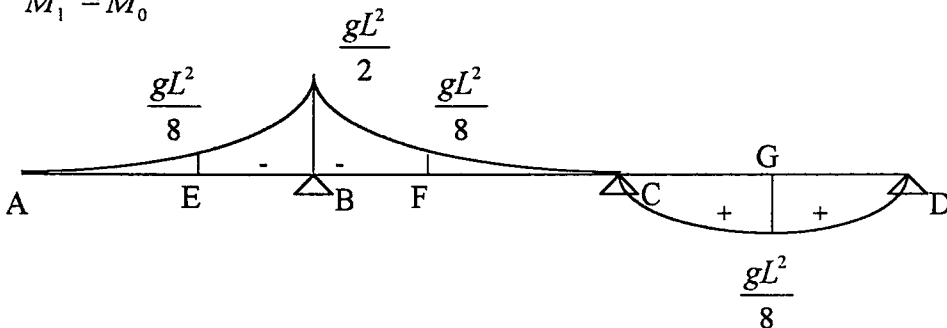
$$\sum M_C = V_B \cdot L - 1 \cdot 2L = 0 \quad V_B = 2$$

$$\sum M_B = V_C^L \cdot 2L + 2 \cdot L = 0 \quad V_C^L = -1$$

M_1^0



$M_1^G = M_0$

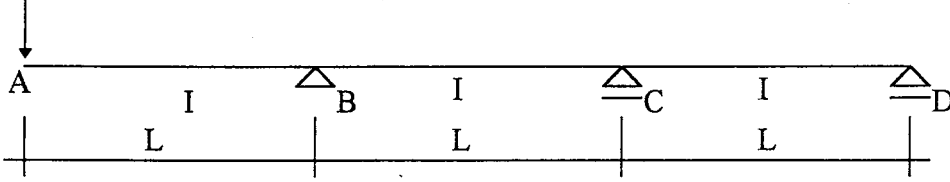


$$\delta_{Ag} = \Delta A_{MAX} = 2 \cdot \frac{1}{4} \cdot L \cdot i.k. \cdot \frac{1}{EI} = 2 \cdot \frac{1}{4} \cdot L \cdot (-L) \cdot \frac{-gL^2}{2} \cdot \frac{1}{EI} = \frac{gL^4}{4EI}$$

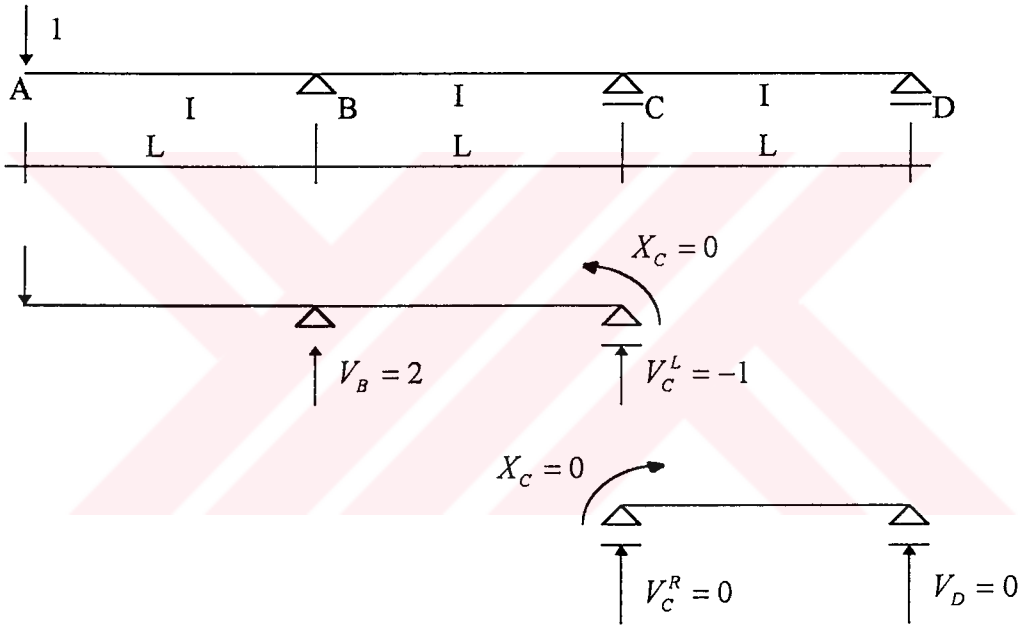
A mesnedindeki maksimum yer değiştirmenin hesabı (2. yol)

$$\delta_{Ag} = \Delta A_{MAX} = \int M_1^1 \cdot M_g^0 \cdot \frac{dx}{EI}$$

M_1^1 : Hiperstatik sistemde birim yükleme



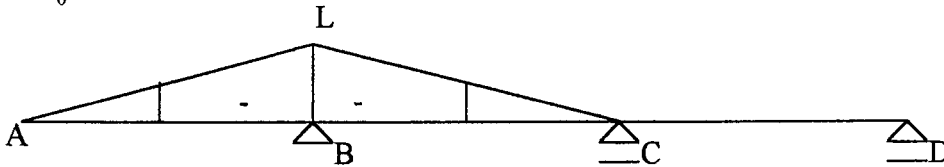
Sıfır yükleme: $X_i = 0$ ($X_C = 0$)

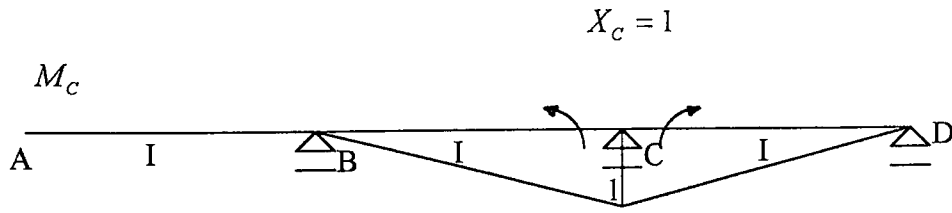


$$\sum M_C = V_B \cdot L - 1 \cdot 2L = 0 \quad V_B = 2$$

$$\sum M_B = V_C^L \cdot 2L + 2 \cdot L = 0 \quad V_C^L = -1$$

M_0





$$\delta_{c_0} = \frac{1}{6} \cdot L \cdot (-L) \cdot 1 \cdot \frac{1}{EI} = \frac{-L^2}{6EI}$$

$$\delta_{c_0} + \delta_{c_c} \cdot X_C = 0$$

$$\frac{-L^2}{6EI} + \frac{2L}{3EI} \cdot X_C = 0$$

$$X_C = M_C = \frac{L}{4}$$

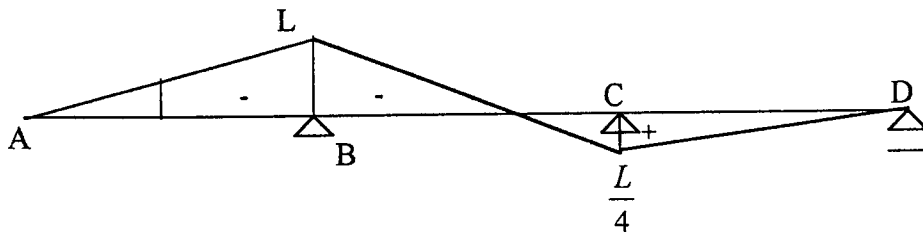
$$M_{\text{sonuç}} = M_0 + M_C \cdot X_C$$

$$M_B = M_{0B} + M_{cB} \cdot X_C = -L + 0 \cdot \frac{L}{4} = -L$$

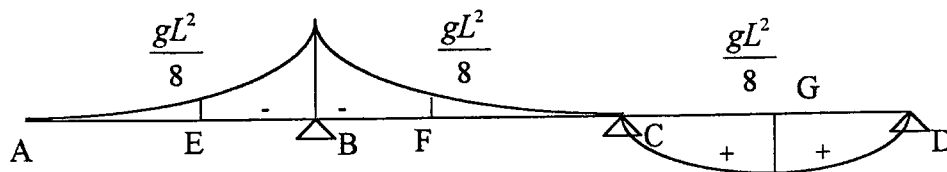
$$M_C = M_{0C} + M_{cC} \cdot X_C = 0 + 1 \cdot \frac{L}{4} = \frac{L}{4}$$

$$M_A = M_D = 0$$

$$M_1^1$$



$$M_g^0$$



$$\delta = \frac{1}{4} \cdot L \cdot i \cdot k$$

$$\delta = \frac{1}{12} \cdot L \cdot i \cdot (k_1 + 3 \cdot k_2)$$

$$\delta = \frac{1}{3} \cdot L \cdot i \cdot k$$

$$\Delta A_{MAX} = \int M_1^1 \cdot M_s^0 \cdot \frac{dx}{EI}$$

$$\Delta A_{MAX} = \delta_{A_g} = \frac{1}{4} \cdot L \cdot (-L) \cdot \frac{-gL^2}{2} \cdot \frac{1}{EI} + \frac{1}{12} \cdot L \cdot \left(\frac{-gL^2}{2}\right) \cdot \left(\frac{L}{4} - 3L\right) \cdot \frac{1}{EI} + \frac{1}{3} \cdot L \cdot \frac{L}{4} \cdot \frac{gL^2}{8} \cdot \frac{1}{EI}$$

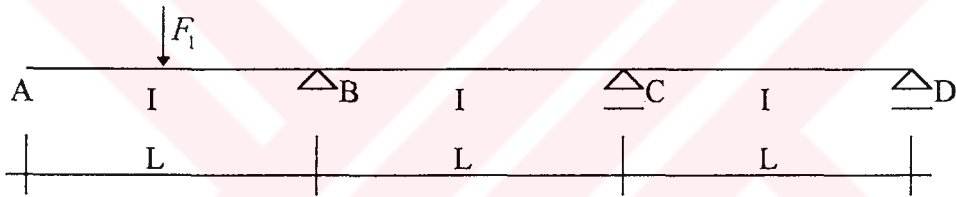
$$\Delta A_{MAX} = \frac{gL^4}{8EI} + \frac{11gL^4}{96EI} + \frac{gL^4}{96EI}$$

$$\Delta A_{MAX} = \frac{gL^4}{4EI}$$

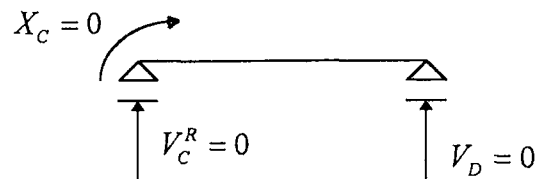
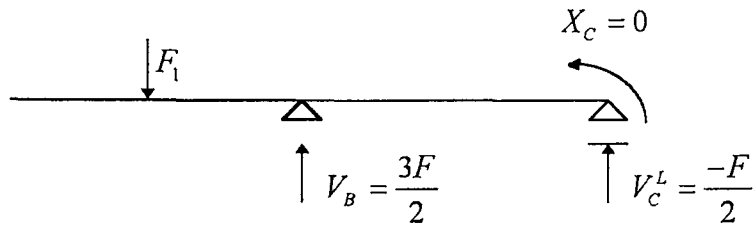
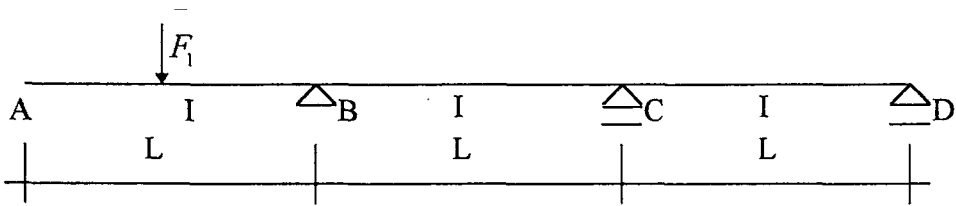
2.3.1.2. 1.Açıklık ortasında F_1 tekil yük hali

$$\delta_{AF_1} = \int M_F^1 \cdot M_1^0 \cdot \frac{dx}{EI}$$

M_F^1 : Hiperstatik sistemde F yüklemesi



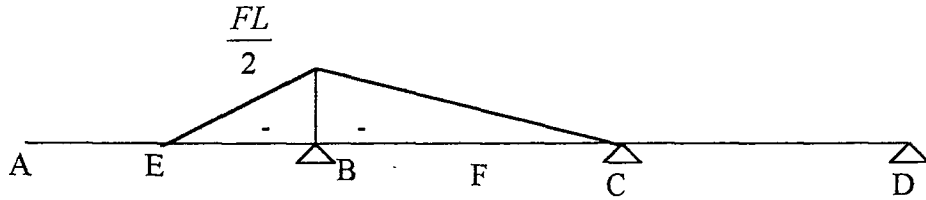
Sıfır yüklemesi : $X_i = 0$ ($X_c = 0$)



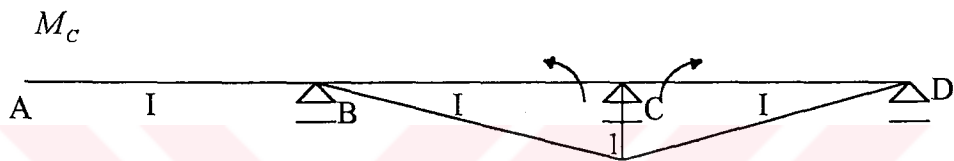
$$\sum M_B = 0 \quad V_C^L \cdot L + \frac{FL}{2} = 0 \quad V_C^L = \frac{-F}{2}$$

$$\sum M_C = 0 \quad V_B \cdot L - F \cdot \frac{3L}{2} = 0 \quad V_B = \frac{3F}{2}$$

M_0



$$X_C = 1$$



$$\delta_{c0} = \frac{1}{6} \cdot L \cdot i \cdot k = \frac{1}{6} \cdot L \cdot 1 \cdot \frac{-FL}{2} \cdot \frac{1}{EI} = \frac{-FL^2}{12EI}$$

$$\delta_{c0} + \delta_{cc} \cdot X_C = 0$$

$$\frac{2L}{3EI} \cdot X_C + \frac{-FL^2}{12EI} = 0$$

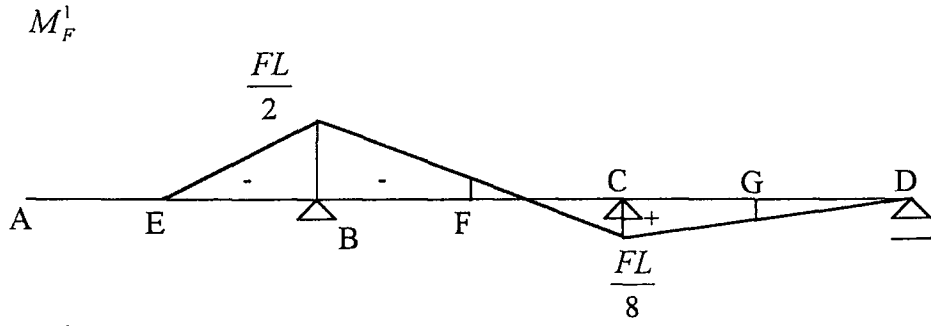
$$X_C = M_C = \frac{FL}{8}$$

$$M_{\text{sonuç}} = M_0 + M_C \cdot X_C$$

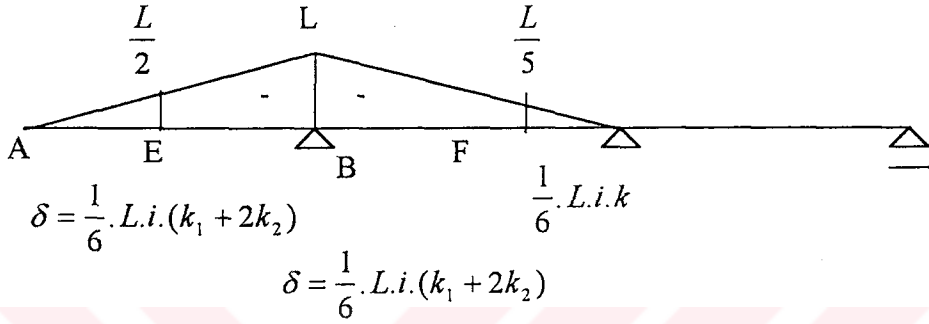
$$M_B = M_{0B} + M_{CB} \cdot X_C = \frac{-FL}{2} + 0 \cdot \frac{FL}{8} = \frac{-FL}{2}$$

$$M_C = M_{0C} + M_{CC} \cdot X_C = 0 + 1 \cdot \frac{FL}{8} = \frac{FL}{8}$$

$$M_A = M_D = 0$$



M_1^0 : İzostatik sistemde birim yükleme



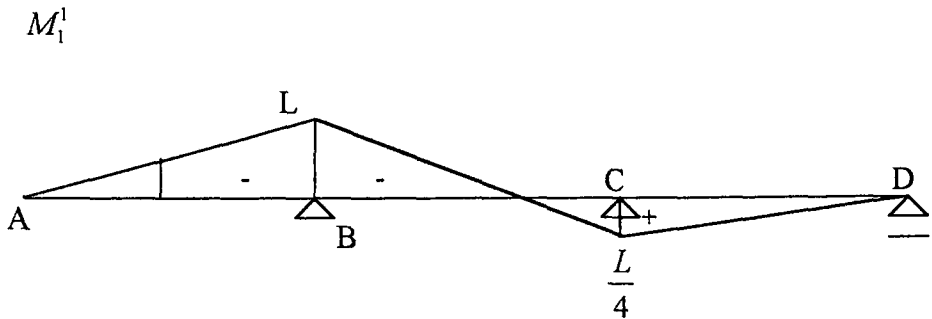
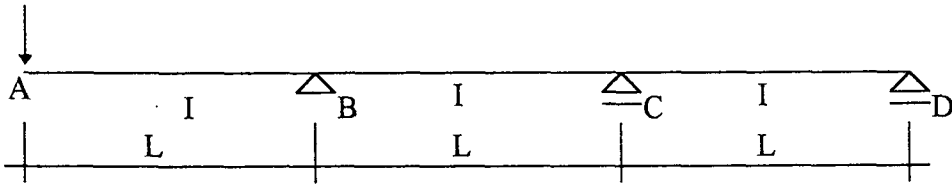
$$\Delta A_{MAX} = \int M_F^1 \cdot M_1^0 \cdot \frac{dx}{EI}$$

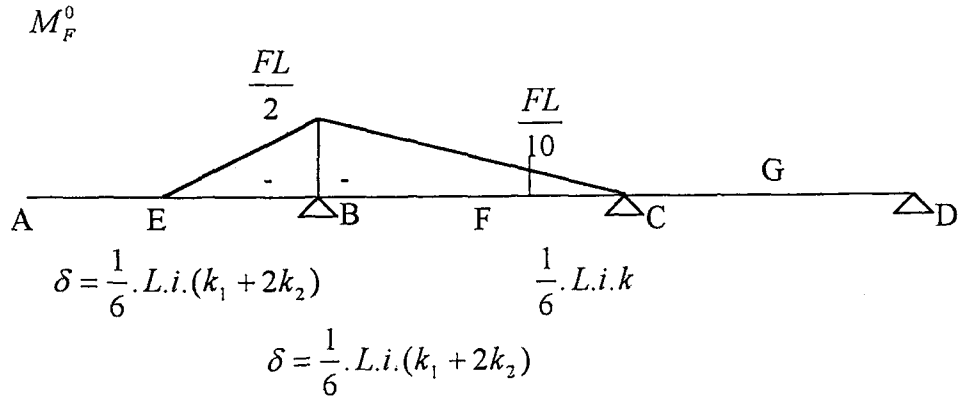
$$\Delta A_{MAX} = \frac{1}{6} \cdot \frac{L}{2} \cdot \frac{-FL}{2} \cdot \left(\frac{L}{2} - 2L\right) \cdot \frac{1}{EI} + \frac{1}{6} \cdot \frac{4L}{5} \cdot \frac{-FL}{2} \cdot \left(\frac{L}{2} - 2L\right) \cdot \frac{1}{EI} + \frac{1}{6} \cdot \frac{L}{5} \cdot \frac{-L}{5} \cdot \frac{FL}{8} \cdot \frac{1}{EI}$$

$$\Delta A_{MAX} = \delta_{AF_1} = \frac{FL^3}{4EI}$$

A mesnedindeki maksimum yer değiştirmenin hesabı (2.yol)

$$\delta_{AF_1} = \Delta A_{MAX} = \int M_1^1 \cdot M_F^0 \cdot \frac{dx}{EI} \quad M_1^1: \text{Hiperstatik sistemde birim yükleme}$$





$$\Delta A_{MAX} = \frac{1}{6} \cdot \frac{L}{2} \cdot \frac{-FL}{2} \cdot \left(\frac{-L}{2} - 2L \right) \cdot \frac{1}{EI} + \frac{1}{6} \cdot \frac{4L}{5} \cdot (-L) \cdot \left(\frac{-FL}{10} - \frac{2FL}{2} \right) \cdot \frac{1}{EI} + \frac{1}{6} \cdot \frac{L}{5} \cdot \frac{-FL}{10} \cdot \frac{L}{4} \cdot \frac{1}{EI}$$

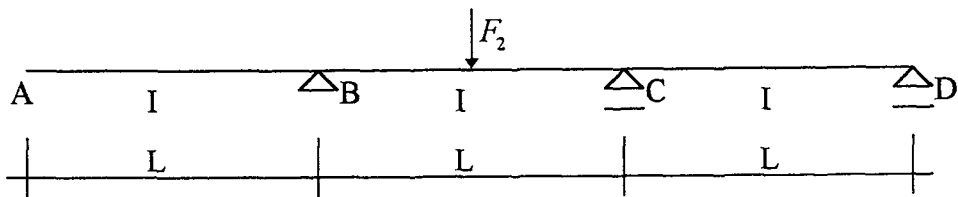
$$\Delta A_{MAX} = \delta_{AF} = \frac{5FL^3}{48EI} + \frac{44FL^3}{300EI} - \frac{FL^3}{1200EI}$$

$$\Delta A_{MAX} = \delta_{AF} = \frac{FL^3}{4EI}$$

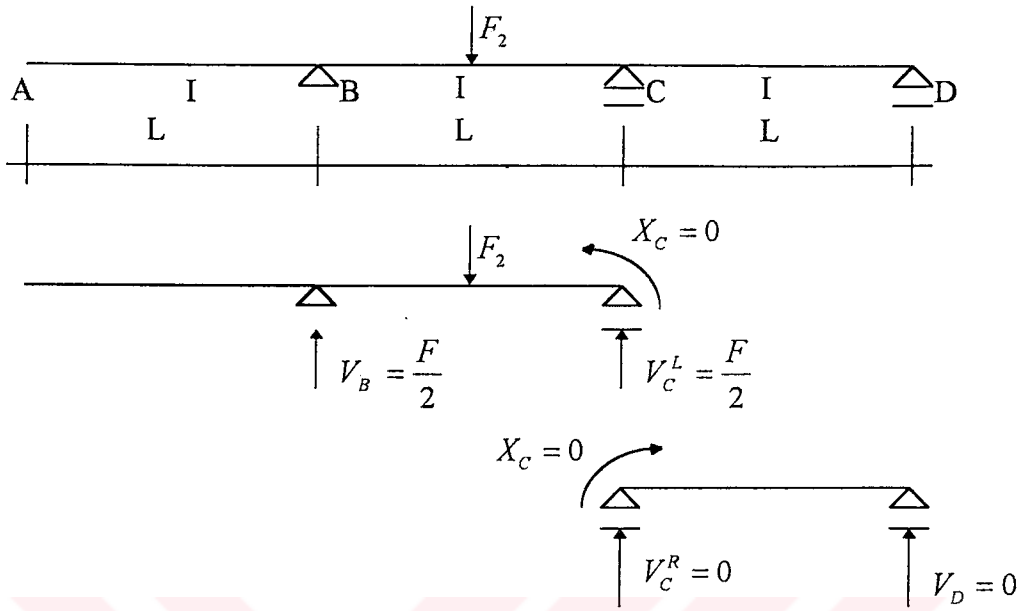
2.3.1.3. 2. Açıklık ortasında F_2 tekil yük hali

$$\delta_{AF_2} = \int M_F^1 \cdot M_1^0 \cdot \frac{dx}{EI}$$

M_F^1 : Hiperstatik sistemde F yüklemesi



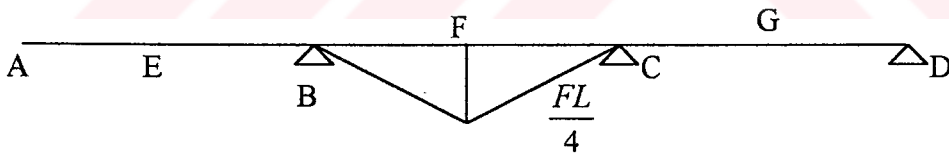
Sıfır yüklemesi : $X_i = 0$ ($X_c = 0$)



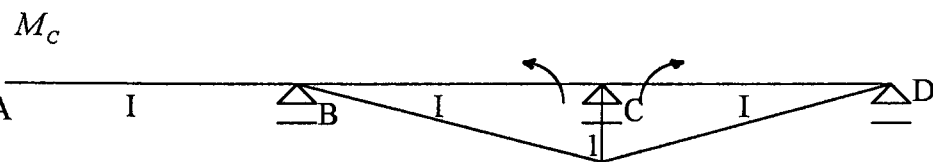
$$\sum M_B = 0 \quad V_C^L \cdot L - \frac{FL}{2} = 0 \quad V_C^L = \frac{F}{2}$$

$$\sum M_C = 0 \quad V_B \cdot L - \frac{FL}{2} = 0 \quad V_B = \frac{F}{2}$$

M_0



$X_c = 1$



$$\delta_{c_0} = \frac{1}{6} \cdot L \cdot (1 + \alpha) \cdot i \cdot k = \frac{1}{6} \cdot L \cdot \left(1 + \frac{1}{2}\right) \cdot 1 \cdot \frac{FL}{4} \cdot \frac{1}{EI} = \frac{FL^2}{16EI}$$

$$\delta_{c_0} + \delta_{cc} \cdot X_c = 0$$

$$\frac{2L}{3EI} \cdot X_C + \frac{FL^2}{16EI} = 0$$

$$X_C = M_C = \frac{-3FL}{32}$$

$$M_{somuç} = M_0 + M_C \cdot X_C$$

$$M_B = M_{0B} + M_{CB} \cdot X_C = 0 + 0 \cdot \frac{-3FL}{32} = 0$$

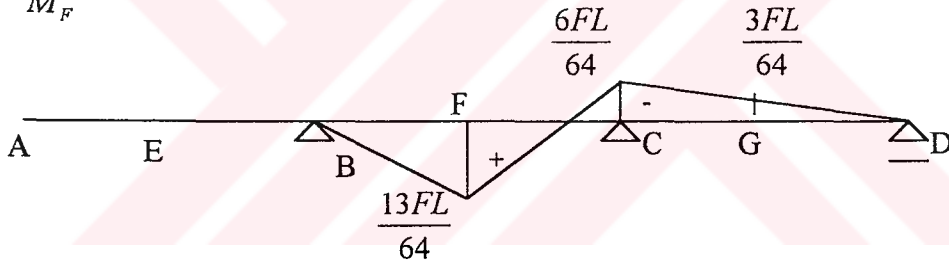
$$M_C = M_{0C} + M_{CC} \cdot X_C = 0 + 1 \cdot \frac{-3FL}{32} = \frac{-3FL}{32}$$

$$M_F = M_{0F} + M_{CF} \cdot X_C = \frac{FL}{4} + \frac{1}{2} \cdot \frac{-3FL}{32} = \frac{13FL}{64}$$

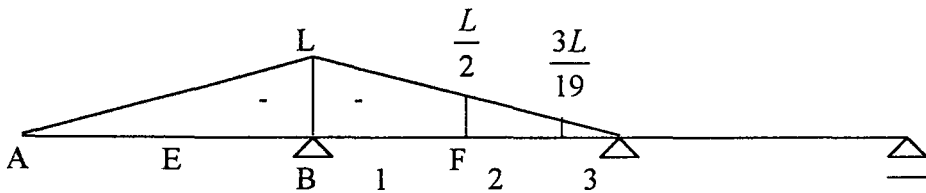
$$M_G = M_{0G} + M_{CG} \cdot X_C = 0 + \frac{1}{2} \cdot \frac{-3FL}{32} = \frac{-3FL}{64}$$

$$M_A = M_D = 0$$

$$M_F^1$$



M_1^0 : İzostatik sistemde birim yükleme



$$1: \delta = \frac{1}{6} \cdot L \cdot i \cdot (k_1 + 2k_2) \quad 2: \delta = \frac{1}{6} \cdot L \cdot i \cdot (k_1 + 2k_2) \quad 3: \frac{1}{6} \cdot L \cdot i \cdot k$$

$$\Delta A_{MAX} = \int M_F^1 \cdot M_1^0 \cdot \frac{dx}{EI}$$

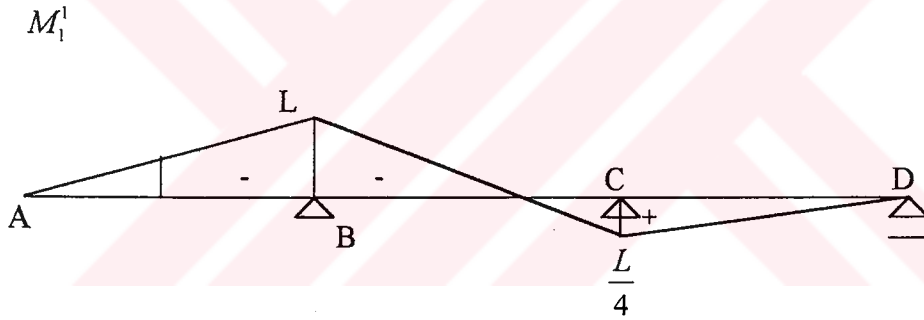
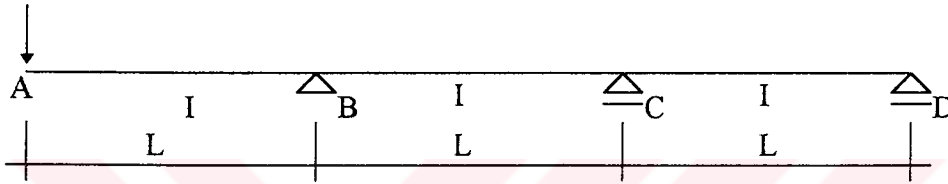
$$\Delta A_{MAX} = \frac{1}{6} \cdot \frac{L}{2} \cdot \frac{13FL}{64} \cdot \left(\frac{-2L}{2} - L\right) \cdot \frac{1}{EI} + \frac{1}{6} \cdot \frac{13L}{38} \cdot \frac{13FL}{64} \cdot \left(\frac{-13L}{19} - \frac{2L}{2}\right) \cdot \frac{1}{EI} + \frac{1}{6} \cdot \frac{3L}{19} \cdot \frac{-3L}{19} \cdot \frac{-6FL}{64} \cdot \frac{1}{EI}$$

$$\Delta A_{MAX} = \frac{-13FL^3}{384EI} - \frac{3718FL^3}{277248EI} + \frac{9FL^3}{23104EI}$$

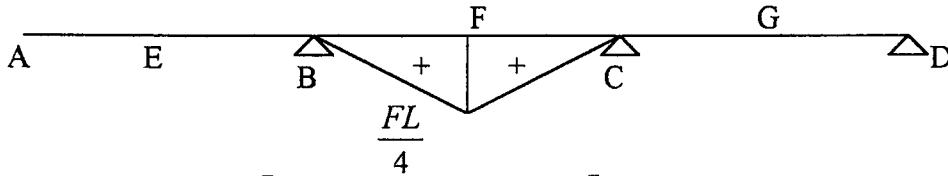
$$\Delta A_{MAX} = \delta_{AF_1} = \frac{-3FL^3}{64EI}$$

A mesnedindeki maksimum yer değıştirmenin hesabı (2.yol)

$$\delta_{AF_1} = \Delta A_{MAX} = \int M_1^1 \cdot M_F^0 \cdot \frac{dx}{EI} \quad M_1^1 : \text{Hiperstatik sistemde birim yükleme}$$



$$M_F^0 \quad \delta = \frac{1}{6} \cdot L \cdot k \cdot [(1 + \beta) \cdot i_1 + (1 + \alpha) \cdot i_2]$$



$$\Delta A_{MAX} = \frac{1}{6} \cdot L \cdot \frac{FL}{4} \cdot \left[\left(1 + \frac{1}{2}\right) \cdot (-L) + \left(1 + \frac{1}{2}\right) \cdot \frac{L}{4} \right]$$

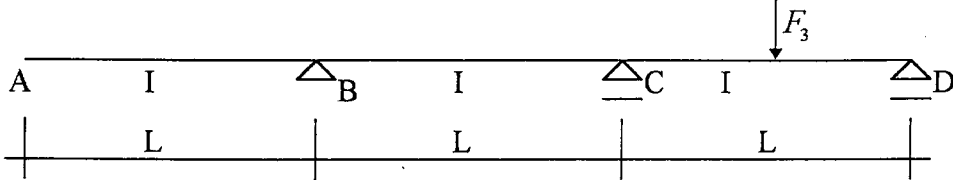
$$\Delta A_{MAX} = \delta_{AF} = \frac{FL^2}{24} \cdot \left[\frac{-3L}{2} + \frac{3L}{8} \right] \cdot \frac{1}{EI}$$

$$\Delta A_{MAX} = \delta_{AF} = \frac{-3}{64} \cdot \frac{FL^3}{EI}$$

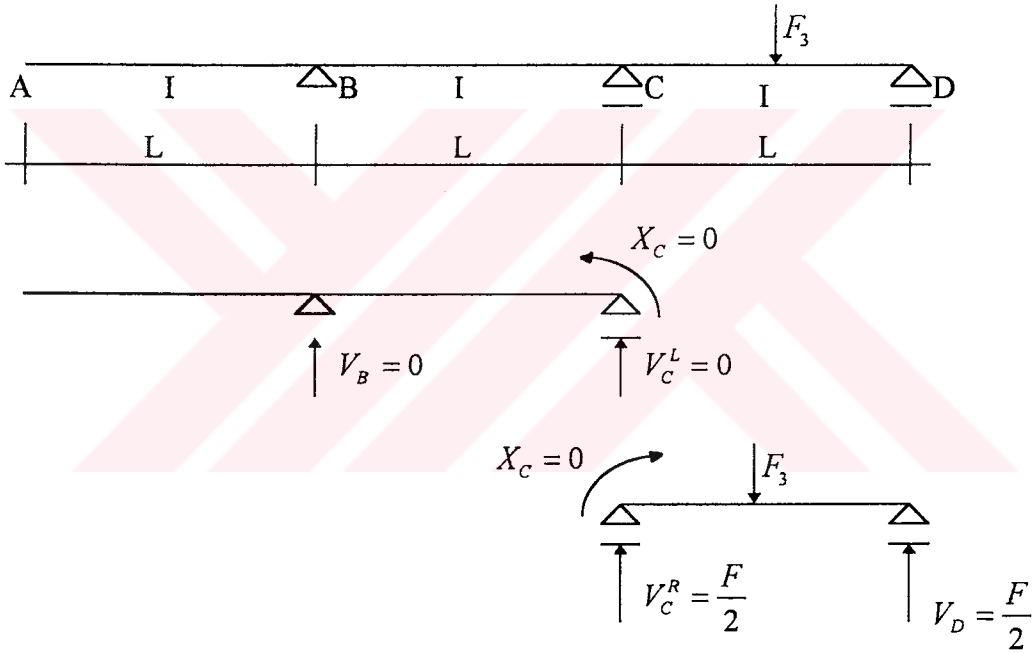
2.3.1.4. 3.Açıklık ortasında F_3 tekil yük hali

$$\delta_{AF_3} = \int M_F^1 \cdot M_1^0 \cdot \frac{dx}{EI}$$

M_F^1 : Hiperstatik sistemde F yüklemesi

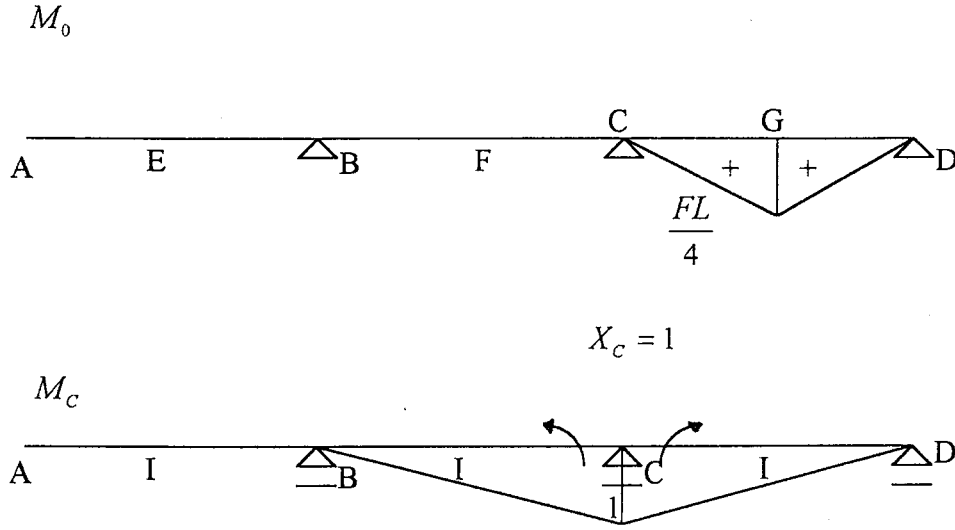


Sıfır yüklemesi : $X_i = 0$ ($X_C = 0$)



$$\sum M_C = 0 \quad V_D \cdot L - \frac{FL}{2} = 0 \quad V_D = \frac{F}{2}$$

$$\sum M_D = 0 \quad V_C^R \cdot L - \frac{FL}{2} = 0 \quad V_B = \frac{F}{2}$$



$$\delta_{c_0} = \frac{1}{6} \cdot L \cdot (1 + \beta) \cdot i \cdot k = \frac{1}{6} \cdot L \cdot \left(1 + \frac{1}{2}\right) \cdot \frac{FL}{4} \cdot 1 \cdot \frac{1}{EI} = \frac{FL^2}{16EI}$$

Sürekli lik denklemi

$$\delta_{c_0} + \delta_{c_c} \cdot X_C = 0$$

$$\frac{2L}{3EI} \cdot X_C + \frac{FL^2}{16EI} = 0$$

$$X_C = M_C = \frac{-3FL}{32}$$

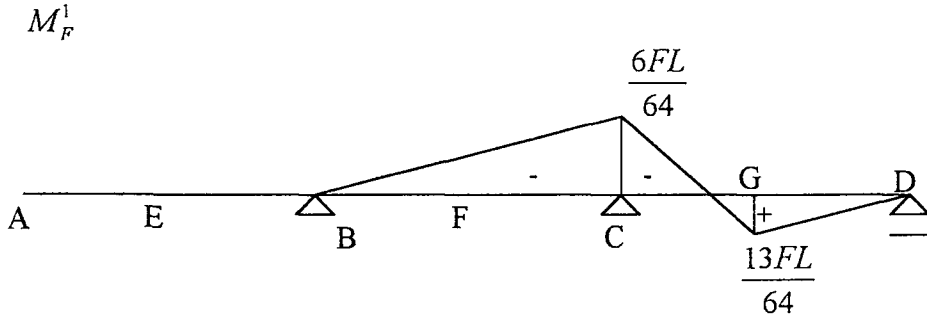
$$M_{\text{sonuç}} = M_0 + M_C \cdot X_C$$

$$M_B = M_{0B} + M_{cB} \cdot X_C = 0 + 0 \cdot \frac{-3FL}{32} = 0$$

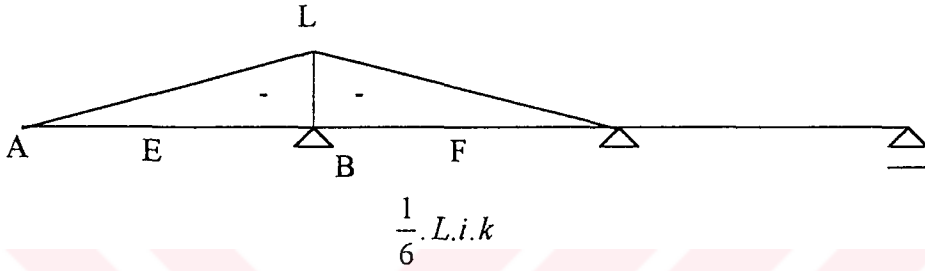
$$M_C = M_{0C} + M_{cC} \cdot X_C = 0 + 1 \cdot \frac{-3FL}{32} = \frac{-3FL}{32}$$

$$M_G = M_{0G} + M_{cG} \cdot X_C = \frac{FL}{4} - \frac{1}{2} \cdot \frac{3FL}{32} = \frac{13FL}{64}$$

$$M_A = M_D = 0$$



M_1^0 : İzostatik sistemde birim yükleme



$$\Delta A_{MAX} = \int M_F^1 \cdot M_1^0 \cdot \frac{dx}{EI}$$

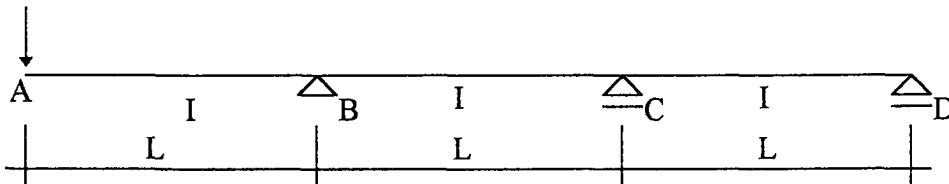
$$\Delta A_{MAX} = \frac{1}{6} \cdot L.i.k = \frac{1}{6} \cdot L \cdot (-L) \cdot \frac{-6FL}{64} \cdot \frac{1}{EI} = \frac{FL^3}{64EI}$$

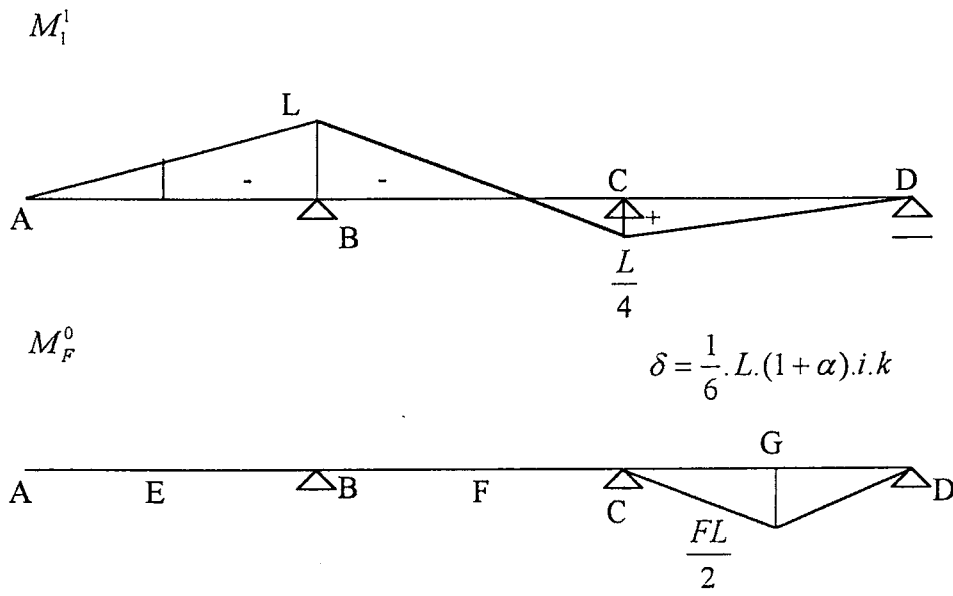
$$\Delta A_{MAX} = \delta_{AF_3} = \frac{FL^3}{64EI}$$

A mesnedindeki maksimum yer değıştirmenin hesabı (2.yol)

$$\delta_{AF_1} = \Delta A_{MAX} = \int M_1^1 \cdot M_F^0 \cdot \frac{dx}{EI}$$

M_1^1 : Hiperstatik sistemde birim yükleme





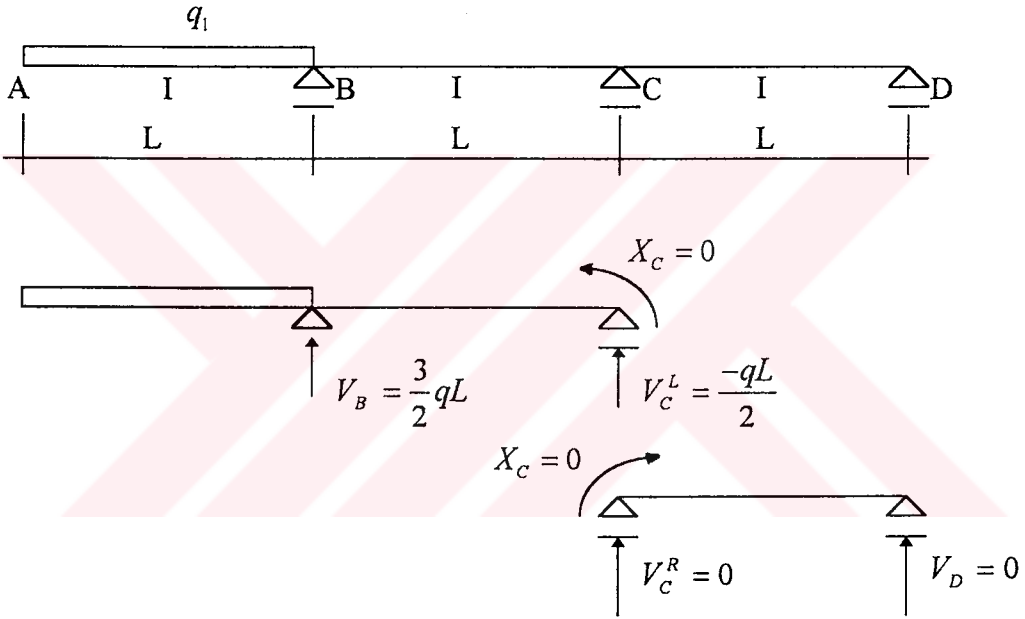
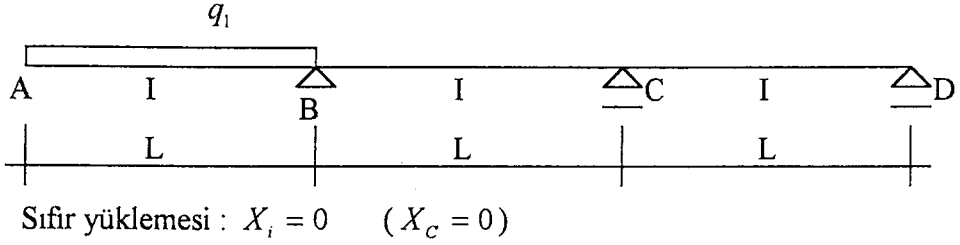
$$\Delta A_{MAX} = \frac{1}{6} \cdot L \cdot \left(1 + \frac{1}{2}\right) \cdot \frac{1}{EI} = \frac{FL^3}{64EI}$$

$$\Delta A_{MAX} = \delta_{AF} = \frac{FL^3}{64EI}$$

2.3.1.5. 1. Açıklıkta q_1 yayılı yük hali

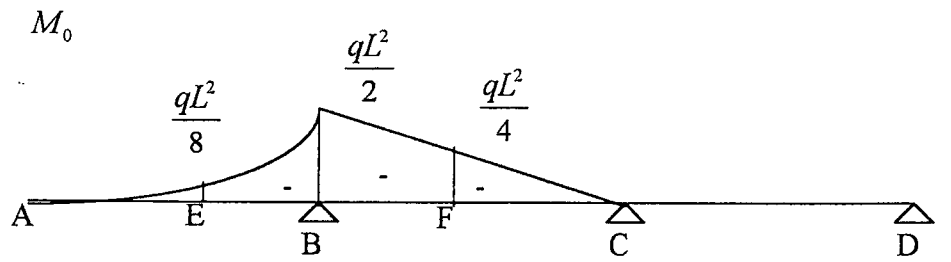
$$\delta_{Aq} = \int M_q^1 \cdot M_1^0 \cdot \frac{dx}{EI}$$

M_q^1 : Hiperstatik sistemde g yüklemesi

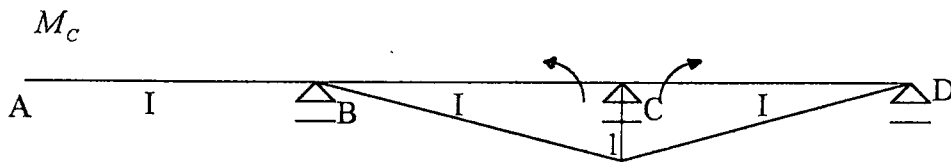


$$\sum M_B = 0 \quad V_C^L \cdot L + q \cdot L \cdot \frac{L}{2} = 0 \quad V_C^L = -\frac{qL}{2}$$

$$\sum M_C = 0 \quad V_B \cdot L - q \cdot L \cdot \frac{3L}{2} = 0 \quad V_B = \frac{3qL}{2}$$



$$X_C = 1$$



$$\delta_{c_0} = \frac{1}{6} \cdot L \cdot i \cdot k = \frac{1}{6} \cdot L \cdot 1 \cdot \frac{-qL^2}{2} \cdot \frac{1}{EI} = \frac{-qL^3}{12EI}$$

$$\delta_{cc} \cdot X_C + \delta_{c_0} = 0$$

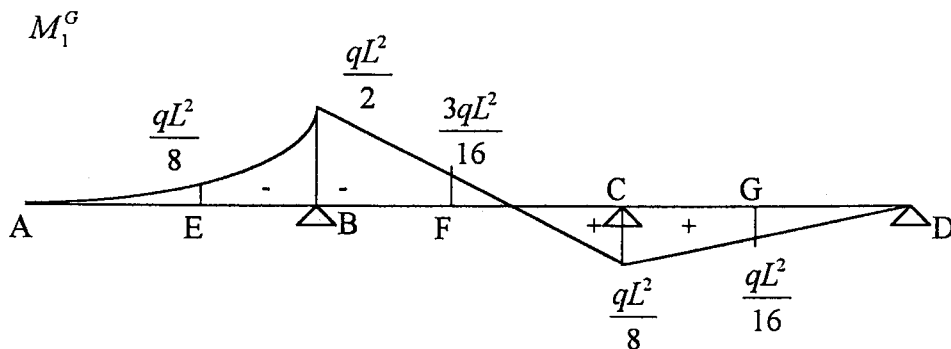
$$\frac{2L}{3EI} \cdot X_C + \frac{-qL^3}{12EI} = 0$$

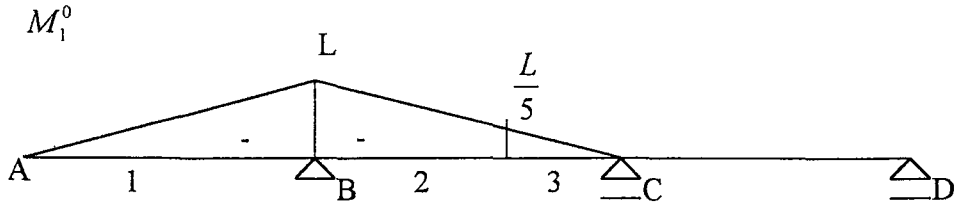
$$X_C = M_C = \frac{qL^2}{8}$$

$$M_E = M_{0E} + M_{CE} \cdot X_C = \frac{qL^2}{8} + 0 \cdot \frac{qL^2}{8} = \frac{qL^2}{8}$$

$$M_F = M_{0F} + M_{CF} \cdot X_C = \frac{-qL^2}{4} + \frac{1}{2} \cdot \frac{qL^2}{8} = \frac{-3qL^2}{16}$$

$$M_G = M_{0G} + M_{CG} \cdot X_C = 0 + \frac{1}{2} \cdot \frac{qL^2}{8} = \frac{qL^2}{16}$$





$$1: \delta = \frac{1}{4} \cdot L \cdot i \cdot k \quad 2: \delta = \frac{1}{6} \cdot L \cdot i \cdot (k_1 + 2k_2) \quad 3: \delta = \frac{1}{6} \cdot L \cdot i \cdot k$$

$$\delta_{Aq} = \Delta A_{MAX} = \frac{1}{4} \cdot L \cdot (-L) \cdot \frac{-qL^2}{2} \cdot \frac{1}{EI} + \frac{1}{6} \cdot \frac{4L}{5} \cdot \frac{-qL^2}{2} \cdot \left(\frac{-L}{5} - 2L\right) \cdot \frac{1}{EI} + \frac{1}{6} \cdot \frac{L}{5} \cdot \frac{-L}{5} \cdot \frac{qL^2}{8} \cdot \frac{1}{EI}$$

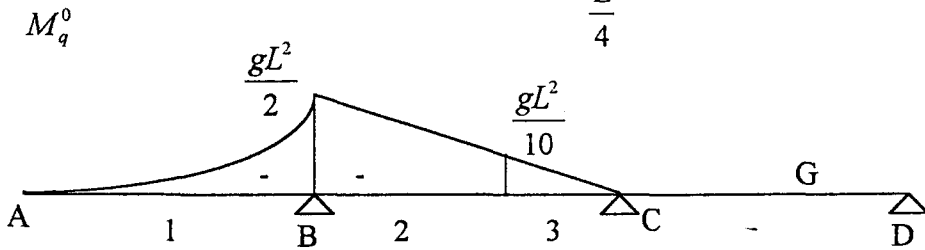
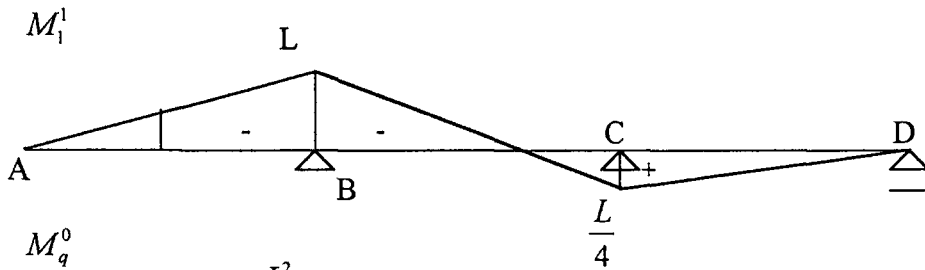
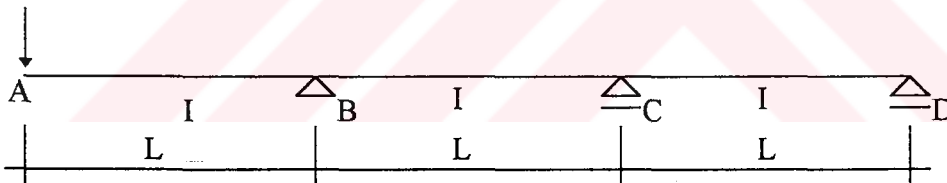
$$\Delta A_{MAX} = \frac{qL^4}{8EI} + \frac{11qL^4}{75EI} - \frac{qL^4}{1200EI}$$

$$\Delta A_{MAX} = \frac{13}{48} \frac{qL^4}{EI}$$

A mesnedindeki maksimum yer değıştirmenin hesabı (2. yol)

$$\delta_{Aq} = \Delta A_{MAX} = \int M_1^1 \cdot M_q^0 \cdot \frac{dx}{EI}$$

M_1^1 : Hiperstatik sistemde birim yükleme



$$1: \delta = \frac{1}{4} \cdot L \cdot i \cdot k \quad 2: \delta = \frac{1}{6} \cdot L \cdot i \cdot (k_1 + 2k_2) \quad 3: \delta = \frac{1}{6} \cdot L \cdot i \cdot k$$

$$\Delta A_{MAX} = \int M_1^1 \cdot M_8^0 \cdot \frac{dx}{EI}$$

$$\Delta A_{MAX} = \frac{1}{4} \cdot L \cdot (-L) \cdot \frac{-qL^2}{2} \cdot \frac{1}{EI} + \frac{1}{6} \cdot \frac{4L}{5} \cdot (-L) \cdot \left(\frac{-qL^2}{10} - \frac{2qL^2}{2} \right) \cdot \frac{1}{EI} + \frac{1}{6} \cdot \frac{L}{5} \cdot \frac{-qL^2}{10} \cdot \frac{L}{4} \cdot \frac{1}{EI}$$

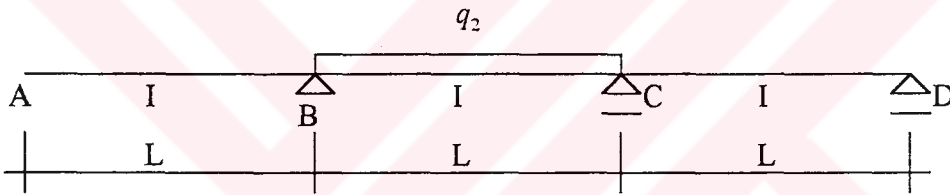
$$\Delta A_{MAX} = \frac{qL^4}{8EI} + \frac{44qL^4}{300EI} - \frac{qL^4}{1200EI}$$

$$\Delta A_{MAX} = \frac{13}{48} \cdot \frac{qL^4}{EI}$$

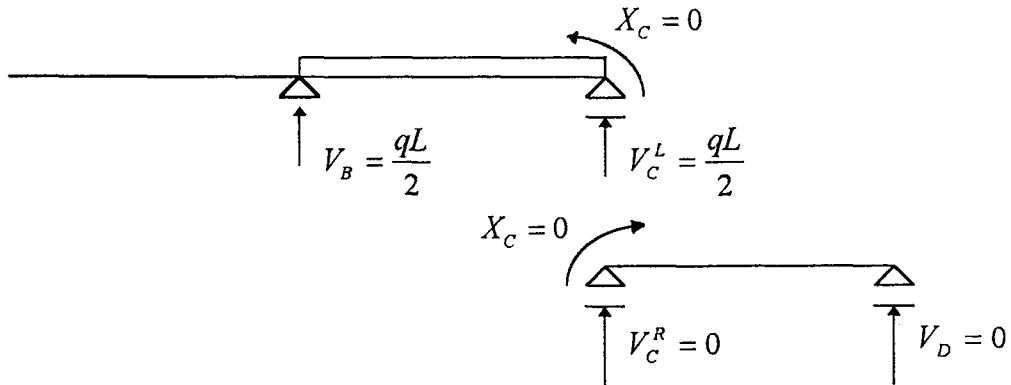
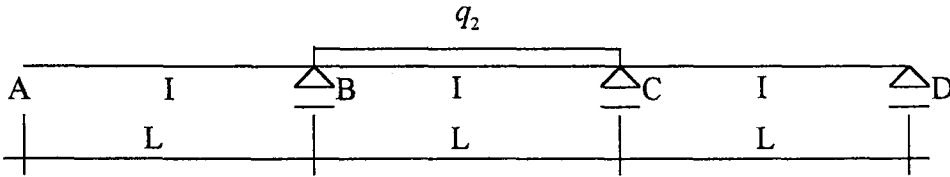
2.3.1.6. 2. Açıklıkta q_2 yayılı yük hali

$$\delta_{Aq} = \int M_q^1 \cdot M_1^0 \cdot \frac{dx}{EI}$$

M_q^1 : Hiperstatik sistemde g yüklemesi



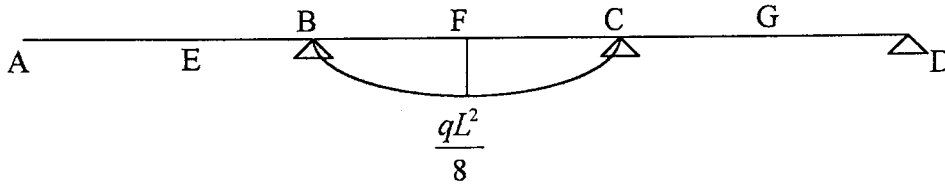
Sıfır yüklemesi : $X_i = 0$ ($X_c = 0$)



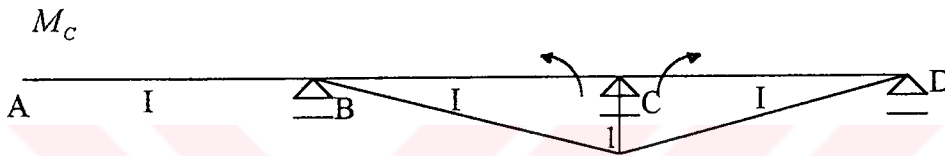
$$\sum M_B = 0 \quad V_C^L \cdot L - q \cdot L \cdot \frac{L}{2} = 0 \quad V_C^L = \frac{qL}{2}$$

$$\sum M_C = 0 \quad V_B \cdot L - q \cdot L \cdot \frac{L}{2} = 0 \quad V_B = \frac{qL}{2}$$

M_0



$$X_C = 1$$



$$\delta_{c0} = \frac{1}{3} \cdot L \cdot i \cdot k = \frac{1}{3} \cdot L \cdot 1 \cdot \frac{qL^2}{8} \cdot \frac{1}{EI} = \frac{qL^3}{24EI}$$

Süreklilik denklemi:

$$\delta_{cc} \cdot X_C + \delta_{c0} = 0$$

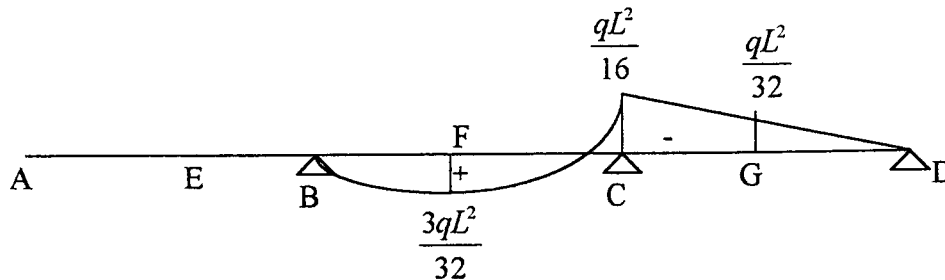
$$\frac{2L}{3EI} \cdot X_C + \frac{qL^3}{24EI} = 0$$

$$X_C = M_C = \frac{-qL^2}{16}$$

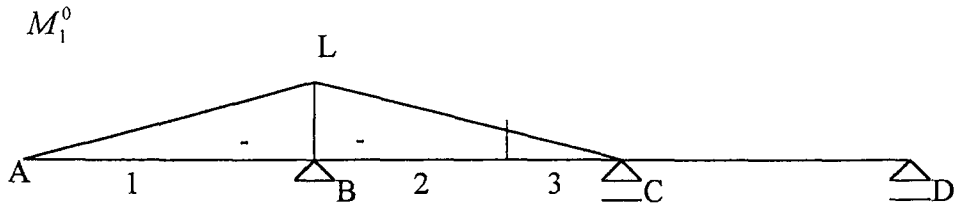
$$M_E = M_{0E} + M_{CE} \cdot X_C = 0 + 0 \cdot \frac{-qL^2}{16} = 0$$

$$M_G = M_{0G} + M_{CG} \cdot X_C = 0 + \frac{1}{2} \cdot \frac{-qL^2}{16} = \frac{-qL^2}{32}$$

M_1^G



M_1^0 : İzostatik sistemde birim yükleme



$$\delta_{Aq} = \Delta A_{MAX} = \frac{\Delta S}{6} \cdot [v_1 \cdot (u_1 + 2u') + v_2 \cdot (u_2 + 2u')]$$

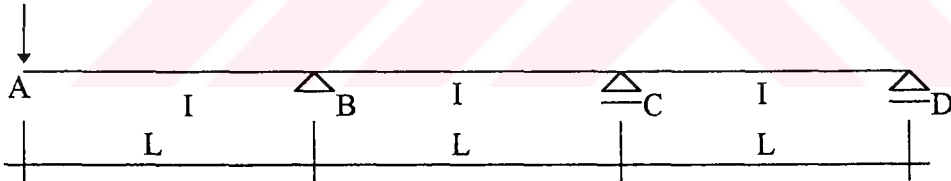
$$\Delta A_{MAX} = \frac{L}{6} \cdot \left[-L \cdot \left(0 + 2 \cdot \frac{3qL^2}{32} \right) + 0 \cdot \left(\frac{-qL^2}{16} + 2 \cdot \frac{3qL^2}{32} \right) \right]$$

$$\Delta A_{MAX} = \frac{-qL^4}{32EI}$$

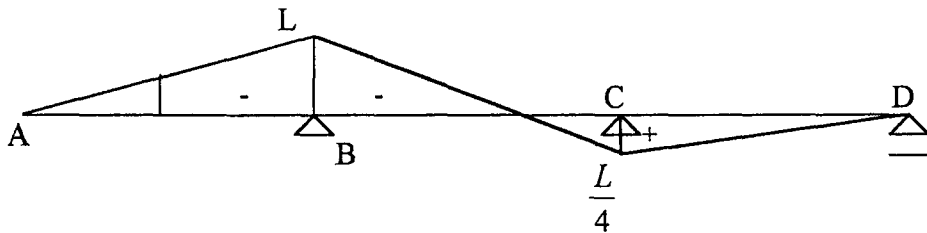
A mesnedindeki maksimum yer değıştirmenin hesabı (2. yol)

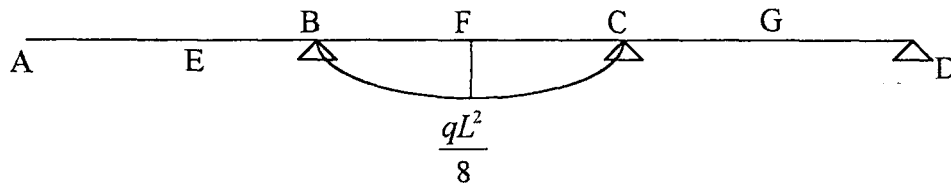
$$\delta_{Aq} = \Delta A_{MAX} = \int M_1^1 \cdot M_q^0 \cdot \frac{dx}{EI}$$

M_1^1 : Hiperstatik sistemde birim yükleme



M_1^1





$$\Delta A_{MAX} = \int M_1^1 \cdot M_2^0 \cdot \frac{dx}{EI}$$

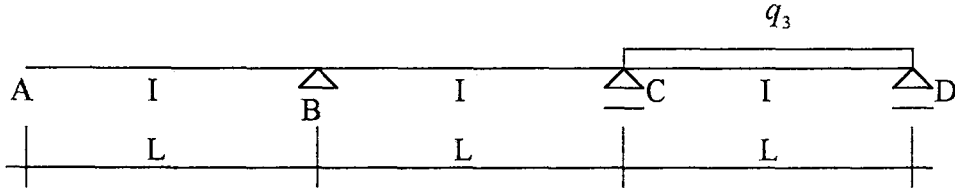
$$\Delta A_{MAX} = \frac{1}{3} \cdot L \cdot (i_1 + i_2) \cdot k = \frac{1}{3} \cdot L \cdot \left(\frac{L}{4} - L\right) \cdot \frac{qL^2}{8} \cdot \frac{1}{EI}$$

$$\Delta A_{MAX} = \frac{-qL^4}{32EI}$$

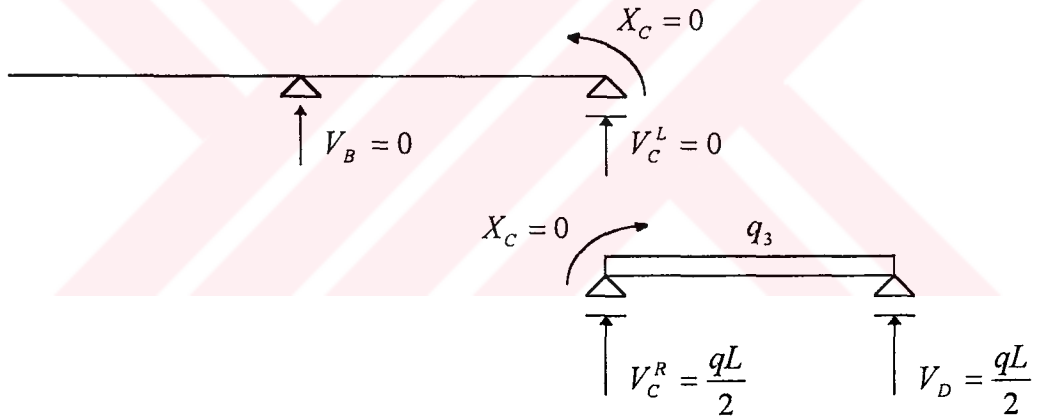
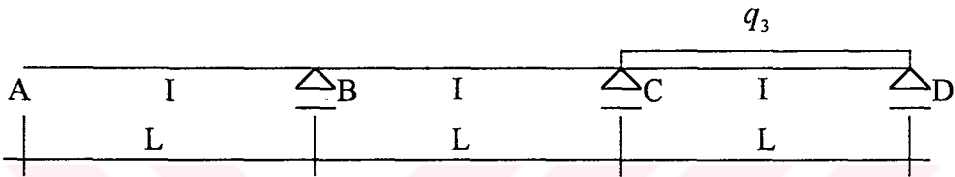
2.3.1.7. 3. Açıklıkta q_3 yayılı yük hali

$$\delta_{Aq} = \int M_q^1 \cdot M_1^0 \cdot \frac{dx}{EI}$$

M_q^1 : Hiperstatik sistemde q yüklemesi



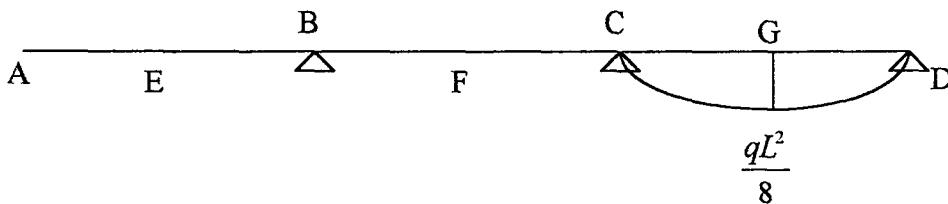
Sıfır yüklemesi : $X_i = 0$ ($X_C = 0$)

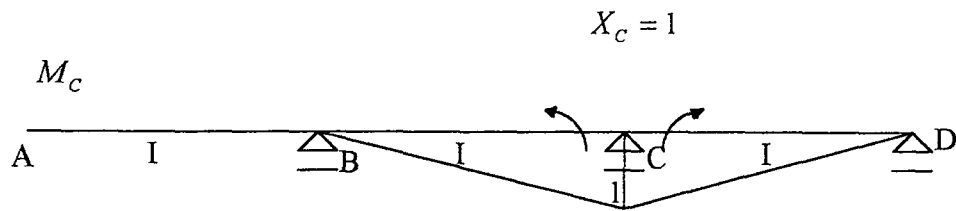


$$\sum M_D = 0 \quad V_C^R \cdot L - q \cdot L \cdot \frac{L}{2} = 0 \quad V_C^R = \frac{qL}{2}$$

$$\sum M_C = 0 \quad V_D \cdot L - q \cdot L \cdot \frac{L}{2} = 0 \quad V_D = \frac{qL}{2}$$

M_0





$$\delta_{c_0} = \frac{1}{3} \cdot L \cdot i \cdot k = \frac{1}{3} \cdot L \cdot l \cdot \frac{qL^2}{8} \cdot \frac{1}{EI} = \frac{qL^3}{24EI}$$

$$\delta_{cc} \cdot X_C + \delta_{c_0} = 0$$

$$\frac{2L}{3EI} \cdot X_C + \frac{qL^3}{24EI} = 0$$

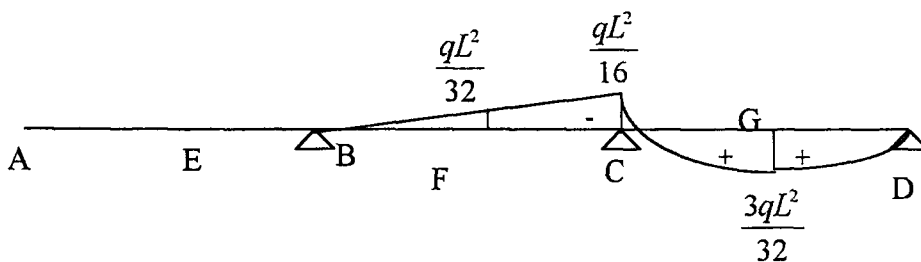
$$X_C = M_C = \frac{-qL^2}{16}$$

$$M_E = M_{0E} + M_{CE} \cdot X_C = 0 + 0 \cdot \frac{-qL^2}{16} = 0$$

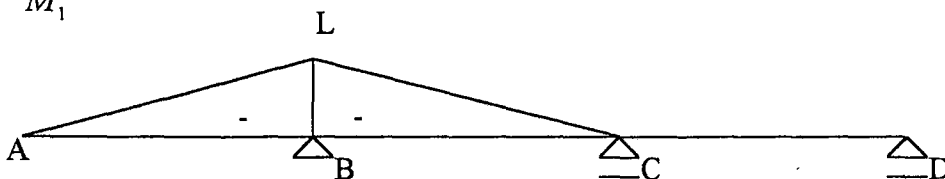
$$M_F = M_{0F} + M_{CF} \cdot X_C = 0 + \frac{1}{2} \cdot \frac{-qL^2}{16} = \frac{-qL^2}{32}$$

$$M_G = M_{0G} + M_{CG} \cdot X_C = \frac{qL^2}{8} + \frac{1}{2} \cdot \frac{-qL^2}{16} = \frac{3qL^2}{32}$$

M_1^G



M_1^0



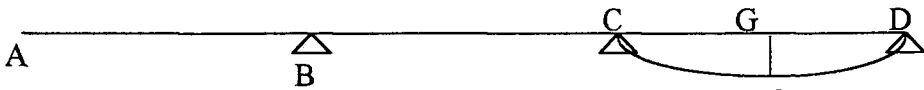
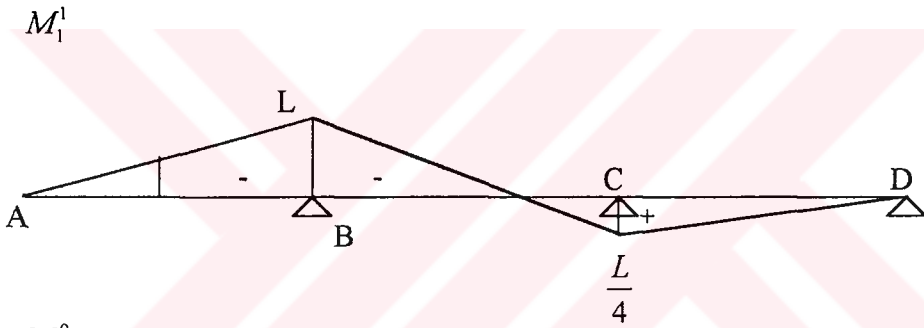
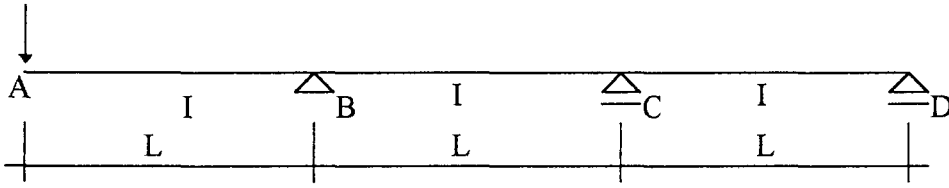
$$\delta = \frac{1}{6} \cdot L \cdot i \cdot k$$

$$\delta_{Aq} = \Delta A_{MAX} = \frac{1}{6} \cdot L \cdot (-L) \cdot \frac{-qL^2}{16} \cdot \frac{1}{EI} = \frac{qL^4}{96} \cdot \frac{1}{EI}$$

$$\Delta A_{MAX} = \frac{1}{96} \cdot \frac{qL^4}{EI}$$

A mesnedindeki maksimum yer değıştirmenin hesabı (2. yol)

$$\delta_{Aq} = \Delta A_{MAX} = \int M_1^1 \cdot M_q^0 \cdot \frac{dx}{EI}$$



$$\delta = \frac{1}{3} \cdot L \cdot i \cdot k$$

$$\Delta A_{MAX} = \int M_1^1 \cdot M_g^0 \cdot \frac{dx}{EI}$$

$$\Delta A_{MAX} = \frac{1}{3} \cdot L \cdot \frac{L}{4} \cdot \frac{gL^2}{8} \cdot \frac{1}{EI} = \frac{1}{96} \cdot \frac{qL^4}{EI}$$

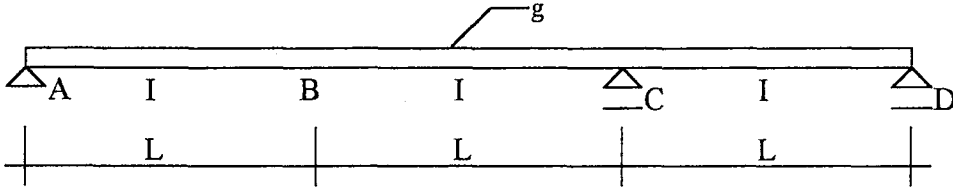
$$\Delta A_{MAX} = \frac{1}{96} \cdot \frac{qL^4}{EI}$$

2.3.2. B kesitindeki maksimum yer deęiřtirmenin hesabı

2.3.2.1. g sabit yük hali

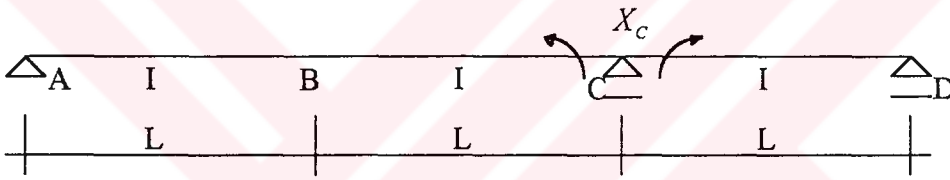
$$\delta_{B_g} = \int M_g^1 \cdot M_1^0 \cdot \frac{dx}{EI}$$

M_g^1 : Hiperstatik sistemde g yüklemesi

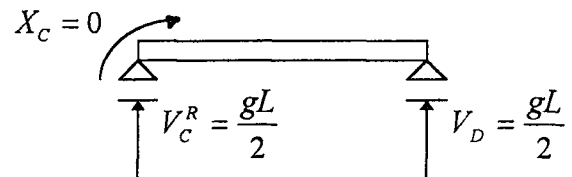
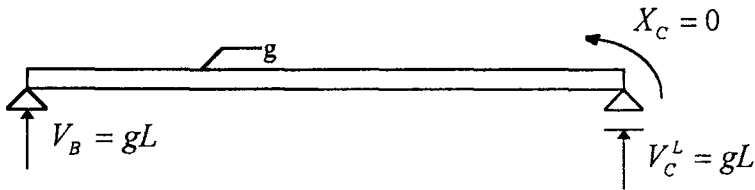
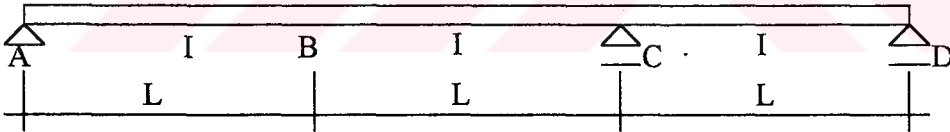


a) 1. dereceden hiperstatik

b) İzostatik esas sistem seçilmesi : İzostatik esas sistem ve hiperstatik bilinmeyenler



c) Sıfır yüklemesi : $X_i = 0$ ($X_c = 0$)



$$\sum M_C = 0$$

$$V_A \cdot 2L - g \cdot 2L \cdot L = 0$$

$$V_A = gL$$

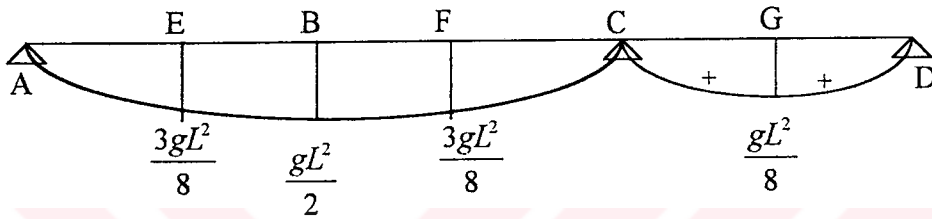
$$\sum M_A = 0 \quad V_C^L \cdot 2L - g \cdot 2L \cdot L = 0 \quad V_C^L = gL$$

$$\sum M_D = 0 \quad V_C^R \cdot L - g \cdot L \cdot \frac{L}{2} = 0 \quad V_C^R = V_D = \frac{gL}{2}$$

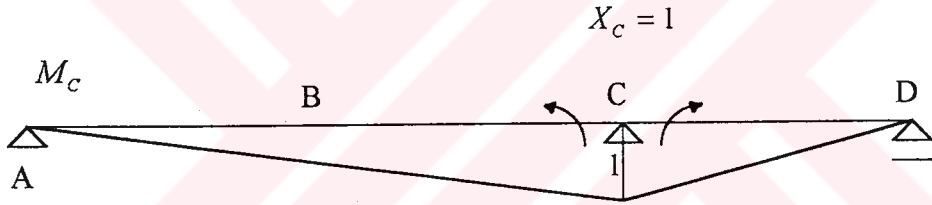
$$M_{MAXG} = V_C^R \cdot \frac{L}{2} - \frac{gL}{2} \cdot \frac{L}{4} = \frac{gL^2}{8}$$

$$M_{MAXB} = V_A \cdot L - g \cdot L \cdot \frac{L}{2} = \frac{gL^2}{2}$$

$$M_0$$



d) Birim yüklemeler :



$$\delta_{CC} = \int M_C \cdot M_C \cdot \frac{dx}{EI} = \frac{1}{3} \cdot 2L \cdot 1 \cdot \frac{1}{EI} + \frac{1}{3} \cdot L \cdot 1 \cdot \frac{1}{EI} = \frac{L}{EI}$$

$$\delta_{C0} = \frac{1}{3} \cdot 2L \cdot \frac{gL^2}{2} \cdot 1 \cdot \frac{1}{EI} + \frac{1}{3} \cdot L \cdot 1 \cdot \frac{gL^2}{8} \cdot \frac{1}{EI} = \frac{3}{8} \cdot \frac{gL^3}{EI}$$

Sürekli denklemler:

$$\delta_{CC} \cdot X_C + \delta_{C0} = 0$$

$$\frac{L}{EI} \cdot X_C + \frac{3}{8} \cdot \frac{gL^3}{EI} = 0$$

$$X_C = M_C = \frac{-3gL^2}{8}$$

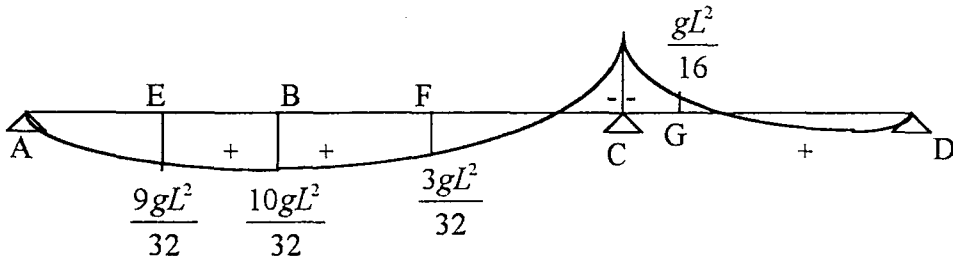
$$M_E = M_{0E} + M_{CE} \cdot X_C = \frac{3gL^2}{8} + \frac{1}{4} \cdot \frac{-3gL^2}{8} = \frac{9gL^2}{32}$$

$$M_B = M_{0B} + M_{CB} \cdot X_C = \frac{gL^2}{2} + \frac{2}{4} \cdot \frac{-3gL^2}{8} = \frac{10gL^2}{32}$$

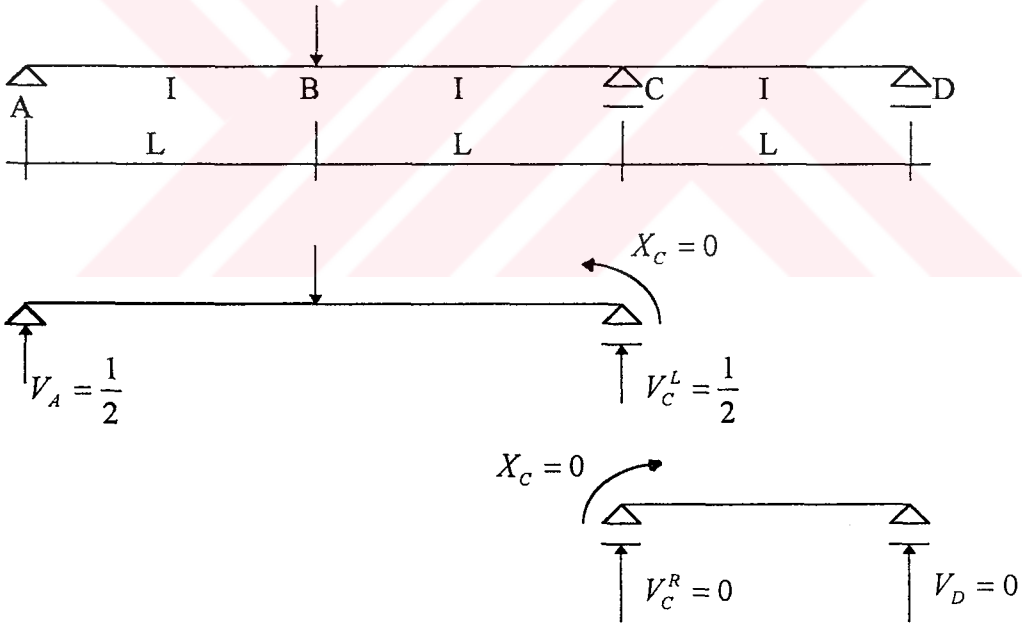
$$M_F = M_{0F} + M_{CF} \cdot X_C = \frac{3gL^2}{8} + \frac{3}{4} \cdot \frac{-3gL^2}{8} = \frac{3gL^2}{32}$$

$$M_G = M_{0G} + M_{CG} \cdot X_C = \frac{gL^2}{8} + \frac{1}{2} \cdot \frac{-3gL^2}{8} = \frac{-gL^2}{16}$$

$$M_1^G$$

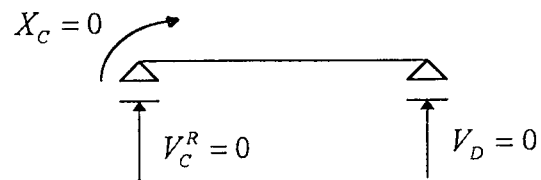


M_1^0 : İzostatik sistemde birim yükleme



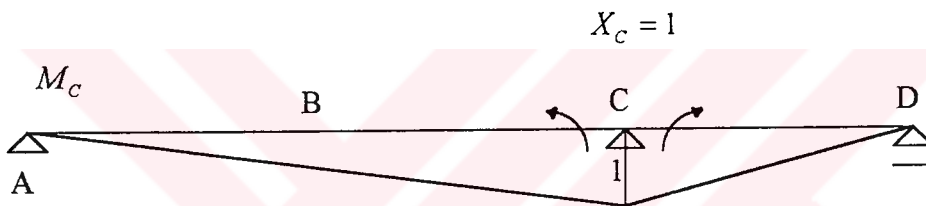
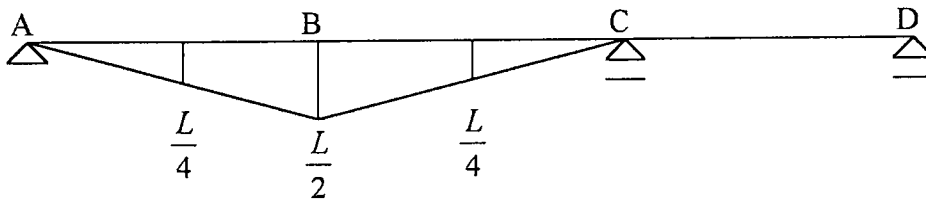
$$\sum M_C = 0 \quad V_A \cdot 2L - 1 \cdot L = 0 \quad V_A = \frac{1}{2} = V_C^L$$

$$\sum M_D = 0 \quad V_C^R = V_D = 0$$



$$\sum M_C = V_A \cdot 2L - 1 \cdot L = 0 \quad V_A = \frac{1}{2} = V_C^L$$

M_0



$$\delta_{c_0} = \frac{1}{6} \cdot L \cdot (1 + \alpha) \cdot i \cdot k = \frac{1}{6} \cdot 2L \cdot \left(1 + \frac{1}{2}\right) \cdot 1 \cdot \frac{L}{2} \cdot \frac{1}{EI} = \frac{L^2}{4EI}$$

$$\delta_{c_0} + \delta_{cc} \cdot X_C = 0$$

$$\frac{L^2}{4EI} + \frac{L}{EI} \cdot X_C = 0$$

$$X_C = M_C = \frac{-L}{4}$$

$$M_{\text{somuq}} = M_0 + M_C \cdot X_C$$

$$M_B = M_{0B} + M_{CB} \cdot X_C = \frac{L}{2} + \frac{2}{4} \cdot \frac{-L}{4} = \frac{6L}{16}$$

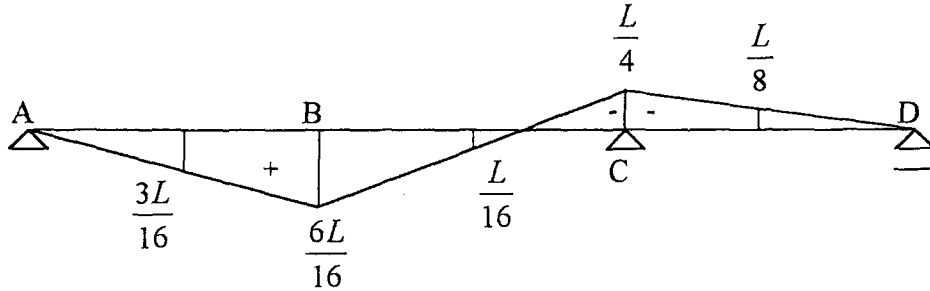
$$M_E = M_{0E} + M_{CE} \cdot X_C = \frac{L}{4} + \frac{1}{4} \cdot \frac{-L}{4} = \frac{3L}{16}$$

$$M_F = M_{0F} + M_{CF} \cdot X_C = \frac{L}{4} + \frac{3}{4} \cdot \frac{-L}{4} = \frac{L}{16}$$

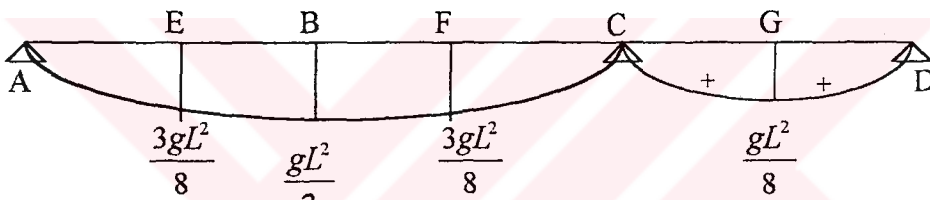
$$M_G = M_{0G} + M_{CG} \cdot X_C = 0 + \frac{1}{2} \cdot \frac{-L}{4} = \frac{-L}{8}$$

$$M_A = M_D = 0$$

$$M_1^1$$



$$M_g^0$$



$$\Delta B_{MAX} = \int M_1^1 \cdot M_g^0 \cdot \frac{dx}{EI}$$

$$\delta_{Bg} = \Delta B_{MAX} = \int u \cdot v \cdot ds = \frac{\Delta S}{6} \cdot [v_1 \cdot (u_1 + 2u') + v_2 \cdot (u_2 + 2u')]$$

$$\Delta B_{MAX1} = \frac{L}{6} \cdot \left[0 + \frac{6L}{16} \cdot \left(\frac{gL^2}{2} + 2 \cdot \frac{3gL^2}{8} \right) \right] \cdot \frac{1}{EI} = \frac{5}{64} \cdot \frac{gL^4}{EI}$$

$$\Delta B_{MAX2} = \frac{L}{6} \cdot \left[\frac{6L}{16} \cdot \left(\frac{gL^2}{2} + 2 \cdot \frac{3gL^2}{8} \right) + \frac{-L}{4} \cdot \left(0 + 2 \cdot \frac{3gL^2}{8} \right) \right] \cdot \frac{1}{EI} = \frac{3}{64} \cdot \frac{gL^4}{EI}$$

$$\Delta B_{MAX3} = \frac{1}{3} \cdot L \cdot i \cdot k = \frac{1}{3} \cdot L \cdot \frac{-L}{4} \cdot \frac{gL^2}{8} \cdot \frac{1}{EI} = \frac{-1}{96} \cdot \frac{gL^4}{EI}$$

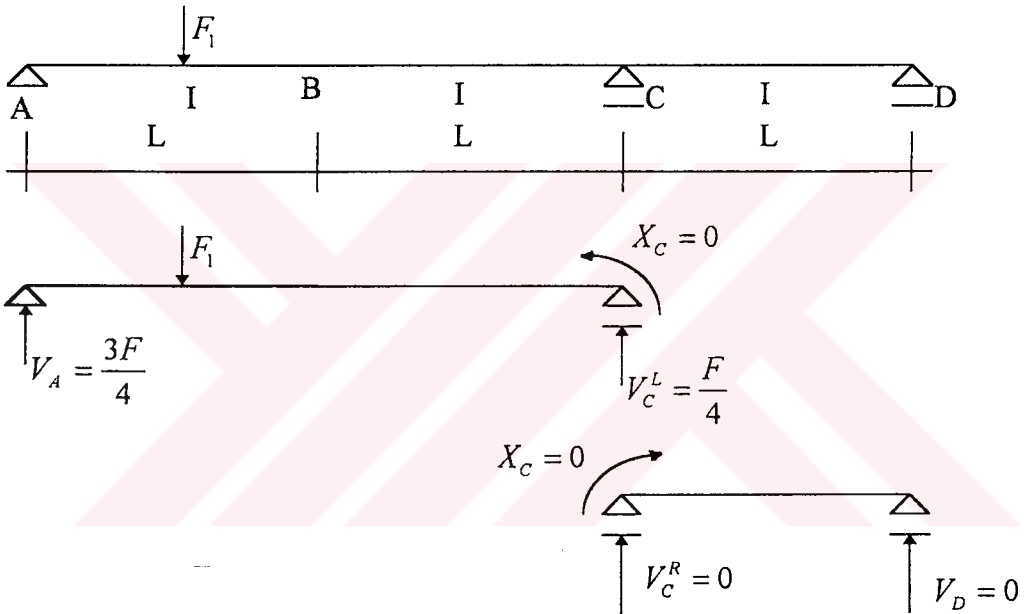
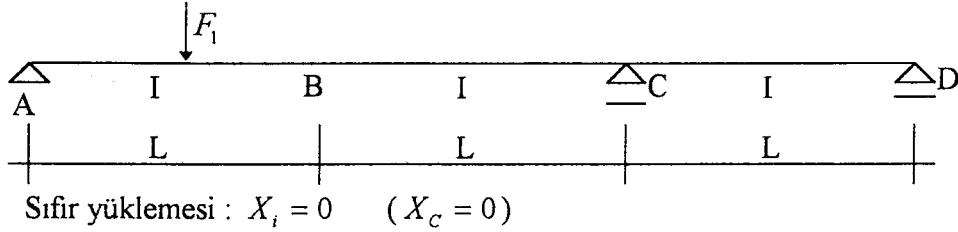
$$\Delta B_{MAX\Sigma} = \Delta B_{MAX1} + \Delta B_{MAX2} + \Delta B_{MAX3} = \frac{5}{64} \cdot \frac{gL^4}{EI} + \frac{3}{64} \cdot \frac{gL^4}{EI} - \frac{1}{96} \cdot \frac{gL^4}{EI} = \frac{11}{96} \cdot \frac{gL^4}{EI}$$

$$\Delta B_{MAX} = \frac{11}{96} \cdot \frac{gL^4}{EI}$$

2.3.2.2. 1.Açıklık ortasında F_1 tekil yük hali

$$\delta_{BF_1} = \int M_F^1 \cdot M_1^0 \cdot \frac{dx}{EI}$$

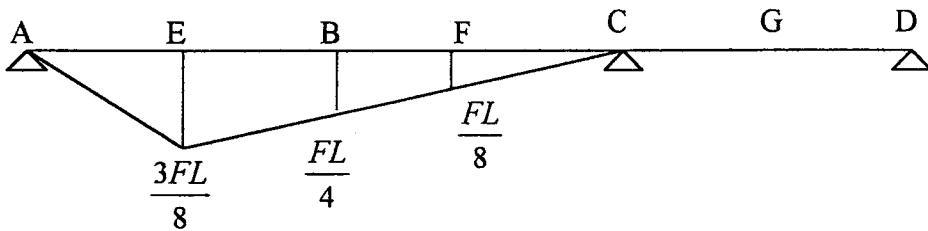
M_F^1 : Hiperstatik sistemde F yüklemesi

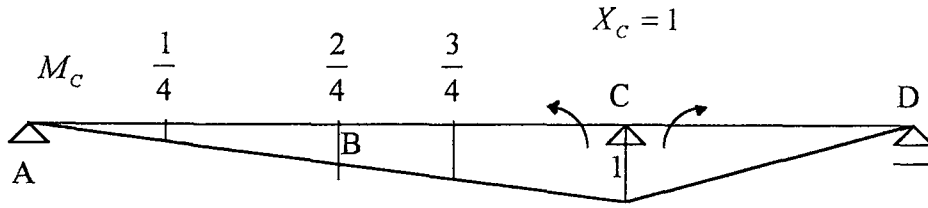


$$\sum M_C = 0 \quad V_A \cdot 2L - F \cdot \frac{3L}{2} = 0 \quad V_A = \frac{3F}{4}$$

$$\sum M_A = 0 \quad V_C^L \cdot 2L - F \cdot \frac{L}{2} = 0 \quad V_B = \frac{F}{4}$$

M_0





$$\delta_{c_0} = \frac{1}{6} \cdot L \cdot (1 + \alpha) \cdot i \cdot k = \frac{1}{6} \cdot 2L \cdot \left(1 + \frac{1}{4}\right) \cdot 1 \cdot \frac{3FL}{8} \cdot \frac{1}{EI} = \frac{5}{32} \cdot \frac{FL^2}{EI}$$

Sürekliлік denklemi:

$$\delta_{CC} \cdot X_C + \delta_{c_0} = 0$$

$$\frac{L}{EI} \cdot X_C + \frac{5}{32} \cdot \frac{FL^2}{EI} = 0$$

$$X_C = M_C = \frac{-5FL}{32}$$

$$M_E = M_{0E} + M_{CE} \cdot X_C = \frac{3FL}{8} + \frac{1}{4} \cdot \frac{-5FL}{32} = \frac{43FL}{32}$$

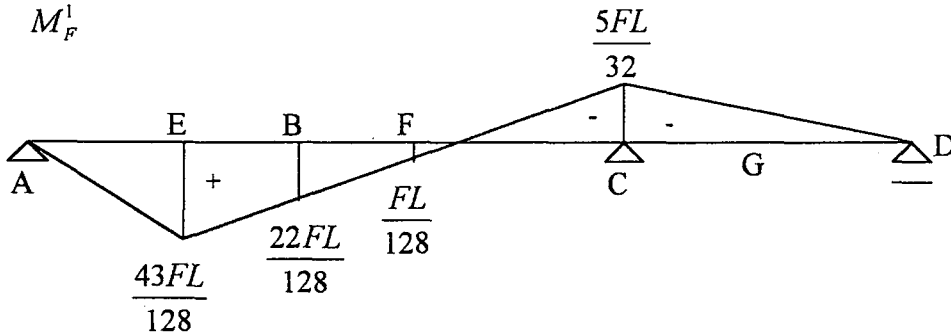
$$M_B = M_{0B} + M_{CB} \cdot X_C = \frac{FL}{4} + \frac{2}{4} \cdot \frac{-5FL}{32} = \frac{22FL}{32}$$

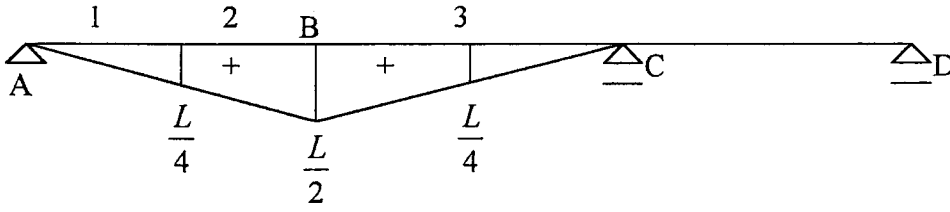
$$M_F = M_{0F} + M_{CF} \cdot X_C = \frac{FL}{8} + \frac{3}{4} \cdot \frac{-5FL}{32} = \frac{FL}{128}$$

$$M_G = M_{0G} + M_{CG} \cdot X_C = 0 + \frac{1}{2} \cdot \frac{-5FL}{32} = \frac{-5FL}{64}$$

$$M_A = M_D = 0$$

M_F^1



M_1^0


$$\Delta B_{MAX} = \int M_F^1 \cdot M_1^0 \cdot \frac{dx}{EI}$$

$$\Delta B_{MAX1} = \frac{1}{3} \cdot L \cdot i \cdot k = \frac{1}{3} \cdot \frac{L}{2} \cdot \frac{43FL}{128} \cdot \frac{L}{4} \cdot \frac{1}{EI} = \frac{43}{3072} \cdot \frac{FL^3}{EI}$$

$$\Delta B_{MAX2} = \frac{1}{6} \cdot L \cdot (2i_1k_1 + i_1k_2 + i_2k_1 + 2i_2k_2)$$

$$\Delta B_{MAX2} = \frac{1}{6} \cdot \frac{L}{2} \cdot \left(2 \cdot \frac{43FL}{128} \cdot \frac{L}{4} + \frac{43FL}{128} \cdot \frac{L}{2} + \frac{22FL}{128} \cdot \frac{L}{4} + 2 \cdot \frac{22FL}{128} \cdot \frac{L}{2} \right) = \frac{141}{3072} \cdot \frac{FL^3}{EI}$$

$$\Delta B_{MAX3} = \frac{1}{6} \cdot L \cdot i \cdot (k_1 + 2k_2)$$

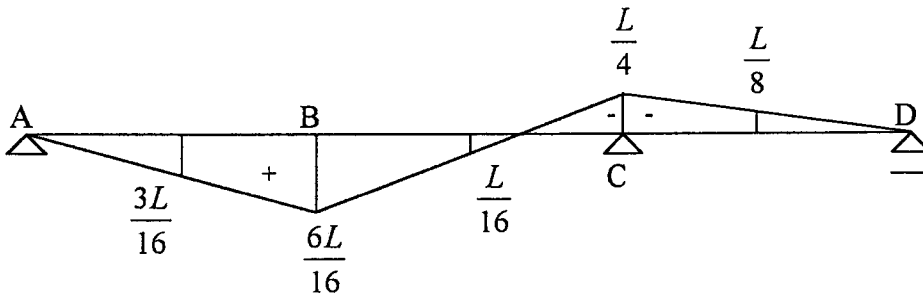
$$\Delta B_{MAX3} = \frac{1}{6} \cdot L \cdot \frac{L}{2} \cdot \left(2 \cdot \frac{22FL}{128} - \frac{20FL}{128} \right) \cdot \frac{1}{EI} = \frac{48}{3072} \cdot \frac{FL^3}{EI}$$

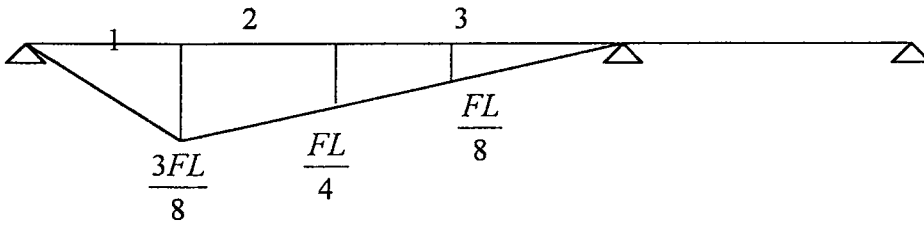
$$\Delta B_{MAX\Sigma} = \Delta B_{MAX1} + \Delta B_{MAX2} + \Delta B_{MAX3} = \frac{43}{3072} \cdot \frac{FL^3}{EI} + \frac{141}{3072} \cdot \frac{FL^3}{EI} + \frac{48}{3072} \cdot \frac{FL^3}{EI} = \frac{232}{3072} \cdot \frac{FL^3}{EI}$$

$$\Delta B_{MAX} = \delta_{BF_1} = \frac{29}{384} \cdot \frac{FL^3}{EI}$$

B mesnedindeki maksimum yer değıştirmenin hesabı (2.yol)

$$\delta_{BF_1} = \Delta B_{MAX} = \int M_1^1 \cdot M_F^0 \cdot \frac{dx}{EI}$$

 M_1^1


M_F^0 

$$\Delta B_{MAX} = \int M_1^1 \cdot M_F^0 \cdot \frac{dx}{EI}$$

$$\Delta B_{MAX_1} = \frac{1}{3} \cdot L \cdot i \cdot k = \frac{1}{3} \cdot \frac{L}{2} \cdot \frac{3FL}{8} \cdot \frac{3L}{16} \cdot \frac{1}{EI} = \frac{3}{256} \cdot \frac{FL^3}{EI}$$

$$\Delta B_{MAX_2} = \frac{1}{6} \cdot L \cdot (2i_1 k_1 + i_1 k_2 + i_2 k_1 + 2i_2 k_2)$$

$$\Delta B_{MAX_2} = \frac{1}{6} \cdot \frac{L}{2} \cdot \left(2 \cdot \frac{3FL}{8} \cdot \frac{3L}{16} + \frac{FL}{4} \cdot \frac{3L}{16} + \frac{3FL}{8} \cdot \frac{6L}{16} + 2 \cdot \frac{FL}{4} \cdot \frac{6L}{16} \right) = \frac{11}{256} \cdot \frac{FL^3}{EI}$$

$$\Delta B_{MAX_3} = \frac{1}{6} \cdot L \cdot i \cdot (k_1 + 2k_2)$$

$$\Delta B_{MAX_3} = \frac{1}{6} \cdot L \cdot \frac{FL}{4} \cdot \left(\frac{-L}{4} + 2 \cdot \frac{6L}{16} \right) \cdot \frac{1}{EI} = \frac{1}{48} \cdot \frac{FL^3}{EI}$$

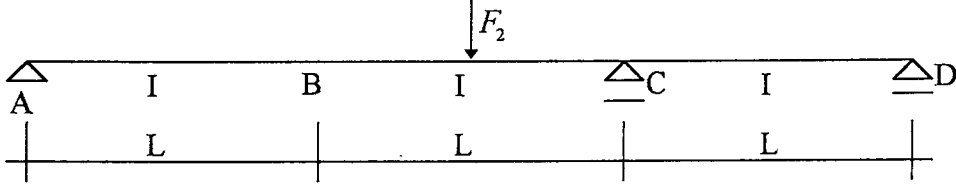
$$\Delta B_{MAX \Sigma} = \Delta B_{MAX_1} + \Delta B_{MAX_2} + \Delta B_{MAX_3} = \frac{3}{256} \cdot \frac{FL^3}{EI} + \frac{11}{256} \cdot \frac{FL^3}{EI} + \frac{1}{48} \cdot \frac{FL^3}{EI} = \frac{232}{3072} \cdot \frac{FL^3}{EI}$$

$$\Delta B_{MAX} = \delta_{BF_1} = \frac{29}{384} \cdot \frac{FL^3}{EI}$$

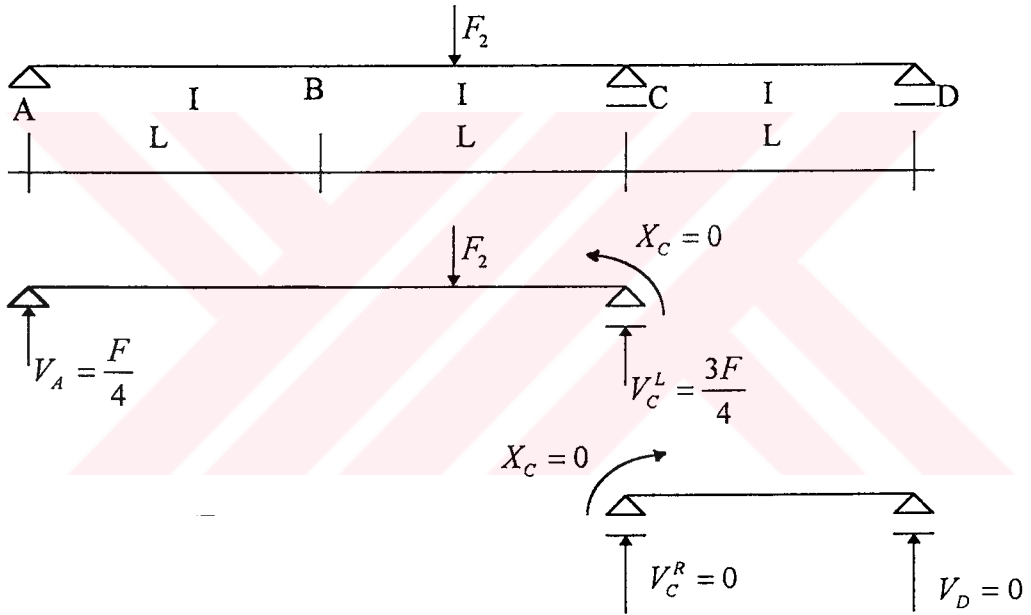
2.3.2.3. 2.Açıklık ortasında F_2 tekil yük hali

$$\delta_{BF_2} = \int M_F^1 \cdot M_1^0 \cdot \frac{dx}{EI}$$

M_F^1 : Hiperstatik sistemde F yüklemesi



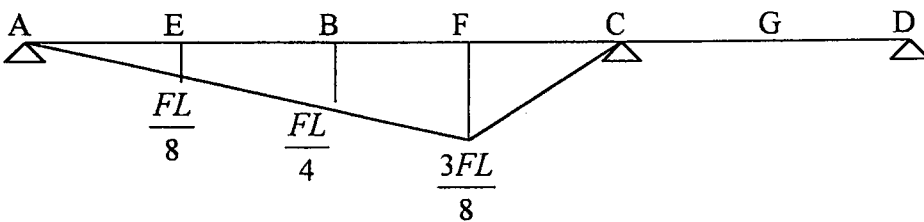
Sıfır yüklemesi : $X_i = 0$ ($X_c = 0$)

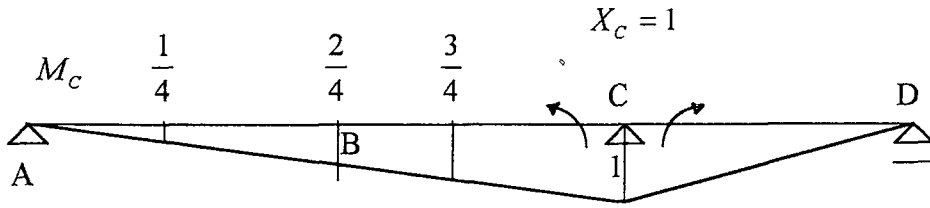


$$\sum M_A = 0 \quad V_C^L \cdot 2L - F \cdot \frac{3L}{2} = 0 \quad V_C^L = \frac{3F}{4}$$

$$\sum M_C = 0 \quad V_A \cdot 2L - F \cdot \frac{L}{2} = 0 \quad V_A = \frac{F}{4}$$

M_0





$$\delta_{c_0} = \frac{1}{3} \cdot L \cdot i \cdot k + \frac{1}{6} \cdot L \cdot i \cdot (2k_1 + k_2) = \frac{1}{3} \cdot \frac{3L}{2} \cdot \frac{3FL}{8} \cdot \frac{3}{4} \cdot \frac{1}{EI} + \frac{1}{6} \cdot \frac{L}{2} \cdot \frac{3FL}{8} \cdot \left(2 \cdot \frac{3}{4} + 1\right) \cdot \frac{1}{EI} = \frac{7}{32} \cdot \frac{FL^2}{EI}$$

$$\delta_{cc} \cdot X_C + \delta_{c_0} = 0$$

$$\frac{L}{EI} \cdot X_C + \frac{7}{32} \cdot \frac{FL^2}{EI} = 0$$

$$X_C = M_C = \frac{-7FL}{32}$$

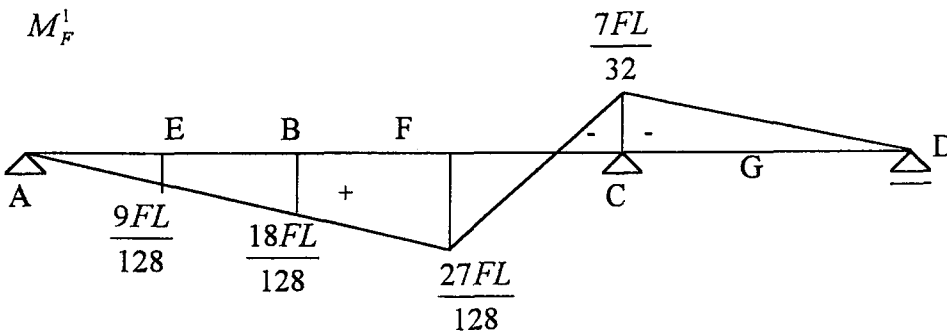
$$M_E = M_{0E} + M_{CE} \cdot X_C = \frac{FL}{8} + \frac{1}{4} \cdot \frac{-7FL}{32} = \frac{9FL}{128}$$

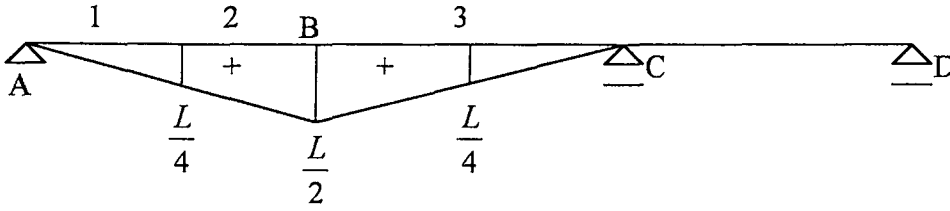
$$M_B = M_{0B} + M_{CB} \cdot X_C = \frac{FL}{4} + \frac{2}{4} \cdot \frac{-7FL}{32} = \frac{18FL}{128}$$

$$M_F = M_{0F} + M_{CF} \cdot X_C = \frac{3FL}{8} + \frac{3}{4} \cdot \frac{-7FL}{32} = \frac{27FL}{128}$$

$$M_G = M_{0G} + M_{CG} \cdot X_C = 0 + \frac{1}{2} \cdot \frac{-7FL}{32} = \frac{-7FL}{64}$$

$$M_A = M_D = 0$$



M_1^0


$$\Delta B_{MAX} = \int M_F^1 \cdot M_1^0 \cdot \frac{dx}{EI}$$

$$\Delta B_{MAX1} = \frac{1}{3} \cdot L \cdot i \cdot k = \frac{1}{3} \cdot L \cdot \frac{18FL}{128} \cdot \frac{L}{2} \cdot \frac{1}{EI} = \frac{72}{3072} \cdot \frac{FL^3}{EI}$$

$$\Delta B_{MAX2} = \frac{1}{6} \cdot L \cdot (2i_1 k_1 + i_1 k_2 + i_2 k_1 + 2i_2 k_2)$$

$$\Delta B_{MAX2} = \frac{1}{6} \cdot \frac{L}{2} \cdot \left(2 \cdot \frac{18FL}{128} \cdot \frac{L}{2} + \frac{18FL}{128} \cdot \frac{L}{4} + \frac{27FL}{128} \cdot \frac{L}{2} + 2 \cdot \frac{27FL}{128} \cdot \frac{L}{4} \right) = \frac{99}{3072} \cdot \frac{FL^3}{EI}$$

$$\Delta B_{MAX3} = \frac{1}{6} \cdot L \cdot i \cdot (k_1 + 2k_2)$$

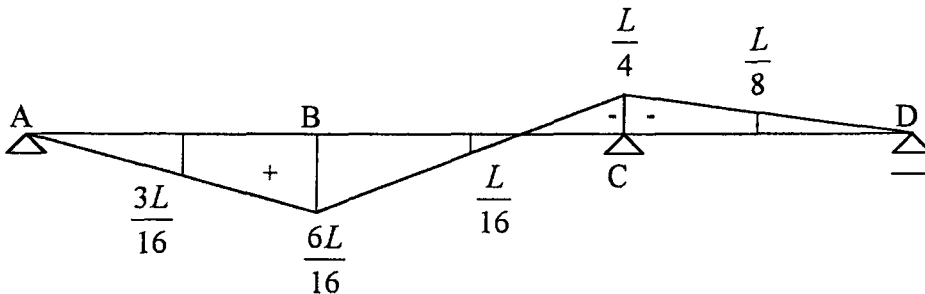
$$\Delta B_{MAX3} = \frac{1}{6} \cdot \frac{L}{2} \cdot \frac{L}{4} \cdot \left(-\frac{28FL}{128} + 2 \cdot \frac{27FL}{128} \right) \cdot \frac{1}{EI} = \frac{13}{3072} \cdot \frac{FL^3}{EI}$$

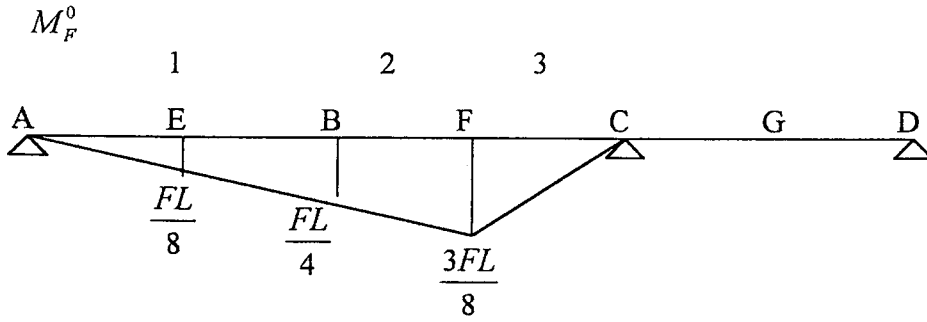
$$\Delta B_{MAX \Sigma} = \Delta B_{MAX1} + \Delta B_{MAX2} + \Delta B_{MAX3} = \frac{72}{3072} \cdot \frac{FL^3}{EI} + \frac{99}{3072} \cdot \frac{FL^3}{EI} + \frac{13}{3072} \cdot \frac{FL^3}{EI} = \frac{184}{3072} \cdot \frac{FL^3}{EI}$$

$$\Delta B_{MAX} = \delta_{BF_2} = \frac{23}{384} \cdot \frac{FL^3}{EI}$$

B mesnedindeki maksimum yer deđiřtirmenin hesabı (2.yol)

$$\delta_{BF_2} = \Delta B_{MAX} = \int M_1^1 \cdot M_F^0 \cdot \frac{dx}{EI}$$

 M_1^1




$$\Delta B_{MAX} = \int M_1^1 \cdot M_F^0 \cdot \frac{dx}{EI}$$

$$\Delta B_{MAX_1} = \frac{1}{3} \cdot L \cdot i \cdot k = \frac{1}{3} \cdot L \cdot \frac{FL}{4} \cdot \frac{6L}{16} \cdot \frac{1}{EI} = \frac{3}{96} \cdot \frac{FL^3}{EI} = \frac{96}{3072} \cdot \frac{FL^3}{EI}$$

$$\Delta B_{MAX_2} = \frac{1}{6} \cdot L \cdot (2i_1 k_1 + i_1 k_2 + i_2 k_1 + 2i_2 k_2)$$

$$\Delta B_{MAX_2} = \frac{1}{6} \cdot \frac{L}{2} \cdot \left(2 \cdot \frac{FL}{4} \cdot \frac{6L}{16} + \frac{3FL}{8} \cdot \frac{6L}{16} + \frac{FL}{4} \cdot \frac{L}{16} + 2 \cdot \frac{3FL}{8} \cdot \frac{L}{16} \right) = \frac{25}{768} \cdot \frac{FL^3}{EI} = \frac{100}{3072} \cdot \frac{FL^3}{EI}$$

$$\Delta B_{MAX_3} = \frac{1}{6} \cdot L \cdot i \cdot (k_1 + 2k_2)$$

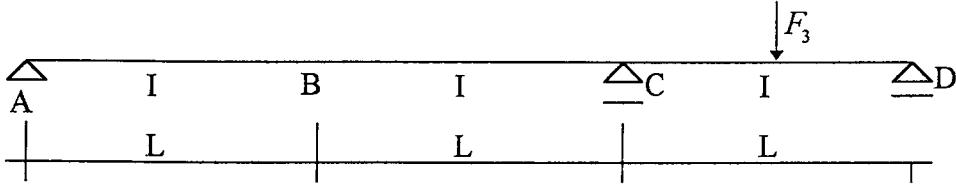
$$\Delta B_{MAX_3} = \frac{1}{6} \cdot \frac{L}{2} \cdot \frac{3FL}{8} \cdot \left(\frac{-L}{4} + 2 \cdot \frac{L}{16} \right) \cdot \frac{1}{EI} = \frac{-6}{1536} \cdot \frac{FL^3}{EI} = \frac{-12}{3072} \cdot \frac{FL^3}{EI}$$

$$\Delta B_{MAX \Sigma} = \Delta B_{MAX_1} + \Delta B_{MAX_2} + \Delta B_{MAX_3} = \frac{96}{3072} \cdot \frac{FL^3}{EI} + \frac{100}{3072} \cdot \frac{FL^3}{EI} - \frac{12}{3072} \cdot \frac{FL^3}{EI} = \frac{184}{3072} \cdot \frac{FL^3}{EI}$$

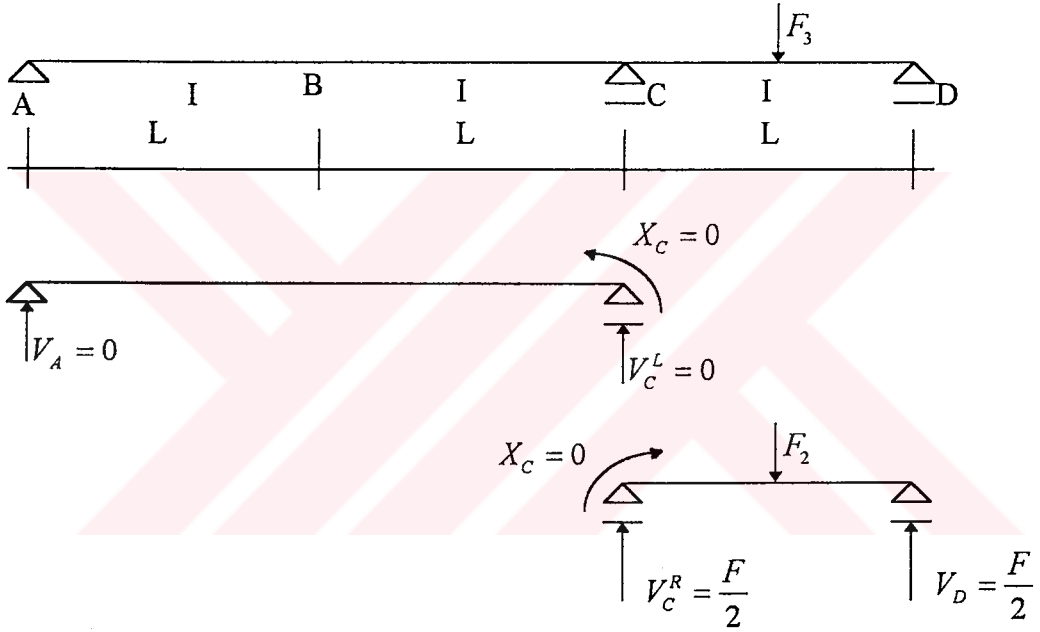
$$\Delta B_{MAX} = \delta_{BF_2} = \frac{23}{384} \cdot \frac{FL^3}{EI}$$

2.3.2.4. 3.Açıklık ortasında F_3 tekil yük hali

$$\delta_{BF_3} = \int M_F^1 \cdot M_1^0 \cdot \frac{dx}{EI}$$

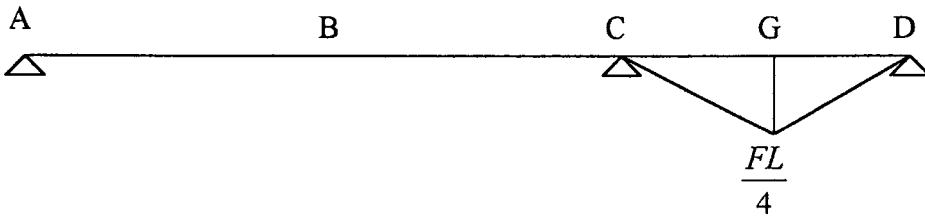


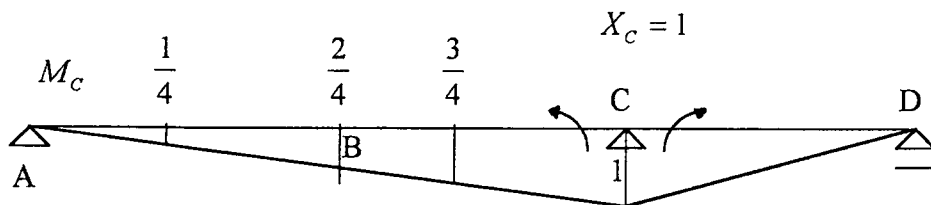
Sıfır yüklemesi : $X_1 = 0$ ($X_c = 0$)



$$\sum M_D = 0 \quad V_C^R \cdot L - F \cdot \frac{L}{2} = 0 \quad V_C^R = V_D = \frac{F}{2}$$

M_0





$$\delta_{c_0} = \frac{1}{6} \cdot L \cdot (1 + \alpha) \cdot i \cdot k = \frac{1}{6} \cdot L \cdot \left(1 + \frac{1}{2}\right) \cdot 1 \cdot \frac{FL}{4} \cdot \frac{1}{EI} = \frac{FL^2}{16EI}$$

$$\delta_{cc} \cdot X_c + \delta_{c_0} = 0$$

$$\frac{L}{EI} \cdot X_c + \frac{1}{16} \cdot \frac{FL^2}{EI} = 0$$

$$X_c = M_c = \frac{-FL}{16}$$

$$M_E = M_{0E} + M_{CE} \cdot X_c = 0 + \frac{1}{4} \cdot \frac{-FL}{16} = \frac{-FL}{64}$$

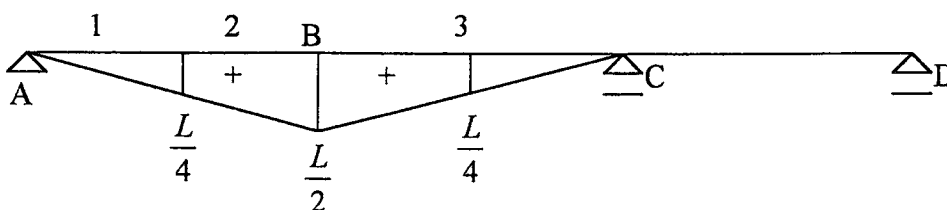
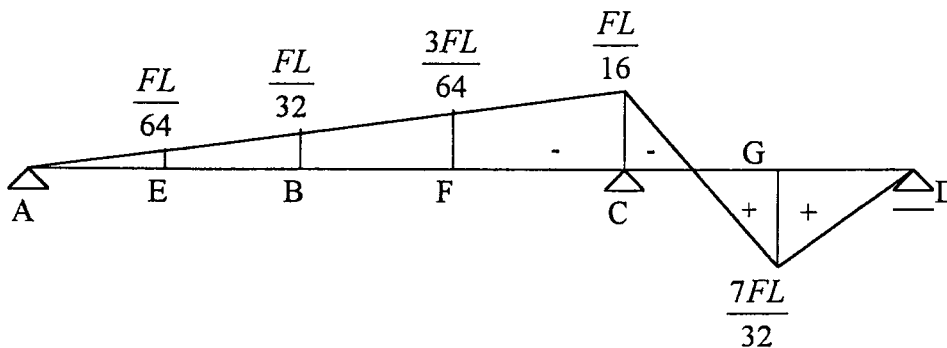
$$M_B = M_{0B} + M_{CB} \cdot X_c = 0 + \frac{2}{4} \cdot \frac{-FL}{16} = \frac{-2FL}{64}$$

$$M_G = M_{0G} + M_{CG} \cdot X_c = \frac{FL}{4} + \frac{1}{2} \cdot \frac{-FL}{16} = \frac{7FL}{32}$$

$$M_F = M_{0F} + M_{CF} \cdot X_c = 0 + \frac{3}{4} \cdot \frac{-FL}{16} = \frac{-3FL}{64}$$

$$M_A = M_D = 0$$

$$M_F^1$$



$$\Delta B_{MAX} = \int M_F^1 \cdot M_1^0 \cdot \frac{dx}{EI}$$

$$\Delta B_{MAX_1} = \frac{1}{3} \cdot L \cdot i \cdot k = \frac{1}{3} \cdot L \cdot \frac{-FL}{32} \cdot \frac{L}{2} \cdot \frac{1}{EI} = \frac{-1}{192} \cdot \frac{FL^3}{EI}$$

$$\Delta B_{MAX_2} = \frac{1}{6} \cdot L \cdot i \cdot (2k_1 + k_2)$$

$$\Delta B_{MAX_2} = \frac{1}{6} \cdot L \cdot \frac{L}{2} \cdot \left(2 \cdot \frac{-FL}{32} + \frac{-FL}{16} \right) \cdot \frac{1}{EI} = \frac{-2}{192} \cdot \frac{FL^3}{EI}$$

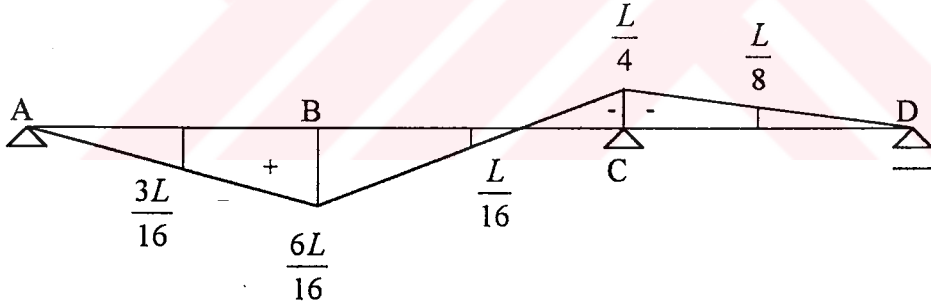
$$\Delta B_{MAX \Sigma} = \Delta B_{MAX_1} + \Delta B_{MAX_2} = \frac{-1}{192} \cdot \frac{FL^3}{EI} + \frac{-2}{192} \cdot \frac{FL^3}{EI} = \frac{-3}{192} \cdot \frac{FL^3}{EI}$$

$$\Delta B_{MAX} = \delta_{BF_3} = \frac{-1}{64} \cdot \frac{FL^3}{EI}$$

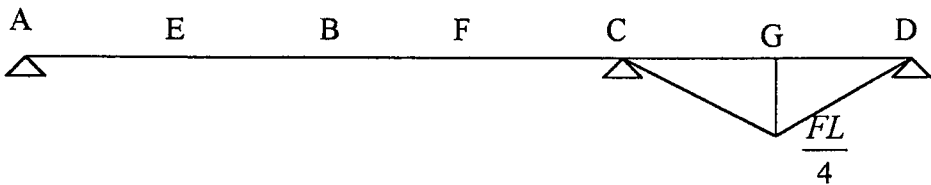
B mesnedindeki maksimum yer deđiřtirmenin hesabı (2.yol)

$$\delta_{BF_3} = \Delta B_{MAX} = \int M_1^1 \cdot M_F^0 \cdot \frac{dx}{EI}$$

M_1^1



M_F^0

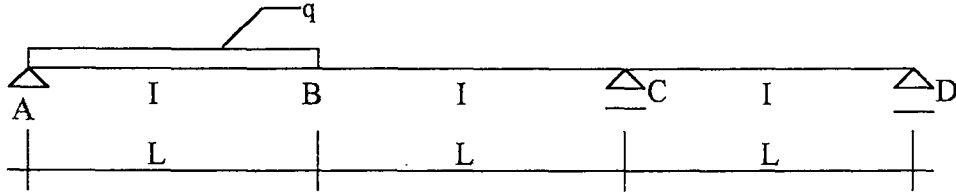


$$\Delta B_{MAX} = \frac{1}{6} \cdot L \cdot (1 + \alpha) \cdot i \cdot k = \frac{1}{6} \cdot L \cdot \left(1 + \frac{1}{2} \right) \cdot \frac{FL}{4} \cdot \frac{-L}{4} \cdot \frac{1}{EI} = \frac{-1}{64} \cdot \frac{FL^3}{EI}$$

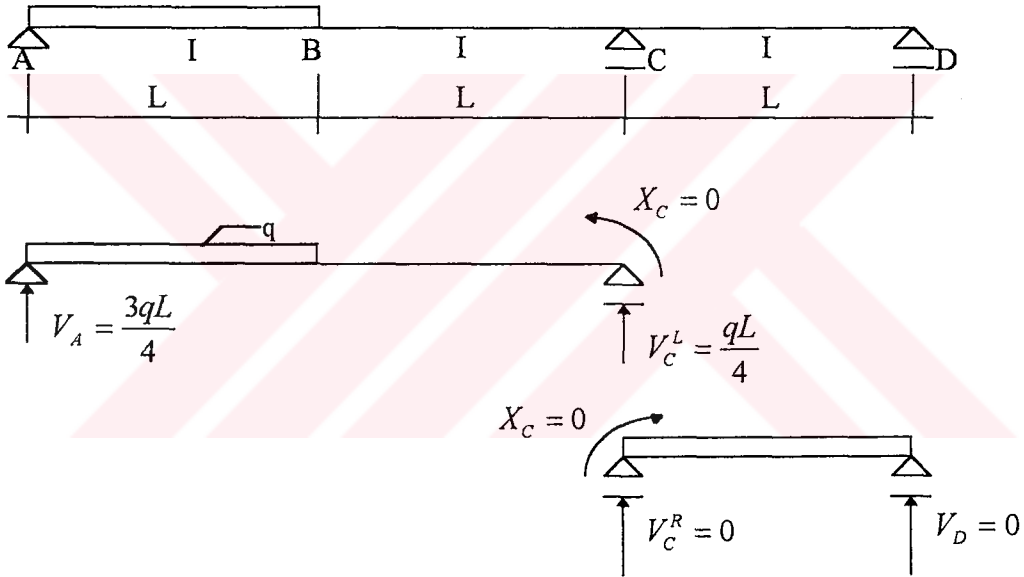
2.3.2.5. 1. açıklıkta q yayılı yük hali

$$\delta_{Bq} = \int M_q^1 \cdot M_1^0 \cdot \frac{dx}{EI}$$

M_q^1 : Hiperstatik sistemde q yüklemesi



Sıfır yüklemesi : $X_i = 0$ ($X_c = 0$)

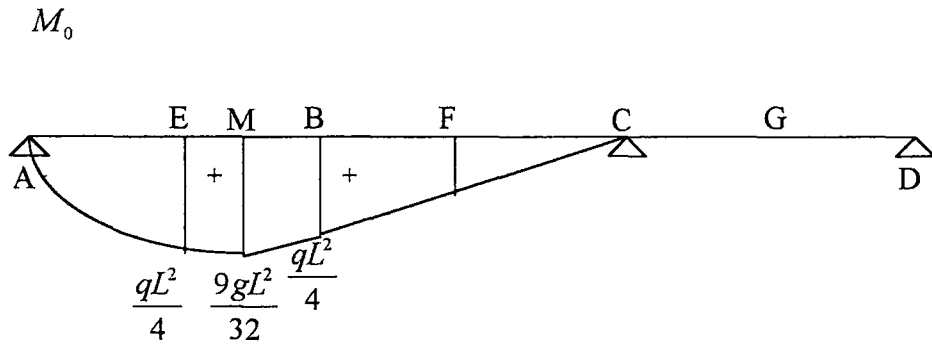


$$\sum M_C = 0 \quad V_A \cdot 2L - q \cdot L \cdot \frac{3L}{2} = 0 \quad V_A = \frac{3qL}{4}$$

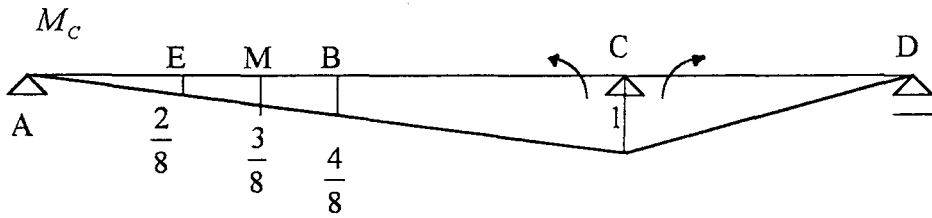
$$\sum M_A = 0 \quad V_C^L \cdot 2L - q \cdot L \cdot \frac{L}{2} = 0 \quad V_C^L = \frac{qL}{4}$$

$$\sum M_D = 0 \quad V_C^R = V_D = 0$$

$$M_E = V_A \cdot \frac{L}{2} - q \cdot \frac{L}{2} \cdot \frac{L}{4} = \frac{3qL}{4} \cdot \frac{L}{2} - q \cdot \frac{L}{2} \cdot \frac{L}{4} = \frac{qL^2}{4}$$



$$X_C = 1$$



$$\delta_{c_0} = \int u \cdot v \cdot ds = \frac{\Delta S}{6} \cdot [v_1 \cdot (u_1 + 2u') + v_2 \cdot (u_2 + 2u')] \cdot \frac{1}{EI} + \frac{1}{6} \cdot L \cdot i \cdot (2k_1 + k_2) \cdot \frac{1}{EI}$$

$$\delta_{c_0} = \frac{L}{6} \cdot \left[0 \cdot \left(0 + 2 \cdot \frac{qL^2}{4} \right) + \frac{1}{2} \cdot \left(\frac{qL^2}{4} + 2 \cdot \frac{qL^2}{4} \right) \right] \cdot \frac{1}{EI} + \frac{1}{6} \cdot L \cdot \frac{qL^2}{4} \cdot \left(2 \cdot \frac{1}{2} + 1 \right) \cdot \frac{1}{EI} = \frac{7}{48} \cdot \frac{qL^3}{EI}$$

$$\delta_{c_0} = \frac{7}{48} \cdot \frac{gL^3}{EI}$$

$$\delta_{c_c} \cdot X_C + \delta_{c_0} = 0$$

$$\frac{L}{EI} \cdot X_C + \frac{7}{48} \cdot \frac{gL^3}{EI} = 0$$

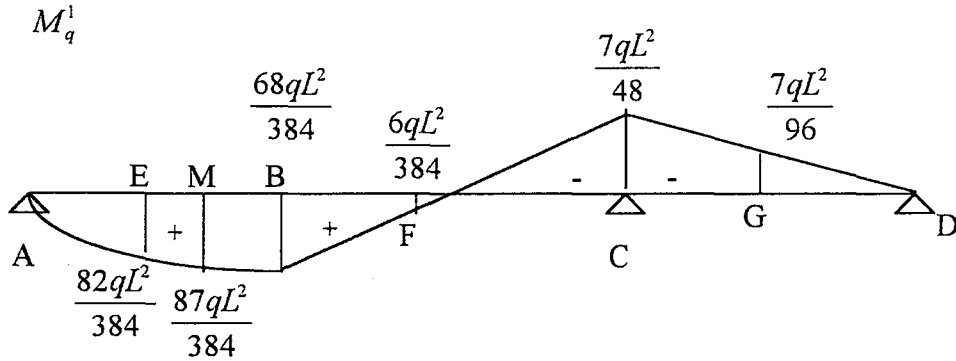
$$X_C = M_C = \frac{-7gL^2}{48}$$

$$M_E = M_{0E} + M_{CE} \cdot X_C = \frac{qL^2}{4} + \frac{2}{8} \cdot \frac{-7qL^2}{48} = \frac{82qL^2}{384}$$

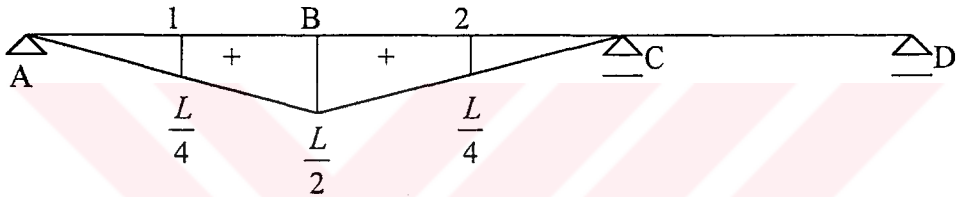
$$M_B = M_{0B} + M_{CB} \cdot X_C = \frac{qL^2}{4} + \frac{4}{8} \cdot \frac{-7qL^2}{48} = \frac{68qL^2}{384}$$

$$M_F = M_{0F} + M_{CF} \cdot X_C = \frac{qL^2}{4} + \frac{3}{4} \cdot \frac{-7qL^2}{48} = \frac{6qL^2}{384}$$

$$M_G = M_{0G} + M_{CG} \cdot X_C = 0 + \frac{1}{2} \cdot \frac{-7qL^2}{48} = \frac{-7qL^2}{96}$$



M_1^0



$$\delta_{Bq} = \Delta B_{MAX} = \int u \cdot v \cdot ds = \frac{\Delta S}{6} \cdot [v_1 \cdot (u_1 + 2u') + v_2 \cdot (u_2 + 2u')] + \frac{1}{6} \cdot L \cdot i \cdot (k_1 + 2k_2)$$

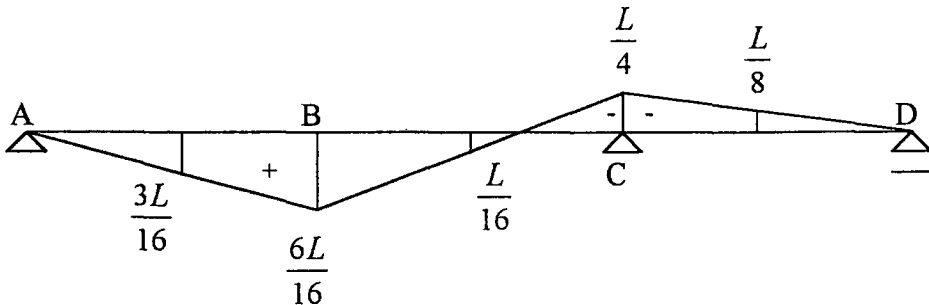
$$\Delta B_{MAX} = \frac{L}{6} \left[0 \cdot \left(0 + 2 \cdot \frac{82qL^2}{384} \right) + \frac{L}{2} \cdot \left(\frac{68qL^2}{384} + 2 \cdot \frac{82qL^2}{384} \right) \right] \cdot \frac{1}{EI} + \frac{1}{6} \cdot L \cdot \frac{L}{2} \cdot \left(\frac{-56qL^2}{384} + 2 \cdot \frac{68qL^2}{384} \right) \cdot \frac{1}{EI}$$

$$\Delta B_{MAX} = \frac{13}{192} \cdot \frac{qL^4}{EI}$$

B mesnedindeki maksimum yer deđiřtirmenin hesabı (2. yol)

$$\delta_{Bq} = \Delta B_{MAX} = \int M_1^1 \cdot M_q^0 \cdot \frac{dx}{EI}$$

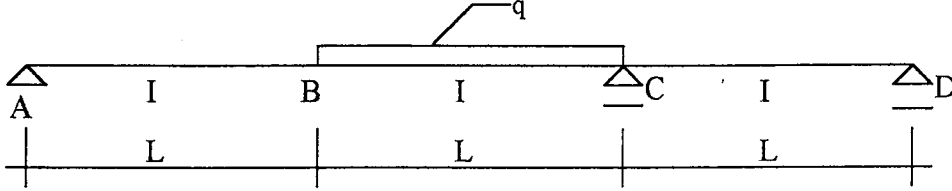
M_1^1



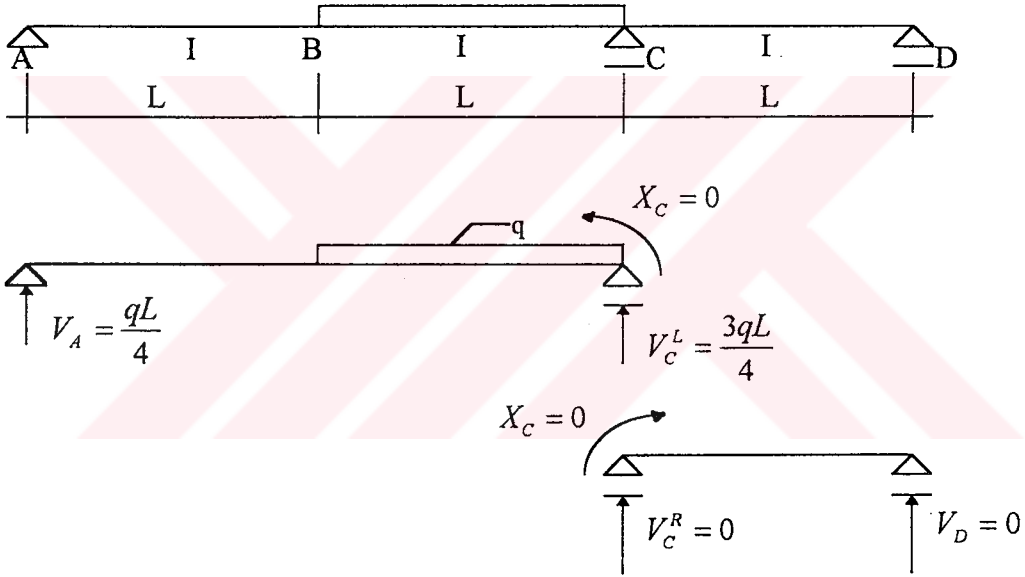
2.3.2.6. 2. açıklıkta q yayılı yük hali

$$\delta_{Bq} = \int M_q^1 \cdot M_1^0 \cdot \frac{dx}{EI}$$

M_q^1 : Hiperstatik sistemde q yüklemesi



Sıfır yüklemesi : $X_1 = 0$ ($X_C = 0$)

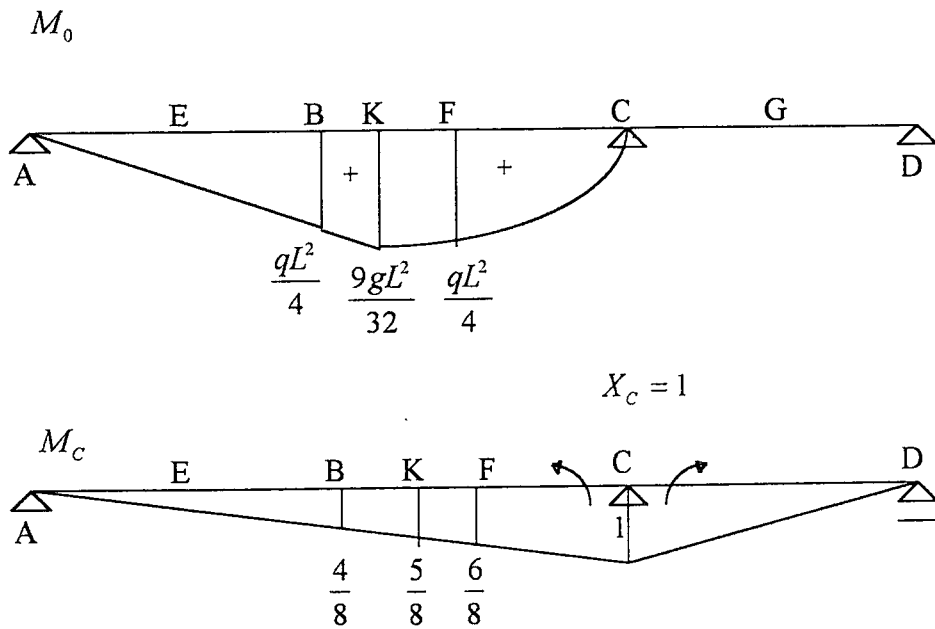


$$\sum M_C = 0 \quad V_A \cdot 2L - q \cdot L \cdot \frac{L}{2} = 0 \quad V_A = \frac{qL}{4}$$

$$\sum M_A = 0 \quad V_C^L \cdot 2L - q \cdot L \cdot \frac{3L}{2} = 0 \quad V_C^L = \frac{3qL}{4}$$

$$\sum M_D = 0 \quad V_C^R = V_D = 0$$

$$M_F = V_A \cdot \frac{3L}{2} - q \cdot \frac{L}{2} \cdot \frac{L}{4} = \frac{qL}{4} \cdot \frac{3L}{2} - q \cdot \frac{L}{2} \cdot \frac{L}{4} = \frac{qL^2}{4}$$



$$\delta_{c_0} = \int u \cdot v \cdot ds = \frac{\Delta S}{6} \cdot [v_1 \cdot (u_1 + 2u') + v_2 \cdot (u_2 + 2u')] \cdot \frac{1}{EI} + \frac{1}{3} \cdot L \cdot i \cdot k \cdot \frac{1}{EI}$$

$$\delta_{c_0} = \frac{L}{6} \cdot \left[\frac{1}{2} \cdot \left(\frac{qL^2}{4} + 2 \cdot \frac{qL^2}{4} \right) + 1 \cdot \left(0 + 2 \cdot \frac{qL^2}{4} \right) \right] \cdot \frac{1}{EI} + \frac{1}{3} \cdot L \cdot \frac{1}{2} \cdot \frac{qL^2}{4} \cdot \frac{1}{EI} = \frac{qL^3}{24EI} + \frac{7qL^3}{48EI} = \frac{9}{48} \cdot \frac{qL^3}{EI}$$

$$\delta_{c_0} = \frac{9}{48} \cdot \frac{qL^3}{EI}$$

$$\delta_{c_c} \cdot X_C + \delta_{c_0} = 0$$

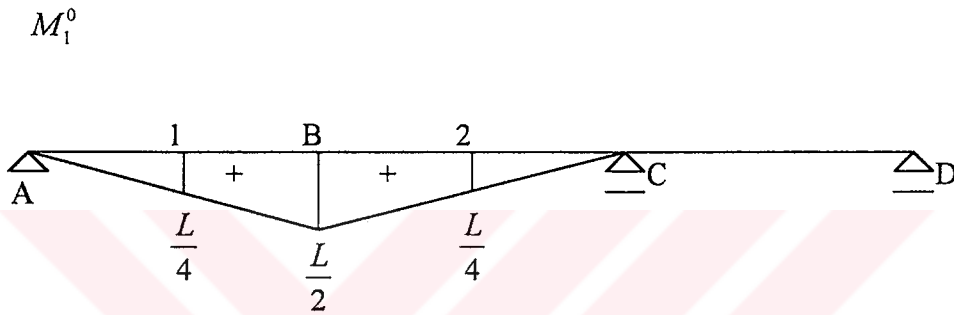
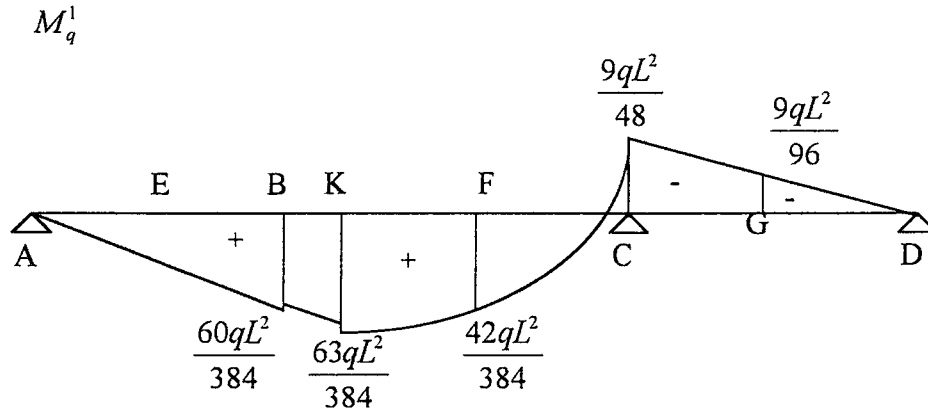
$$\frac{L}{EI} \cdot X_C + \frac{9}{48} \cdot \frac{qL^3}{EI} = 0$$

$$X_C = M_C = \frac{-9qL^2}{48}$$

$$M_K = M_{0K} + M_{CK} \cdot X_C = \frac{9qL^2}{32} + \frac{5}{8} \cdot \frac{-9qL^2}{48} = \frac{63qL^2}{384}$$

$$M_B = M_{0B} + M_{CB} \cdot X_C = \frac{qL^2}{4} + \frac{4}{8} \cdot \frac{-9qL^2}{48} = \frac{60qL^2}{384}$$

$$M_F = M_{0F} + M_{CF} \cdot X_C = \frac{qL^2}{4} + \frac{3}{4} \cdot \frac{-9qL^2}{48} = \frac{42qL^2}{384}$$



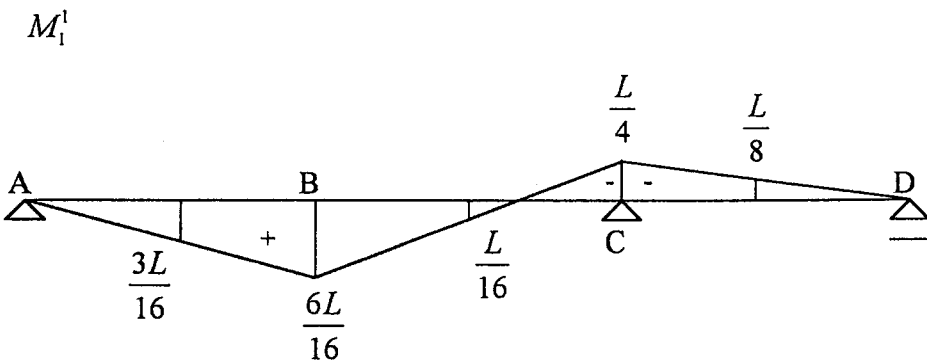
$$\delta_{Bq} = \Delta B_{MAX} = \int u \cdot v \cdot ds = \frac{\Delta S}{6} \cdot [v_1 \cdot (u_1 + 2u') + v_2 \cdot (u_2 + 2u')] + \frac{1}{3} \cdot L \cdot i \cdot k$$

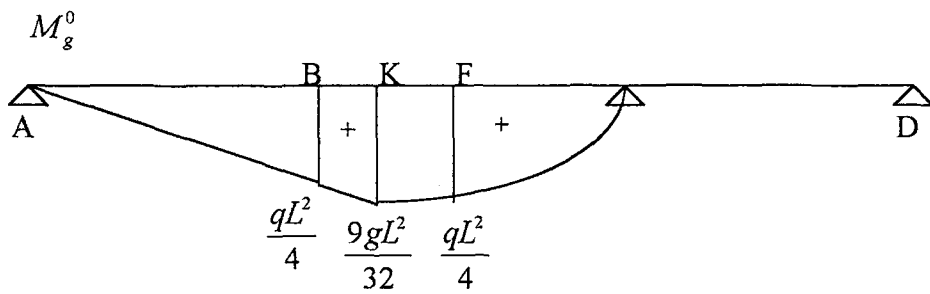
$$\Delta B_{MAX} = \frac{L}{6} \cdot \left[\frac{L}{2} \cdot \left(\frac{60qL^2}{384} + 2 \cdot \frac{42qL^2}{384} \right) + 0 \cdot \left(\frac{-9qL^2}{48} + 2 \cdot \frac{42qL^2}{384} \right) \right] \cdot \frac{1}{EI} + \frac{1}{3} \cdot L \cdot \frac{L}{2} \cdot \frac{60qL^2}{384} \cdot \frac{1}{EI} = \frac{11}{192} \cdot \frac{qL^4}{EI}$$

$$\Delta B_{MAX} = \frac{11}{192} \cdot \frac{qL^4}{EI}$$

B mesnedindeki maksimum yer değıştirmenin hesabı (2. yol)

$$\delta_{Bq} = \Delta B_{MAX} = \int M_1^0 \cdot M_q^1 \cdot \frac{dx}{EI}$$





$$\Delta B_{MAX} = \int M_1^1 \cdot M_g^0 \cdot \frac{dx}{EI}$$

$$\delta_{Bq} = \Delta B_{MAX} = \int u \cdot v \cdot ds = \frac{\Delta S}{6} \cdot [v_1 \cdot (u_1 + 2u') + v_2 \cdot (u_2 + 2u')] + \frac{1}{3} \cdot L \cdot i \cdot k$$

$$\Delta B_{MAX} = \frac{L}{6} \cdot \left[\frac{6L}{16} \cdot \left(\frac{qL^2}{4} + 2 \cdot \frac{qL^2}{4} \right) + \frac{-L}{4} \cdot \left(0 + 2 \cdot \frac{qL^2}{4} \right) \right] \cdot \frac{1}{EI} + \frac{1}{3} \cdot L \cdot \frac{qL^2}{4} \cdot \frac{6L}{16} \cdot \frac{1}{EI}$$

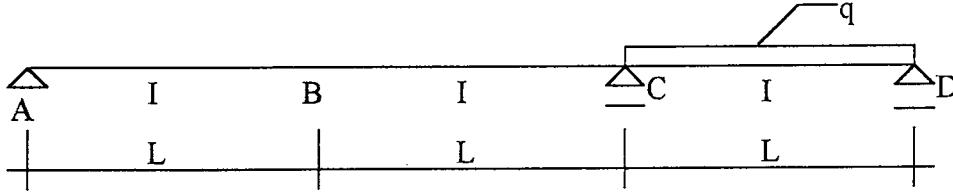
$$\Delta B_{MAX} = \frac{9}{32} \cdot \frac{qL^4}{EI} + \frac{5}{192} \cdot \frac{qL^4}{EI} = \frac{11}{192} \cdot \frac{qL^4}{EI}$$

$$\Delta B_{MAX} = \frac{11}{192} \cdot \frac{qL^4}{EI}$$

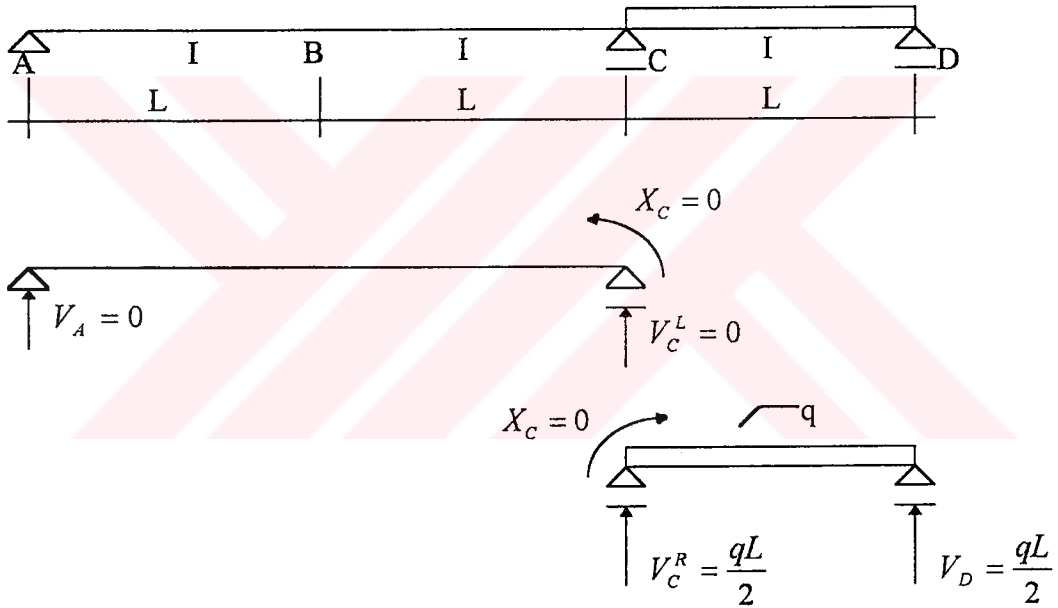
2.3.2.7. 3. açıklıkta q yayılı yük hali

$$\delta_{Bq} = \int M_q^1 \cdot M_1^0 \cdot \frac{dx}{EI}$$

M_q^1 : Hiperstatik sistemde q yüklemesi



Sıfır yüklemesi : $X_i = 0$ ($X_C = 0$)

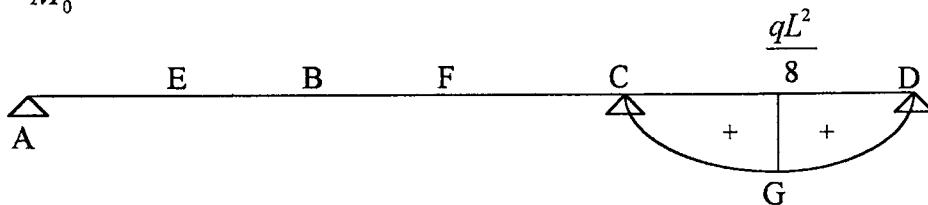


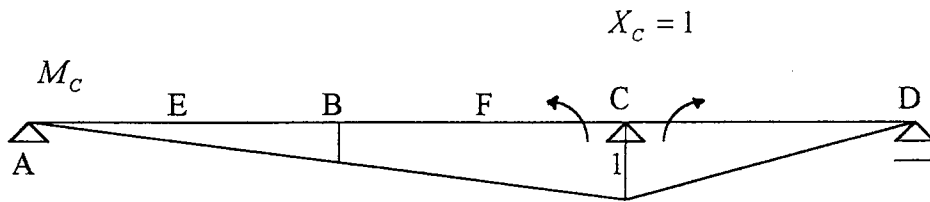
$$\sum M_C = 0 \quad V_D \cdot L - q \cdot L \cdot \frac{L}{2} = 0 \quad V_D = V_C^R = \frac{qL}{2}$$

$$V_C^L = V_A = 0$$

$$M_G = V_C^R \cdot \frac{L}{2} - q \cdot \frac{L}{2} \cdot \frac{L}{4} = \frac{qL}{2} \cdot \frac{L}{2} - q \cdot \frac{L}{2} \cdot \frac{L}{4} = \frac{qL^2}{8}$$

M_0





$$\delta_{c_0} = \int u \cdot v \cdot ds = \frac{1}{3} \cdot L \cdot i \cdot k \cdot \frac{1}{EI}$$

$$\delta_{c_0} = \frac{1}{3} \cdot L \cdot \frac{qL^2}{8} \cdot \frac{1}{EI} = \frac{qL^3}{24EI}$$

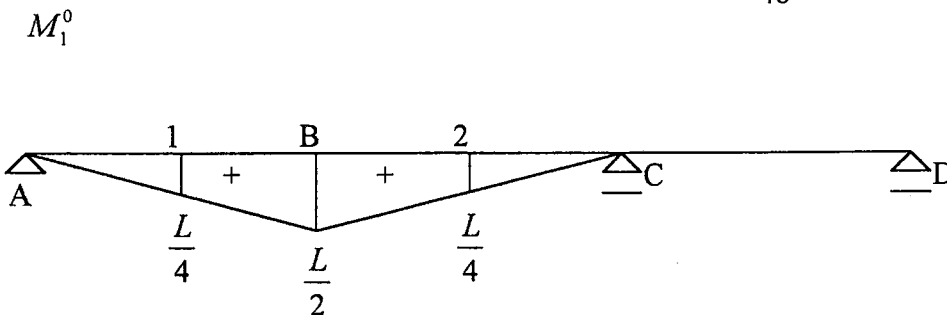
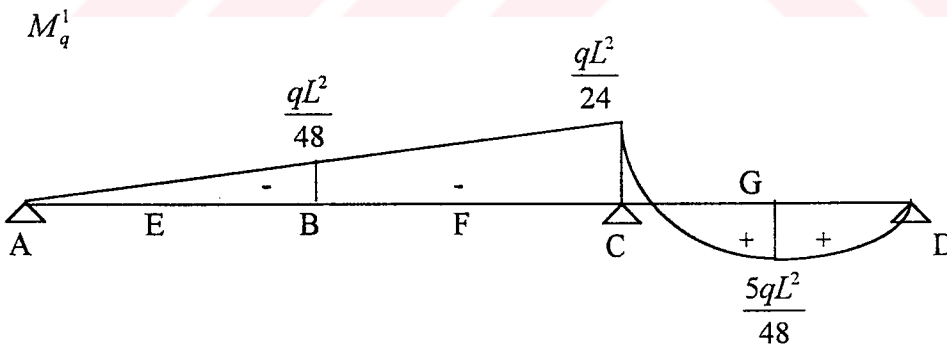
$$\delta_{cc} \cdot X_c + \delta_{c_0} = 0$$

$$\frac{L}{EI} \cdot X_c + \frac{qL^3}{24EI} = 0$$

$$X_c = M_c = \frac{-qL^2}{24}$$

$$M_B = M_{0B} + M_{cB} \cdot X_c = 0 + \frac{1}{2} \cdot \frac{-qL^2}{24} = \frac{-qL^2}{48}$$

$$M_G = M_{0G} + M_{cG} \cdot X_c = \frac{qL^2}{8} + \frac{1}{2} \cdot \frac{-qL^2}{24} = \frac{5qL^2}{48}$$



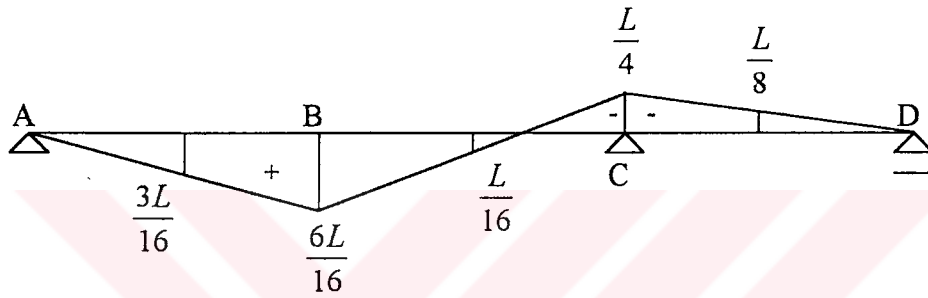
$$\delta_{Bq} = \Delta B_{MAX} = \int u \cdot v \cdot ds = \frac{1}{3} \cdot L \cdot i \cdot k + \frac{1}{6} \cdot L \cdot i \cdot (2k_1 + k_2)$$

$$\Delta B_{MAX} = \frac{1}{3} \cdot L \cdot \frac{L}{2} \cdot \frac{-qL^2}{48EI} \cdot \frac{1}{EI} + \frac{1}{6} \cdot L \cdot \frac{L}{2} \cdot \left(2 \cdot \frac{qL^2}{48} - \frac{qL^2}{24} \right) \cdot \frac{1}{EI} = \frac{-1}{96} \cdot \frac{qL^4}{EI}$$

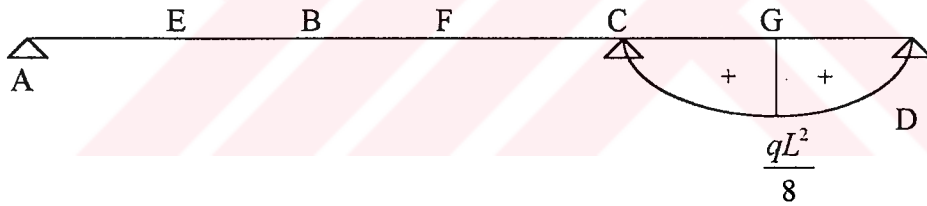
B mesnedindeki maksimum yer değıştirmenin hesabı (2. yol)

$$\delta_{Bq} = \Delta B_{MAX} = \int M_1^1 \cdot M_q^0 \cdot \frac{dx}{EI}$$

M_1^1



M_g^0



$$\Delta B_{MAX} = \int M_1^1 \cdot M_g^0 \cdot \frac{dx}{EI}$$

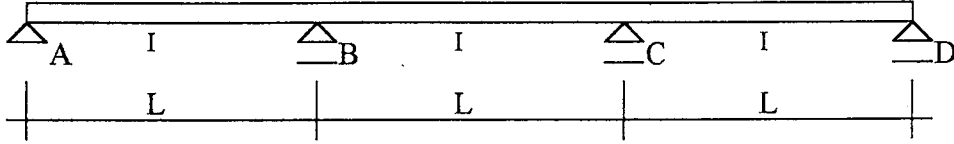
$$\delta_{Bq} = \Delta B_{MAX} = \int u \cdot v \cdot ds = \frac{1}{3} \cdot L \cdot i \cdot k = \frac{1}{3} \cdot L \cdot \frac{-L}{4} \cdot \frac{qL^2}{8} \cdot \frac{1}{EI} = \frac{-1}{96} \cdot \frac{qL^4}{EI}$$

$$\delta_{Bq} = \frac{-1}{96} \cdot \frac{qL^4}{EI}$$

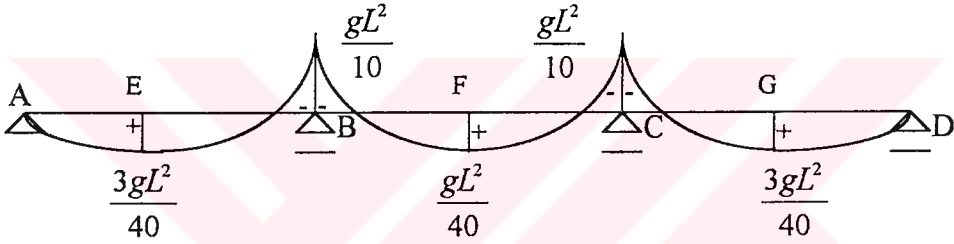
2.4. Üç açıklıklı köprü kirişlerinde çeşitli yükleme durumlarında mesnet eğilme momentlerinin maksimum mesnet hareketlerine bağlı değişimi

2.4.1. B mesnet eğilme momentinin B mesnedindeki maksimum mesnet hareketine bağlı değişimi

2.4.1.1. g sabit yük hali

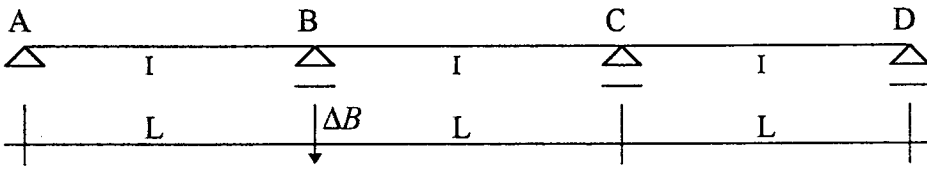


$M_{sonuç}$

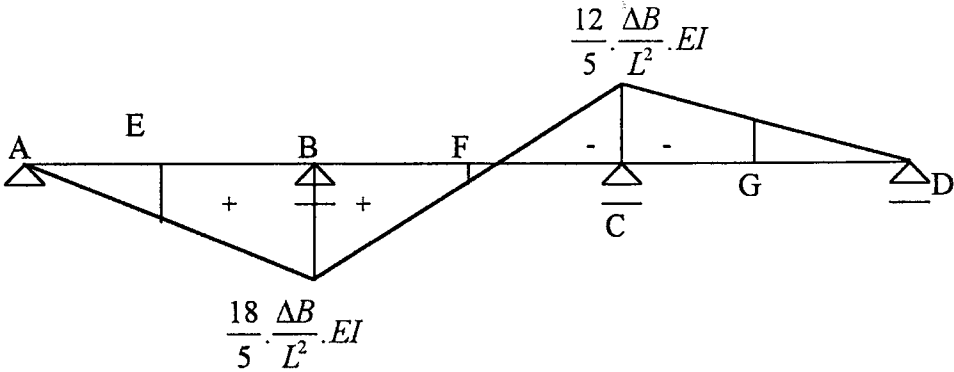


$$M_{B_g} = \frac{-gL^2}{10}$$

ΔB mesnet hareketi halinde eğilme momentleri



$M_{\Delta B}$



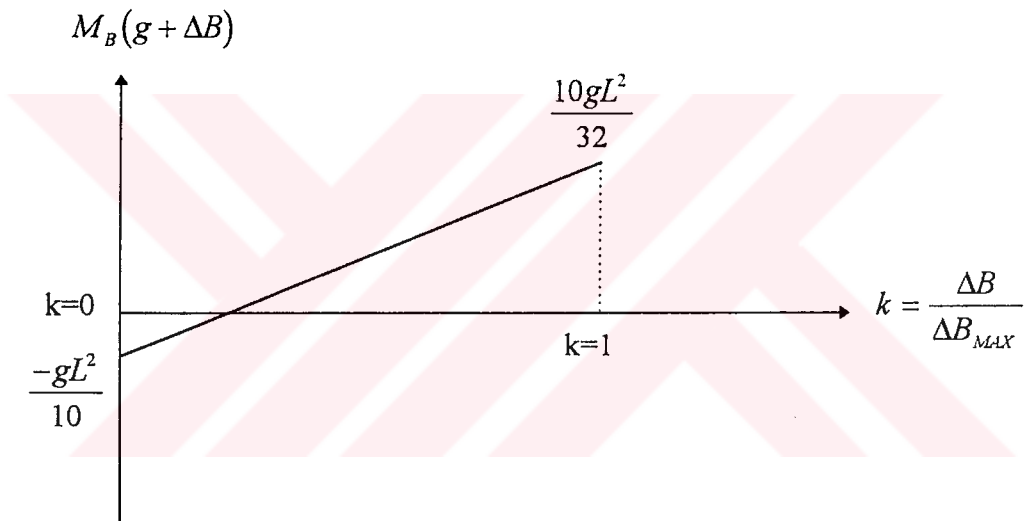
$$\Delta B_{MAX} = \frac{11}{96} \cdot \frac{gL^4}{EI}$$

$$\Delta B = k \cdot \Delta B_{MAX}$$

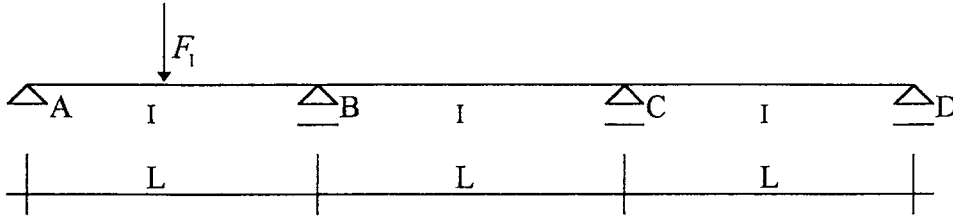
$$M_B = M_{Bg} + M_{B,\Delta B} = \frac{-gL^2}{10} + \frac{18}{5} \cdot \frac{\Delta B}{L^2} \cdot EI = \frac{-gL^2}{10} + \frac{18}{5} \cdot \frac{k \cdot \Delta B_{MAX}}{L^2} \cdot EI$$

$$M_B = \frac{-gL^2}{10} + \frac{18}{5} \cdot \frac{k}{L^2} \cdot \frac{11}{96} \cdot \frac{gL^4}{EI} \cdot EI$$

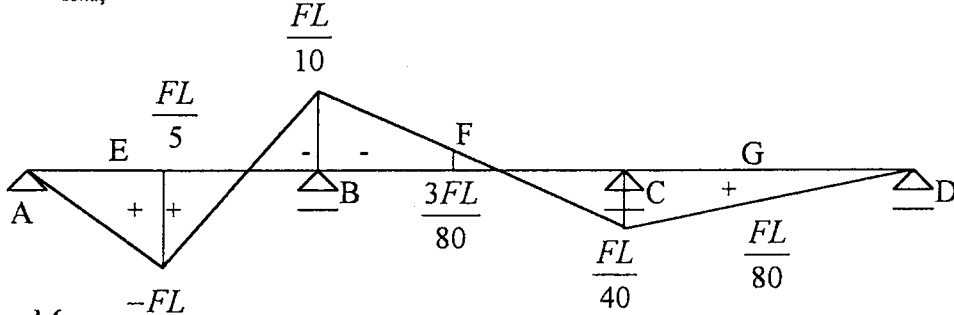
$$M_B = \frac{gL^2}{80} \cdot (33k - 8)$$



2.4.1.2. 1. açıklık ortasında F_1 tekil yük hali



$M_{sonuç}$



$$M_{B_F} = \frac{-FL}{10}$$

$$\Delta B_{MAX} = \frac{29}{384} \cdot \frac{FL^3}{EI}$$

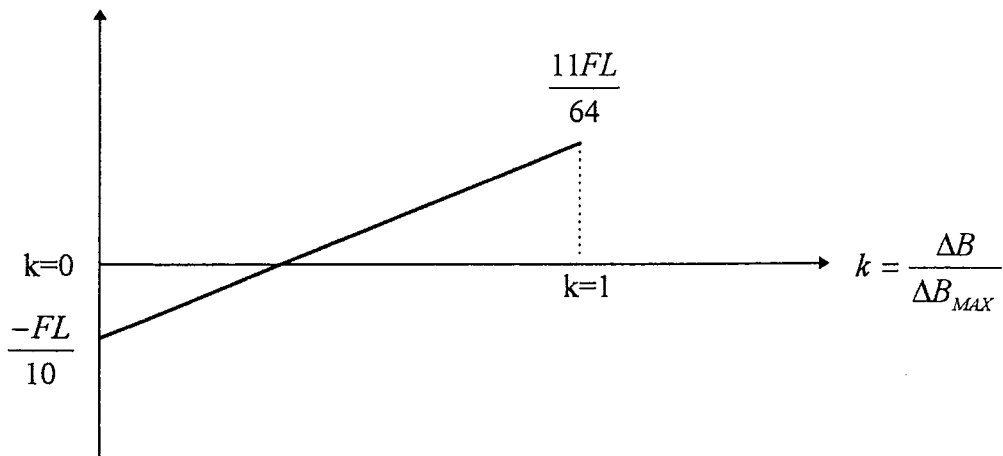
$$\Delta B = k \cdot \Delta B_{MAX}$$

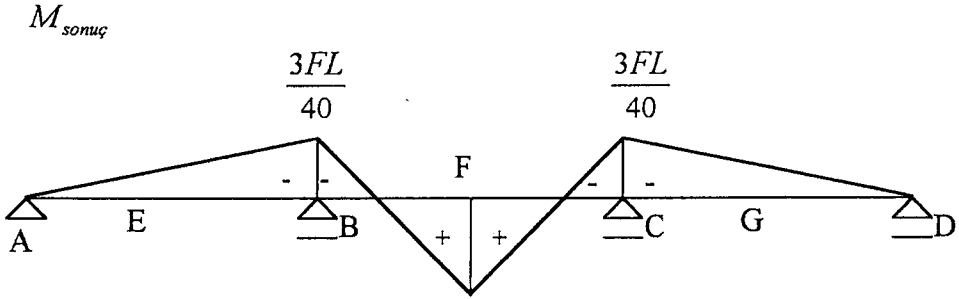
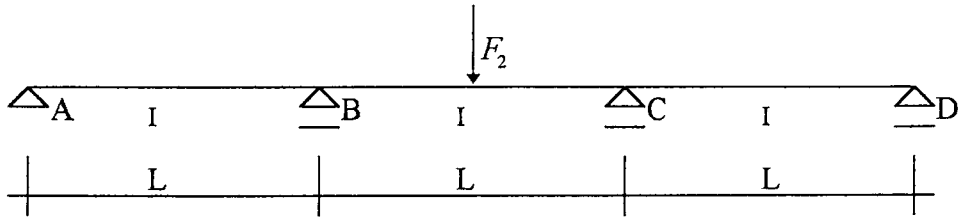
$$M_B = M_{B_F} + M_{B,\Delta B} = \frac{-FL}{10} + \frac{18}{5} \cdot \frac{\Delta B}{L^2} \cdot EI = \frac{-FL}{10} + \frac{18}{5} \cdot \frac{k \cdot \Delta B_{MAX}}{L^2} \cdot EI$$

$$M_B = \frac{-FL}{10} + \frac{18}{5} \cdot \frac{k}{L^2} \cdot \frac{29}{384} \cdot \frac{FL^3}{EI} \cdot EI$$

$$M_B = \frac{FL}{320} \cdot (87k - 32)$$

$M_B(F + \Delta B)$



2.4.1.3. 2. açıklık ortasında F_2 tekil yük hali

$$M_{B_F} = \frac{-3FL}{40}$$

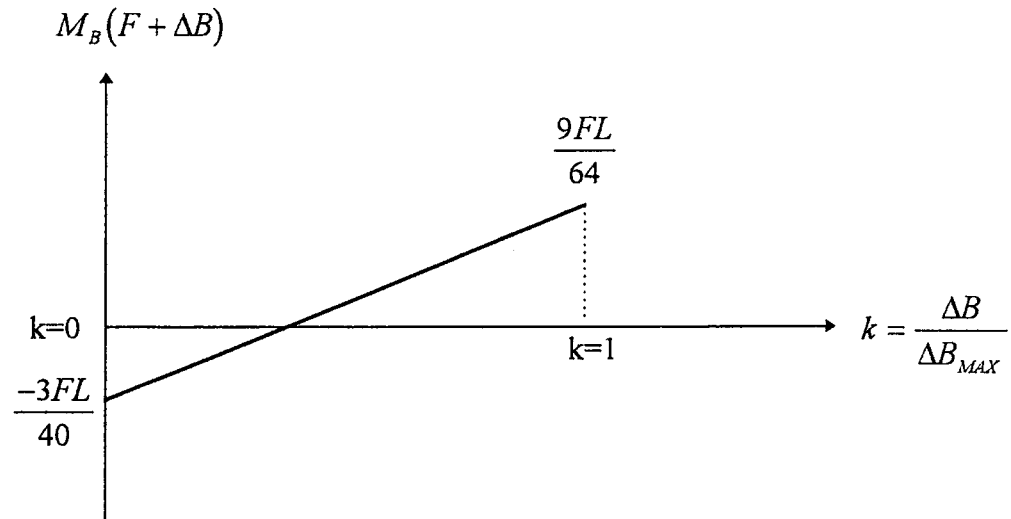
$$\Delta B_{MAX} = \frac{23}{384} \cdot \frac{FL^3}{EI}$$

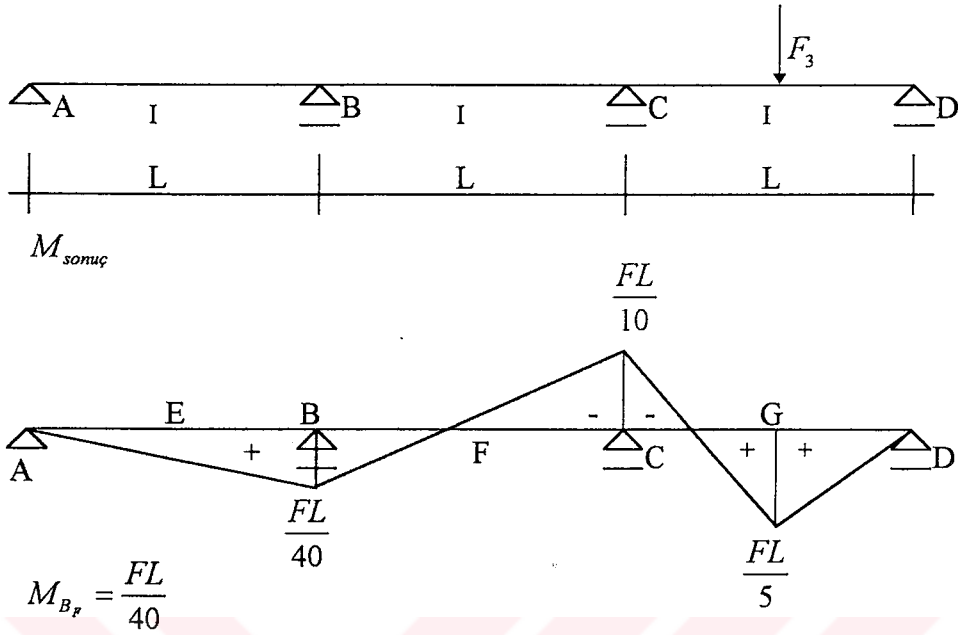
$$\Delta B = k \cdot \Delta B_{MAX}$$

$$M_B = M_{B_F} + M_{B,\Delta B} = \frac{-3FL}{40} + \frac{18}{5} \cdot \frac{\Delta B}{L^2} \cdot EI = \frac{-3FL}{40} + \frac{18}{5} \cdot \frac{k \cdot \Delta B_{MAX}}{L^2} \cdot EI$$

$$M_B = \frac{-3FL}{40} + \frac{18}{5} \cdot \frac{k}{L^2} \cdot \frac{23}{384} \cdot \frac{FL^3}{EI} \cdot EI$$

$$M_B = \frac{FL}{320} \cdot (69k - 24)$$



2.4.1.4. 3. açıklık ortasında F_3 tekil yük hali

$$M_{B_F} = \frac{FL}{40}$$

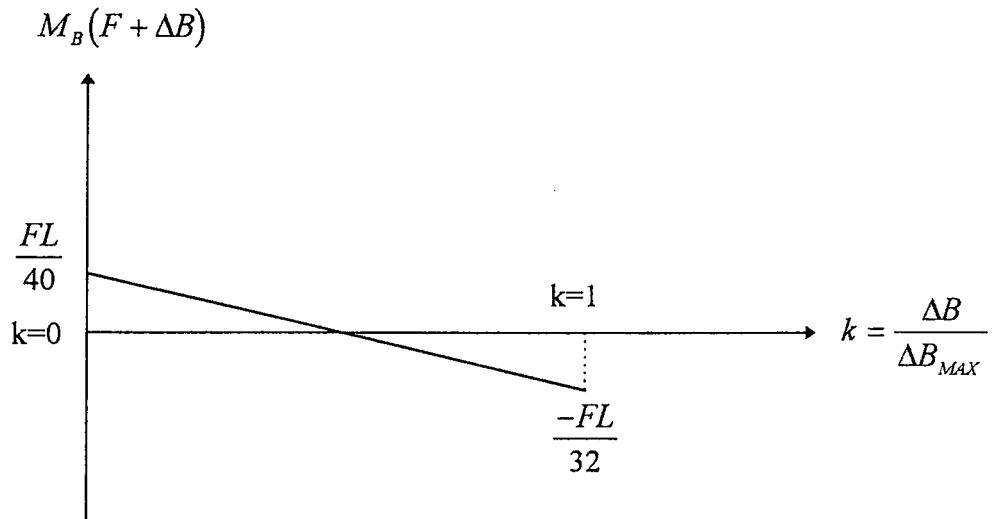
$$\Delta B_{MAX} = \frac{-1}{64} \cdot \frac{FL^3}{EI}$$

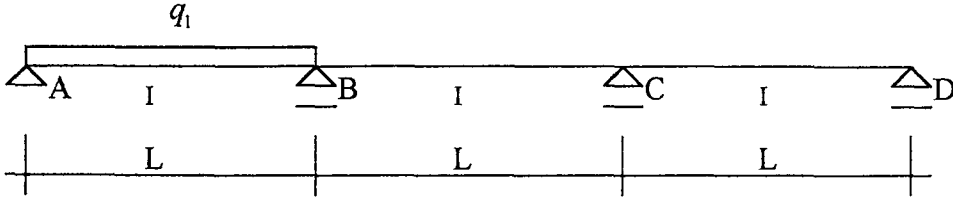
$$\Delta B = k \cdot \Delta B_{MAX}$$

$$M_B = M_{B_F} + M_{B,\Delta B} = \frac{FL}{40} + \frac{18}{5} \cdot \frac{\Delta B}{L^2} \cdot EI = \frac{FL}{40} + \frac{18}{5} \cdot \frac{k \cdot \Delta B_{MAX}}{L^2} \cdot EI$$

$$M_B = \frac{FL}{40} + \frac{18}{5} \cdot \frac{k}{L^2} \cdot \frac{-1}{64} \cdot \frac{FL^3}{EI} \cdot EI$$

$$M_B = \frac{FL}{160} \cdot (4 - 9k)$$



2.4.1.5. 1. açıklıkta q_1 yayılı yük hali

$$M_{Bq} = \frac{-qL^2}{15}$$

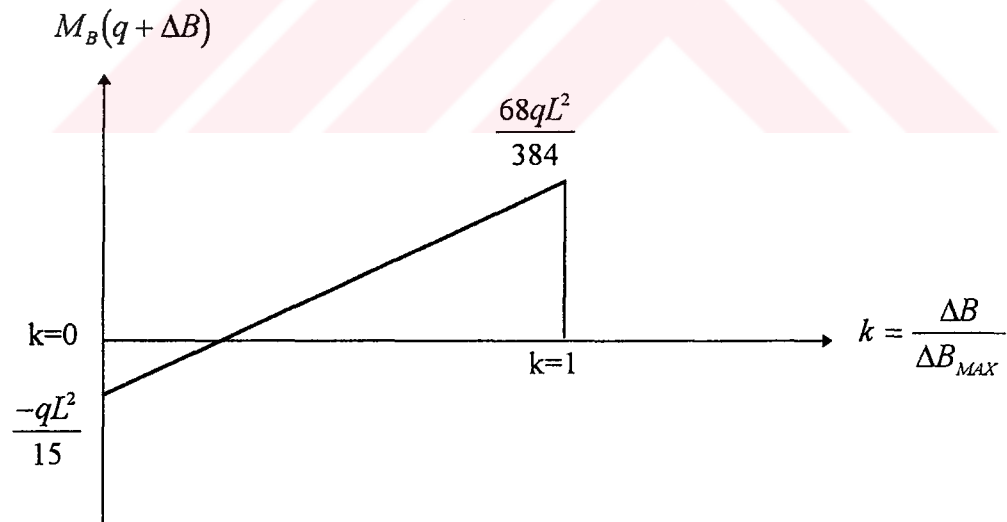
$$\Delta B_{MAX} = \frac{13}{192} \cdot \frac{qL^4}{EI}$$

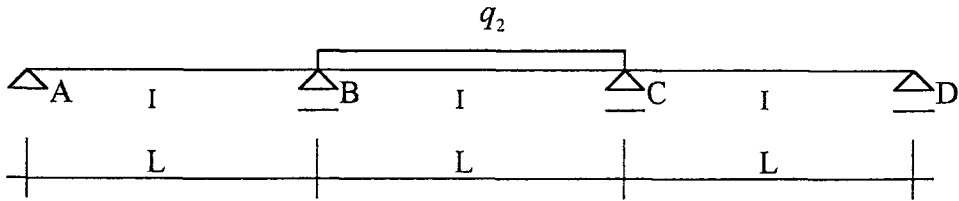
$$\Delta B = k \cdot \Delta B_{MAX}$$

$$M_B = M_{Bq} + M_{B,\Delta B} = \frac{-qL^2}{15} + \frac{18}{5} \cdot \frac{\Delta B}{L^2} \cdot EI = \frac{-qL^2}{15} + \frac{18}{5} \cdot \frac{k \cdot \Delta B_{MAX}}{L^2} \cdot EI$$

$$M_B = \frac{-qL^2}{15} + \frac{18}{5} \cdot \frac{k}{L^2} \cdot \frac{13}{192} \cdot \frac{qL^4}{EI} \cdot EI$$

$$M_B = \frac{qL^2}{160} \cdot \left(39k - \frac{32}{3} \right)$$



2.4.1.6. 2. açıklıkta q_2 yayılı yük hali

$$M_{Bq} = \frac{-qL^2}{20}$$

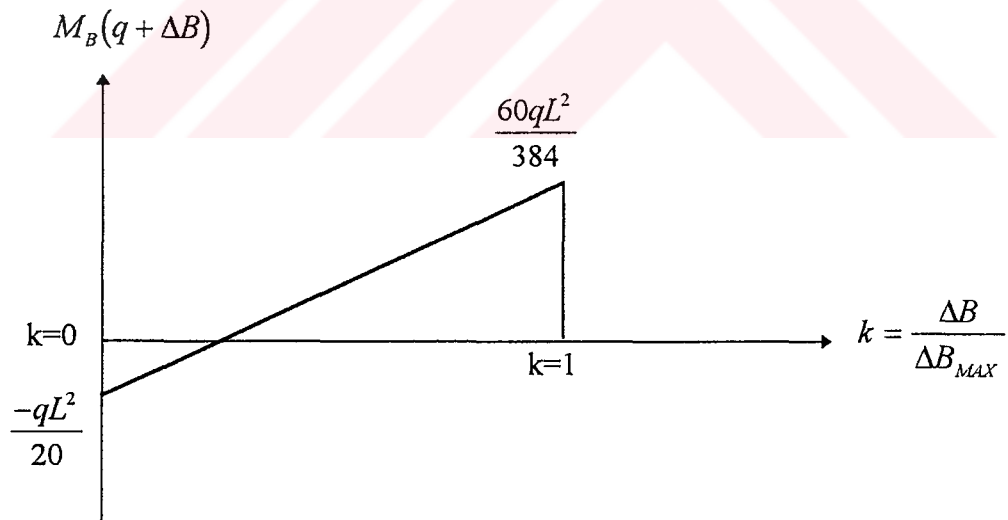
$$\Delta B_{MAX} = \frac{11}{192} \cdot \frac{qL^4}{EI}$$

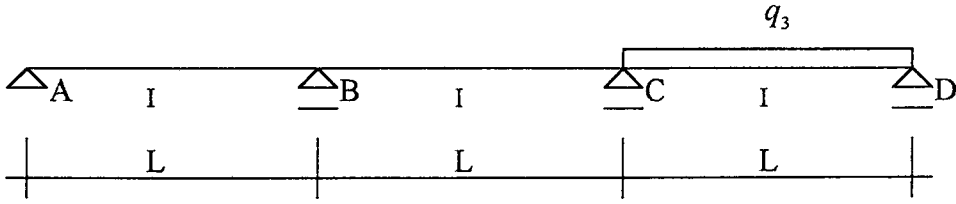
$$\Delta B = k \cdot \Delta B_{MAX}$$

$$M_B = M_{BF} + M_{B,\Delta B} = \frac{-qL^2}{20} + \frac{18}{5} \cdot \frac{\Delta B}{L^2} \cdot EI = \frac{-qL^2}{20} + \frac{18}{5} \cdot \frac{k \cdot \Delta B_{MAX}}{L^2} \cdot EI$$

$$M_B = \frac{-qL^2}{20} + \frac{18}{5} \cdot \frac{k}{L^2} \cdot \frac{11}{192} \cdot \frac{qL^4}{EI} \cdot EI$$

$$M_B = \frac{qL^2}{160} \cdot (33k - 8)$$



2.4.1.7. 3. açıklıkta q_3 yayılı yük hali

$$M_{Bq} = \frac{qL^2}{60}$$

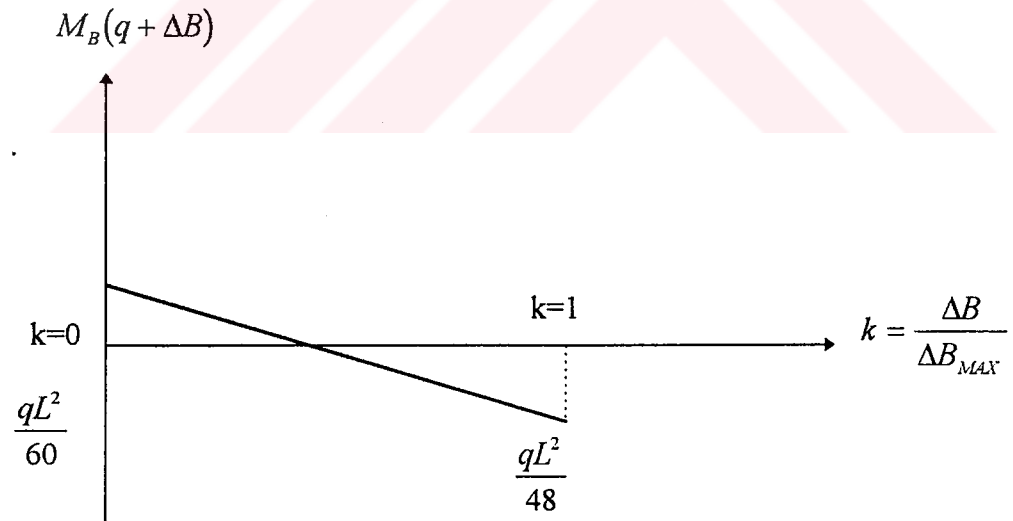
$$\Delta B_{MAX} = \frac{-1}{96} \cdot \frac{qL^4}{EI}$$

$$\Delta B = k \cdot \Delta B_{MAX}$$

$$M_B = M_{BF} + M_{B,\Delta B} = \frac{qL^2}{60} + \frac{18}{5} \cdot \frac{\Delta B}{L^2} \cdot EI = \frac{qL^2}{60} + \frac{18}{5} \cdot \frac{k \cdot \Delta B_{MAX}}{L^2} \cdot EI$$

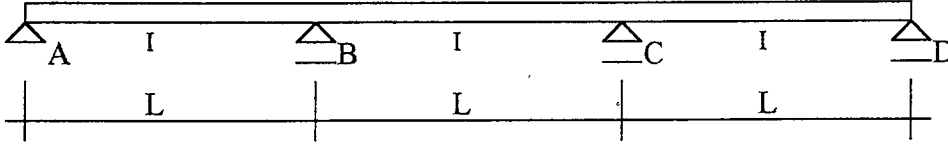
$$M_B = \frac{qL^2}{60} + \frac{18}{5} \cdot \frac{k}{L^2} \cdot \frac{-1}{96} \cdot \frac{qL^4}{EI} \cdot EI$$

$$M_B = \frac{qL^2}{240} \cdot (4 - 9k)$$

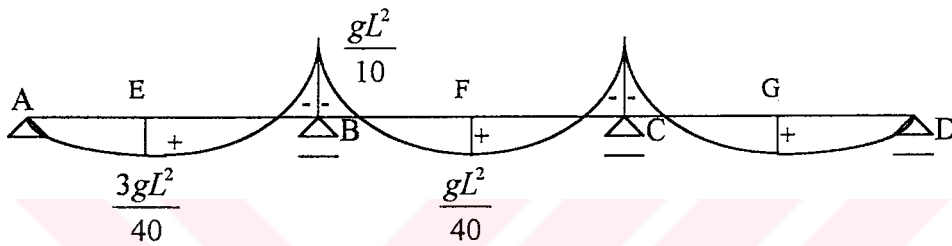


2.4.2. B mesnet eğilme momentinin A mesnedindeki maksimum mesnet hareketine bağlı değişimi

2.4.2.1. g sabit yük hali

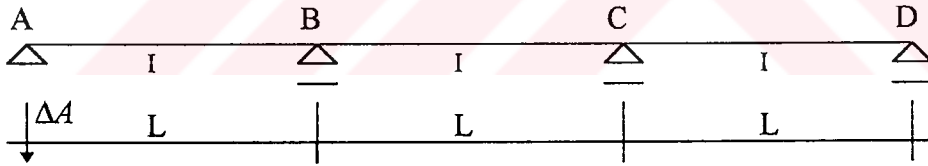


$M_{sonuç}$

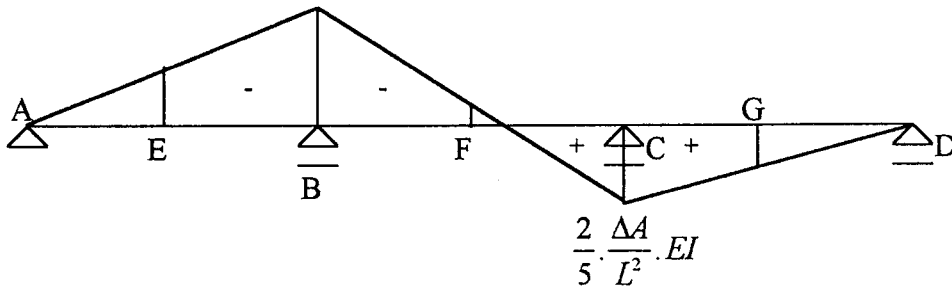


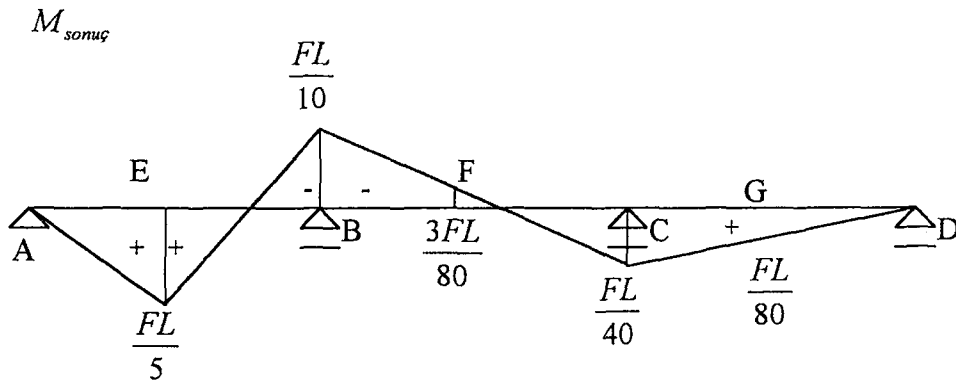
$$M_{B_s} = -\frac{gL^2}{10}$$

ΔA mesnet hareketi halinde eğilme momentleri



$$M_{\Delta A} \quad \frac{8}{5} \cdot \frac{\Delta A}{L^2} \cdot EI$$





$$M_{B_F} = \frac{-FL}{10}$$

$$\Delta A_{MAX} = \frac{1}{4} \cdot \frac{FL^3}{EI}$$

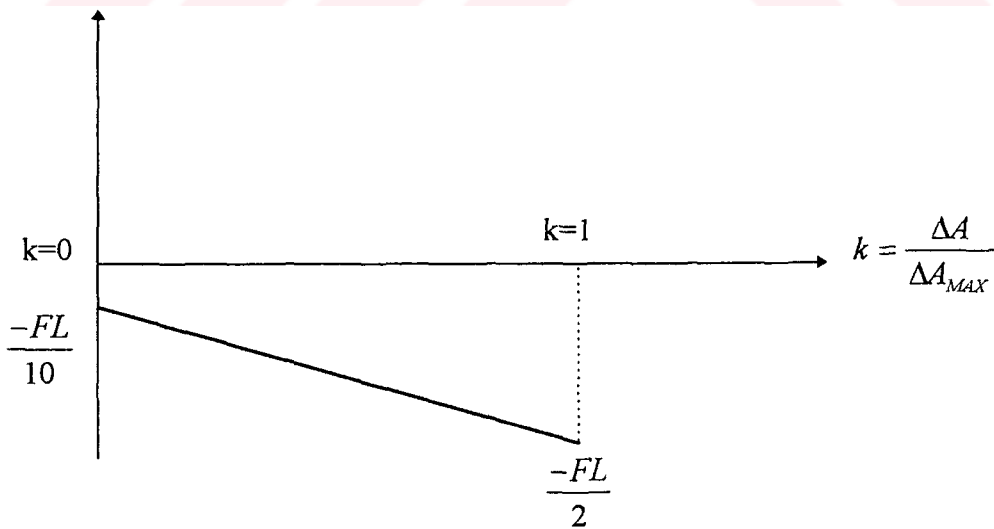
$$\Delta A = k \cdot \Delta A_{MAX}$$

$$M_B = M_{BF} + M_{B,\Delta A} = \frac{-FL}{10} - \frac{8}{5} \cdot \frac{\Delta A}{L^2} \cdot EI = \frac{-FL}{10} - \frac{8}{5} \cdot \frac{k \cdot \Delta A_{MAX}}{L^2} \cdot EI$$

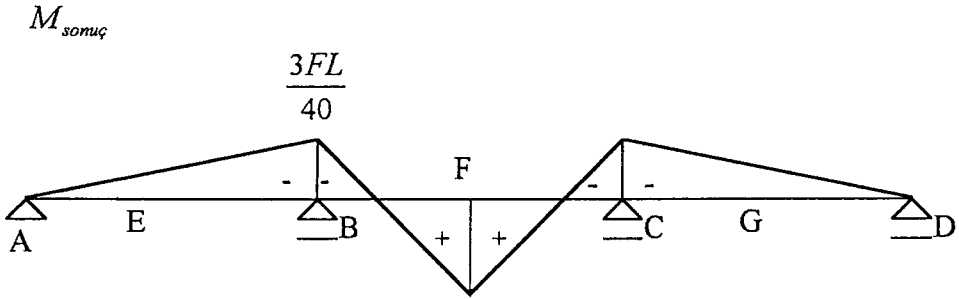
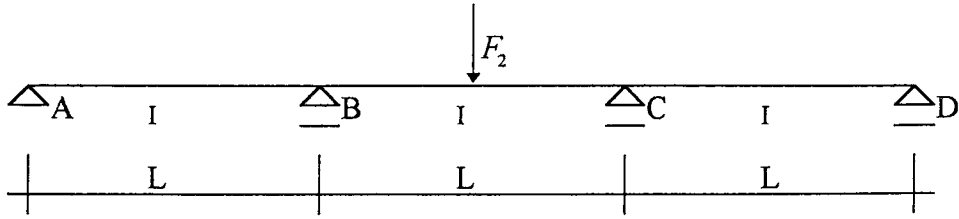
$$M_B = \frac{-FL}{10} - \frac{8}{5} \cdot \frac{k}{L^2} \cdot \frac{1}{4} \cdot \frac{FL^3}{EI} \cdot EI$$

$$M_B = \frac{-FL}{10} \cdot (4k + 1)$$

$$M_B(F + \Delta A)$$



2.4.2.3. 2. açıklık ortasında F_2 tekil yük hali



$$M_{B_F} = \frac{-3FL}{40}$$

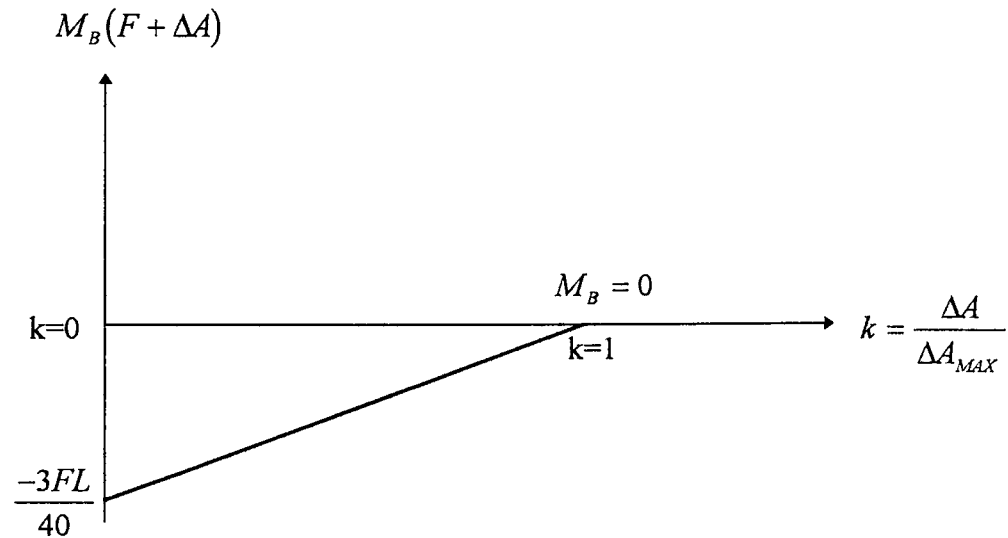
$$\Delta A_{MAX} = \frac{-3}{64} \cdot \frac{FL^3}{EI}$$

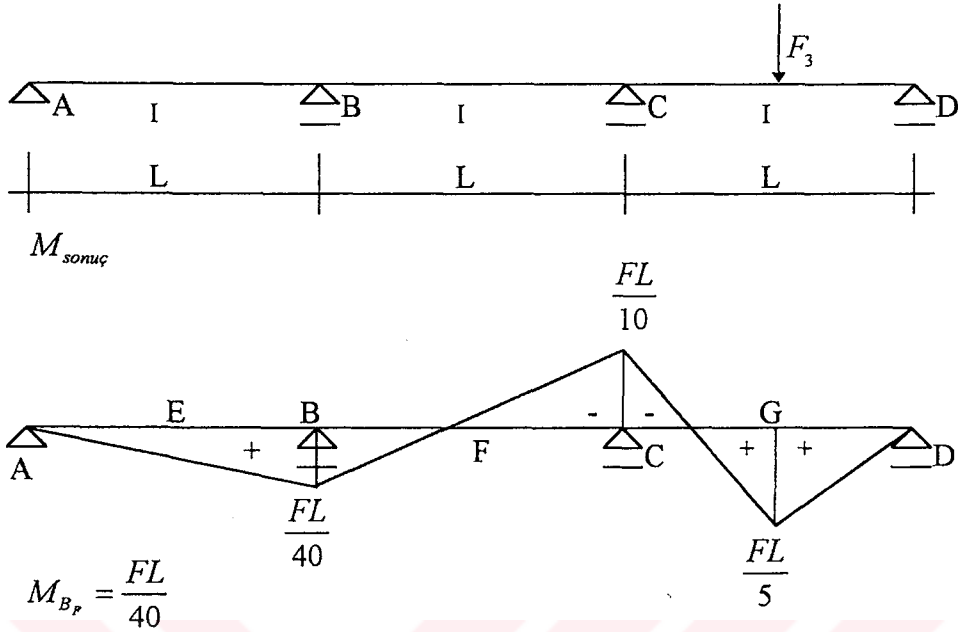
$$\Delta A = k \cdot \Delta A_{MAX}$$

$$M_B = M_{B_F} + M_{B,\Delta A} = \frac{-3FL}{40} - \frac{8}{5} \cdot \frac{\Delta A}{L^2} \cdot EI = \frac{-3FL}{40} - \frac{8}{5} \cdot \frac{k \cdot \Delta A_{MAX}}{L^2} \cdot EI$$

$$M_B = \frac{-3FL}{40} - \frac{8}{5} \cdot \frac{k}{L^2} \cdot \frac{-3}{64} \cdot \frac{FL^3}{EI} \cdot EI$$

$$M_B = \frac{3FL}{40} \cdot (k - 1)$$



2.4.2.4. 3. açıklık ortasında F_3 tekil yük hali

$$M_{B_p} = \frac{FL}{40}$$

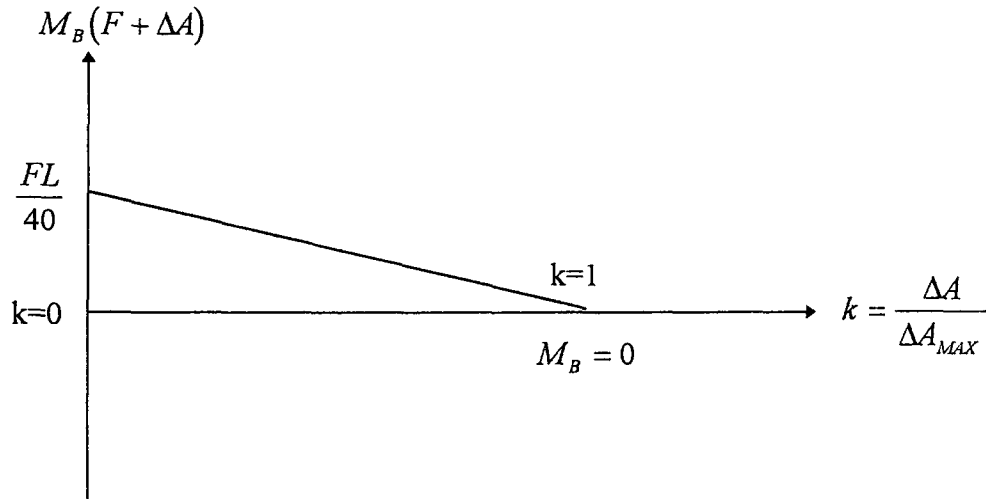
$$\Delta B_{MAX} = \frac{1}{64} \cdot \frac{FL^3}{EI}$$

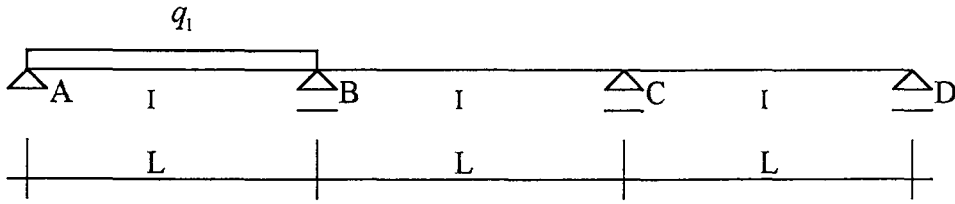
$$\Delta A = k \cdot \Delta A_{MAX}$$

$$M_B = M_{BF} + M_{B,\Delta A} = \frac{FL}{40} - \frac{8}{5} \cdot \frac{\Delta A}{L^2} \cdot EI = \frac{FL}{40} - \frac{8}{5} \cdot \frac{k \cdot \Delta A_{MAX}}{L^2} \cdot EI$$

$$M_B = \frac{FL}{40} - \frac{8}{5} \cdot \frac{k}{L^2} \cdot \frac{1}{64} \cdot \frac{FL^3}{EI} \cdot EI$$

$$M_B = \frac{FL}{40} \cdot (1 - k)$$



2.4.2.5. 1. açıklıkta q_1 yayılı yük hali

$$M_{Bq} = \frac{-qL^2}{15}$$

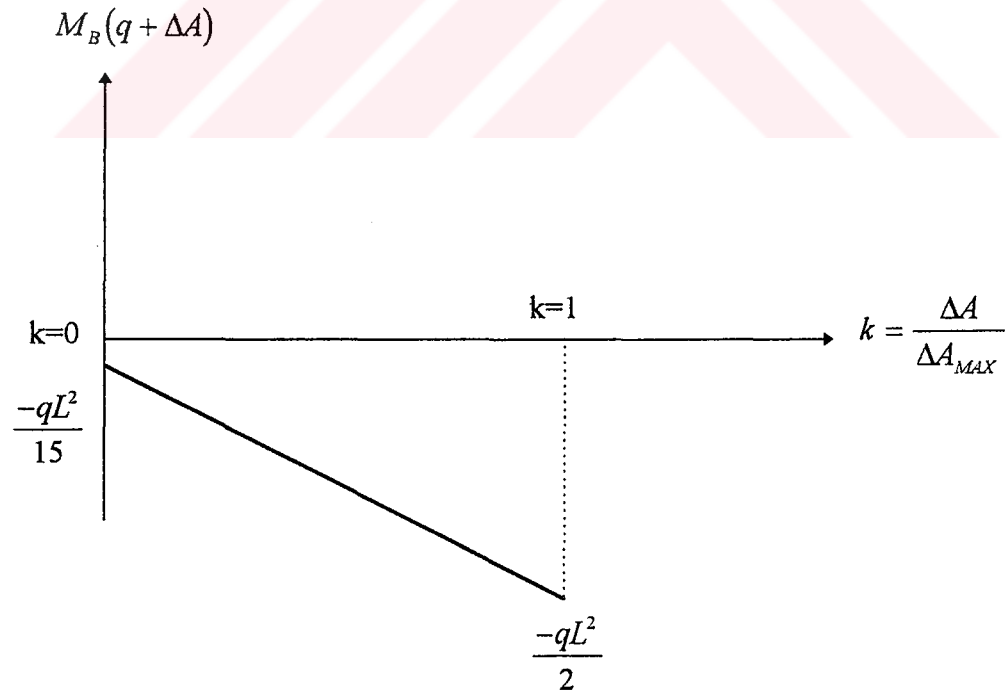
$$\Delta A_{MAX} = \frac{13}{48} \cdot \frac{qL^4}{EI}$$

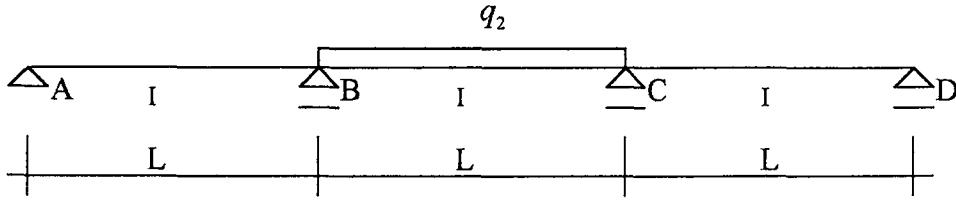
$$\Delta A = k \cdot \Delta A_{MAX}$$

$$M_B = M_{BF} + M_{B,\Delta A} = \frac{-qL^2}{15} - \frac{8}{5} \cdot \frac{\Delta A}{L^2} \cdot EI = \frac{-qL^2}{15} - \frac{8}{5} \cdot \frac{k \cdot \Delta A_{MAX}}{L^2} \cdot EI$$

$$M_B = \frac{-qL^2}{15} - \frac{8}{5} \cdot \frac{k}{L^2} \cdot \frac{13}{48} \cdot \frac{qL^4}{EI} \cdot EI$$

$$M_B = \frac{-qL^2}{30} \cdot (13k + 2)$$



2.4.2.6. 2. açıklıkta q_2 yayılı yük hali

$$M_{Bq} = \frac{-qL^2}{20}$$

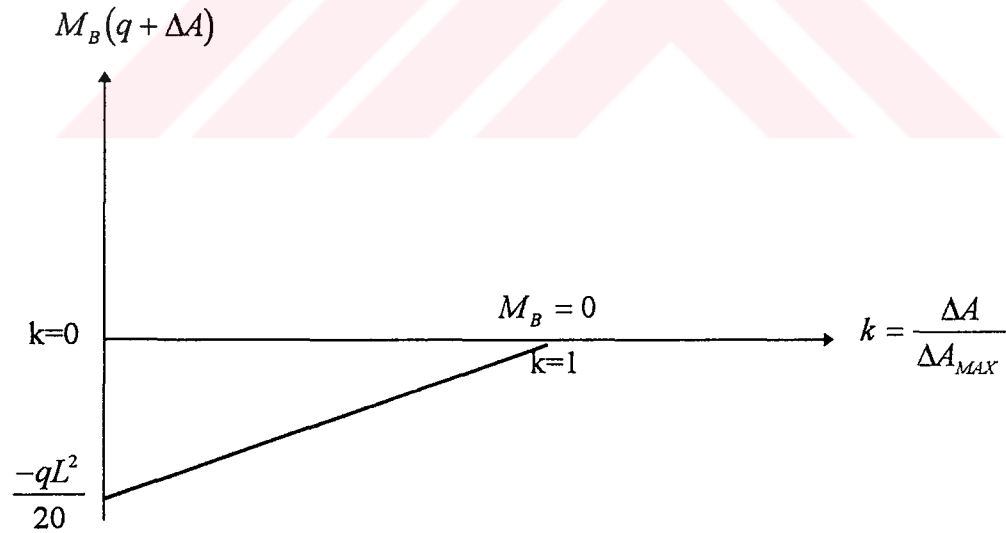
$$\Delta A_{MAX} = \frac{-1}{32} \cdot \frac{qL^4}{EI}$$

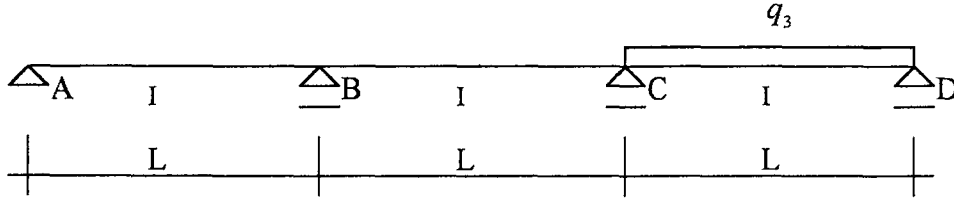
$$\Delta A = k \cdot \Delta A_{MAX}$$

$$M_B = M_{BF} + M_{B,\Delta A} = \frac{-qL^2}{20} - \frac{8}{5} \cdot \frac{\Delta A}{L^2} \cdot EI = \frac{-qL^2}{20} - \frac{8}{5} \cdot \frac{k \cdot \Delta A_{MAX}}{L^2} \cdot EI$$

$$M_B = \frac{-qL^2}{20} - \frac{8}{5} \cdot \frac{k}{L^2} \cdot \frac{-1}{32} \cdot \frac{qL^4}{EI} \cdot EI$$

$$M_B = \frac{qL^2}{20} \cdot (k - 1)$$



2.4.2.7. 3. açıklıkta q_3 yayılı yük hali

$$M_{Bq} = \frac{qL^2}{60}$$

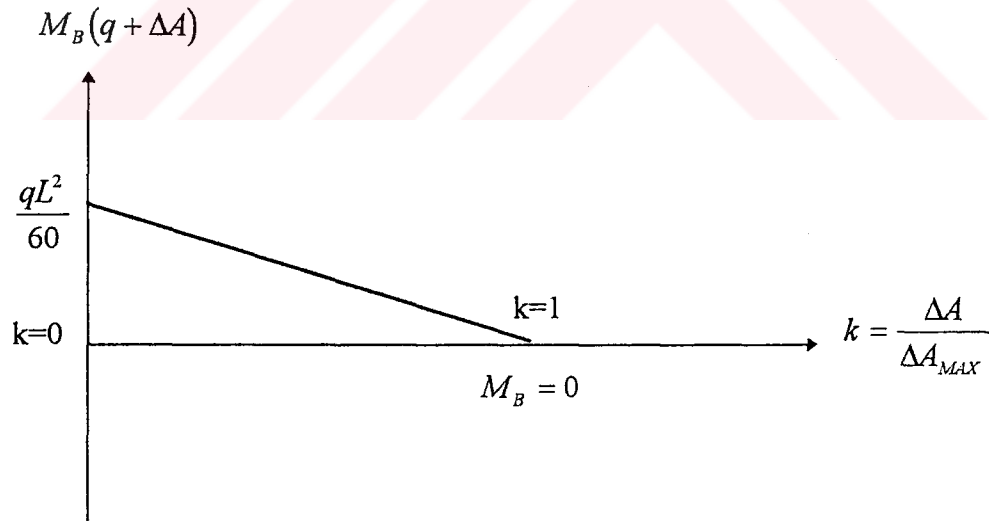
$$\Delta A_{MAX} = \frac{1}{96} \cdot \frac{qL^4}{EI}$$

$$\Delta A = k \cdot \Delta A_{MAX}$$

$$M_B = M_{Bq} + M_{B,\Delta A} = \frac{qL^2}{60} - \frac{8}{5} \cdot \frac{\Delta A}{L^2} \cdot EI = \frac{qL^2}{60} - \frac{8}{5} \cdot \frac{k \cdot \Delta A_{MAX}}{L^2} \cdot EI$$

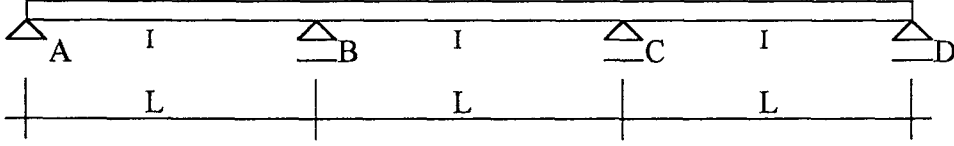
$$M_B = \frac{qL^2}{60} - \frac{8}{5} \cdot \frac{k}{L^2} \cdot \frac{1}{96} \cdot \frac{qL^4}{EI} \cdot EI$$

$$M_B = \frac{qL^2}{60} \cdot (1 - k)$$

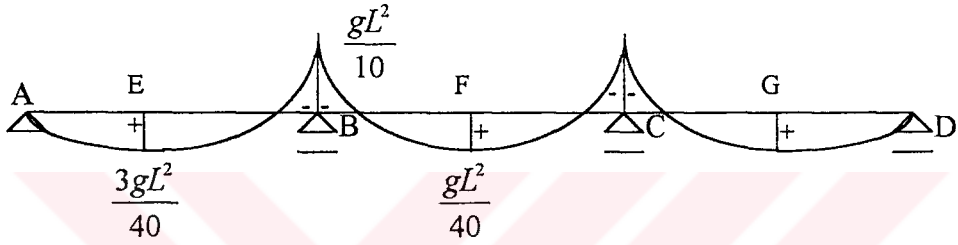


2.4.3. C mesnet eğilme momentinin B mesnedindeki maksimum mesnet hareketine bağlı değişimi

2.4.3.1. g sabit yük hali

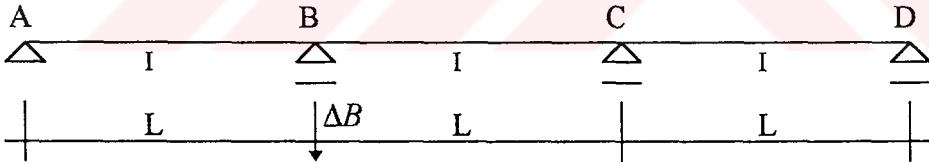


$M_{sonuç}$

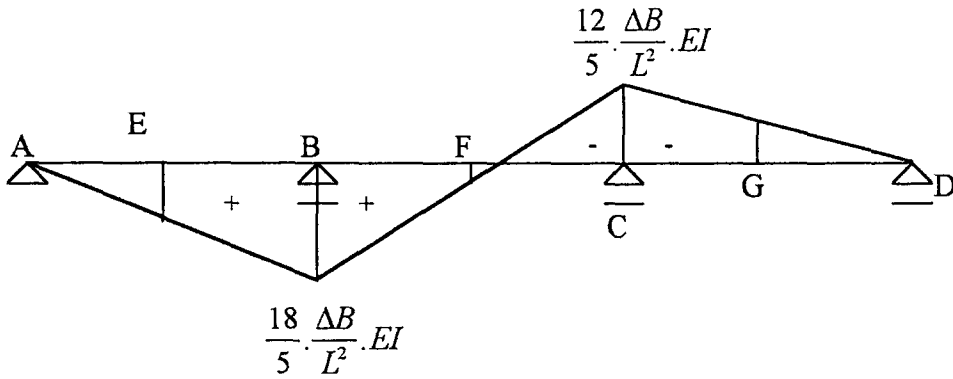


$$M_{C_s} = \frac{-gL^2}{10}$$

ΔB mesnet hareketi halinde eğilme momentleri



$M_{\Delta B}$



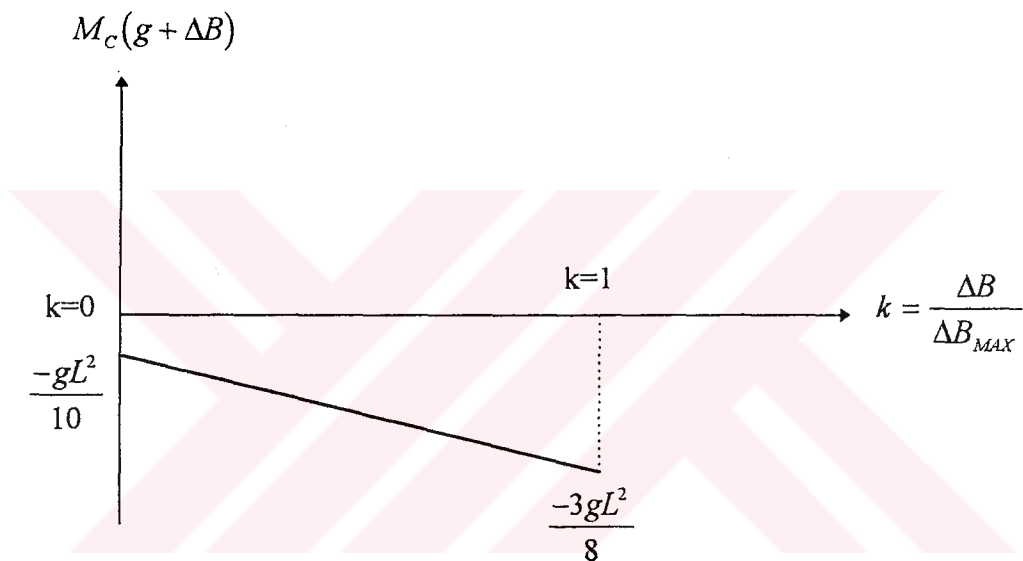
$$\Delta B_{MAX} = \frac{11}{96} \cdot \frac{gL^4}{EI}$$

$$\Delta B = k \cdot \Delta B_{MAX}$$

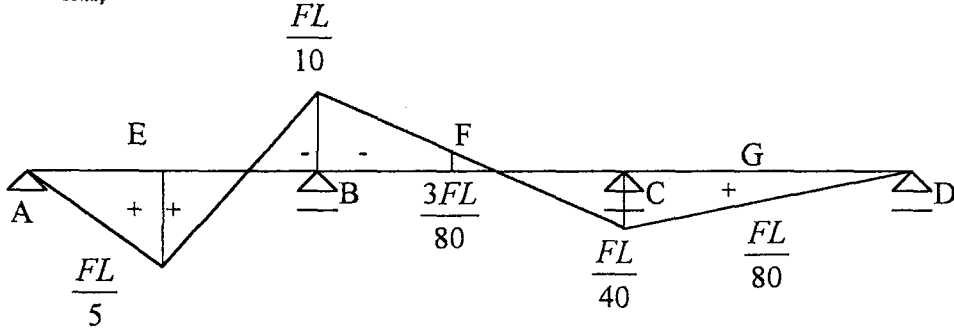
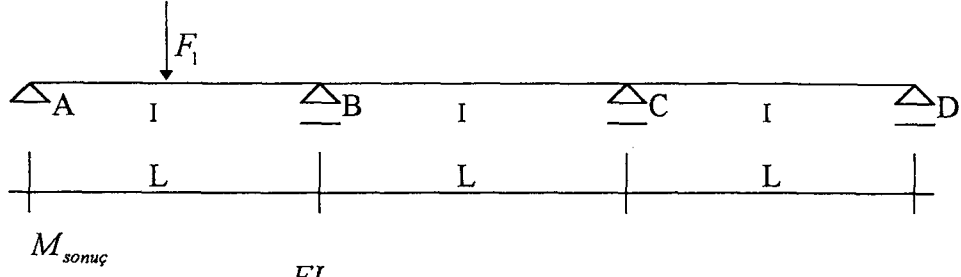
$$M_C = M_{Cg} + M_{C,\Delta B} = \frac{-gL^2}{10} - \frac{12}{5} \cdot \frac{\Delta B}{L^2} \cdot EI = \frac{-gL^2}{10} - \frac{12}{5} \cdot \frac{k \cdot \Delta B_{MAX}}{L^2} \cdot EI$$

$$M_C = \frac{-gL^2}{10} - \frac{12}{5} \cdot \frac{k}{L^2} \cdot \frac{11}{96} \cdot \frac{gL^4}{EI} \cdot EI$$

$$M_C = \frac{-gL^2}{40} \cdot (11k + 4)$$



2.4.3.2. 1. açıklık ortasında F_1 tekil yük hali



$$M_{C_F} = \frac{FL}{40}$$

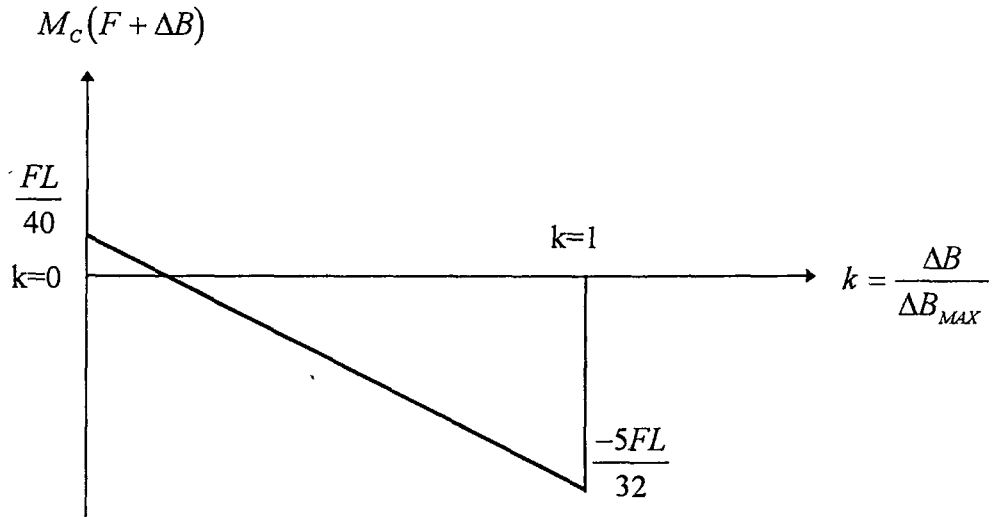
$$\Delta B_{MAX} = \frac{29}{384} \cdot \frac{FL^3}{EI}$$

$$\Delta B = k \cdot \Delta B_{MAX}$$

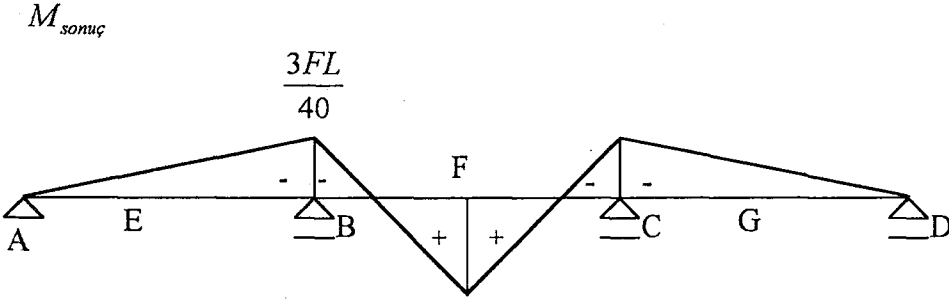
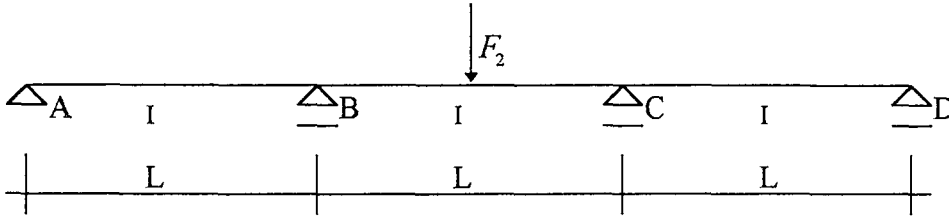
$$M_C = M_{C_F} + M_{C,\Delta B} = \frac{FL}{40} - \frac{12}{5} \cdot \frac{\Delta B}{L^2} \cdot EI = \frac{FL}{40} - \frac{12}{5} \cdot \frac{k \cdot \Delta B_{MAX}}{L^2} \cdot EI$$

$$M_C = \frac{FL}{40} - \frac{12}{5} \cdot \frac{k}{L^2} \cdot \frac{29}{384} \cdot \frac{FL^3}{EI} \cdot EI$$

$$M_C = \frac{FL}{160} \cdot (4 - 29k)$$



2.4.3.3. 2. açıklık ortasında F_2 tekil yük hali



$$M_{C_F} = \frac{-3FL}{40}$$

$$\Delta B_{MAX} = \frac{23}{384} \cdot \frac{FL^3}{EI}$$

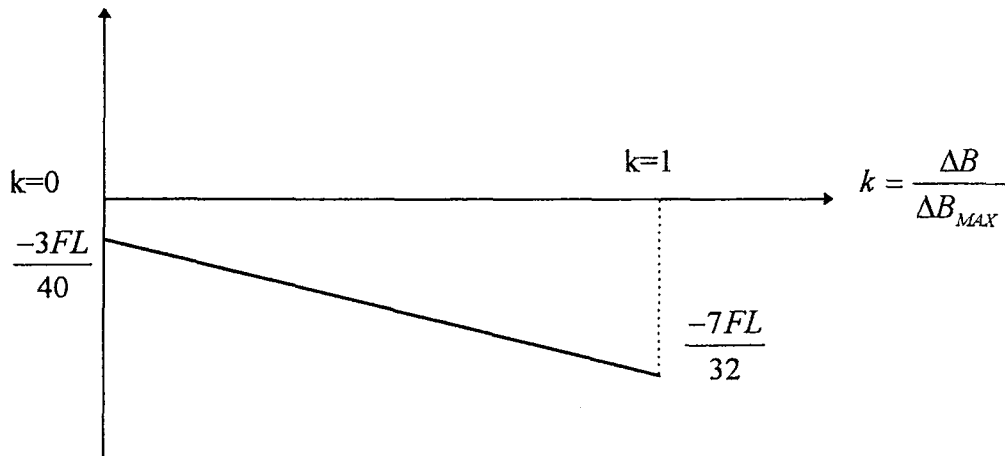
$$\Delta B = k \cdot \Delta B_{MAX}$$

$$M_C = M_{C_F} + M_{C,\Delta B} = \frac{-3FL}{40} - \frac{12}{5} \cdot \frac{\Delta B}{L^2} \cdot EI = \frac{-3FL}{40} - \frac{12}{5} \cdot \frac{k \cdot \Delta B_{MAX}}{L^2} \cdot EI$$

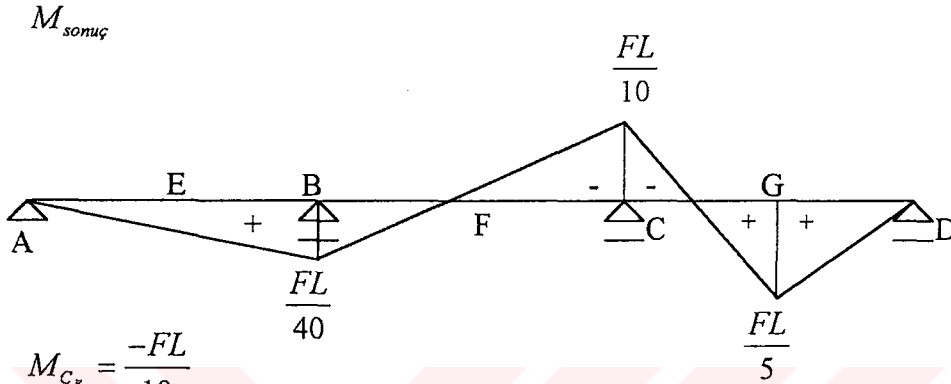
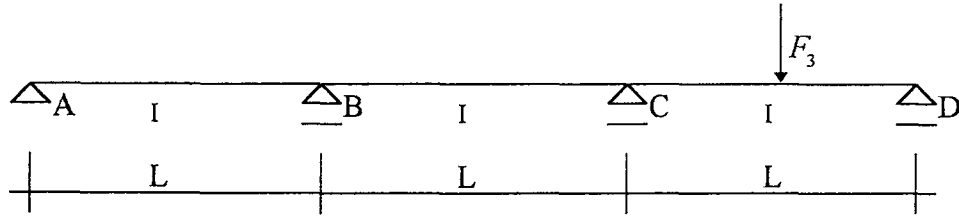
$$M_C = \frac{-3FL}{40} - \frac{12}{5} \cdot \frac{k}{L^2} \cdot \frac{23}{384} \cdot \frac{FL^3}{EI} \cdot EI$$

$$M_C = \frac{-FL}{160} \cdot (12 + 23k)$$

$$M_C(F + \Delta B)$$



2.4.3.4. 3. açıklık ortasında F_3 tekil yük hali



$$M_{C_F} = \frac{-FL}{10}$$

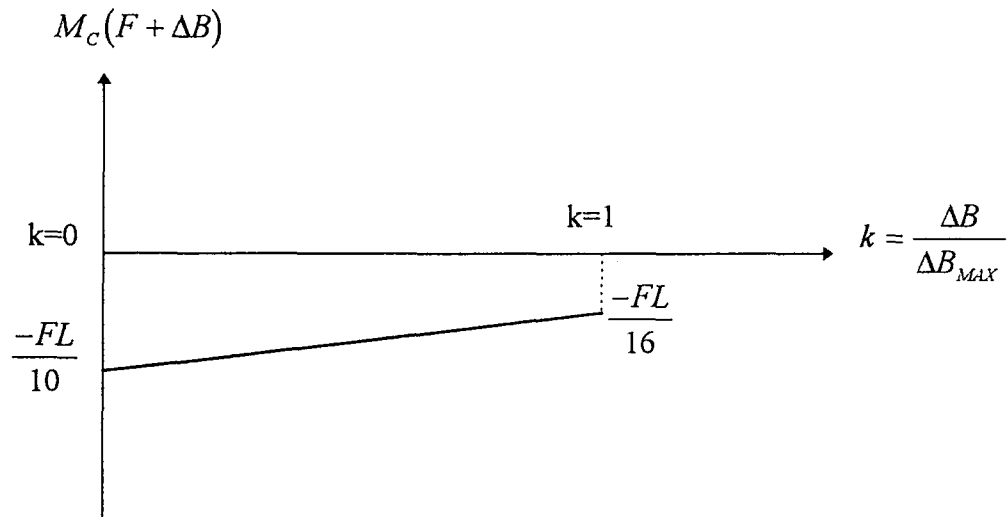
$$\Delta B_{MAX} = \frac{-1}{64} \cdot \frac{FL^3}{EI}$$

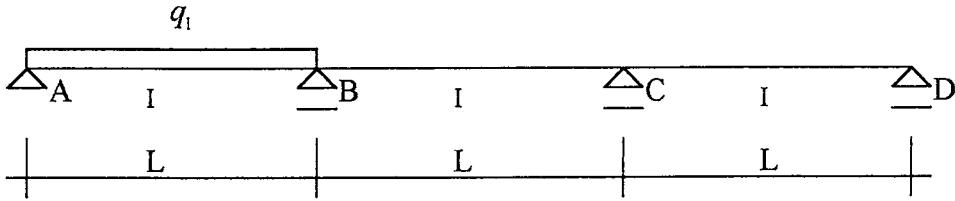
$$\Delta B = k \cdot \Delta B_{MAX}$$

$$M_C = M_{C_F} + M_{C,\Delta B} = \frac{-FL}{10} - \frac{12}{5} \cdot \frac{\Delta B}{L^2} \cdot EI = \frac{-FL}{10} - \frac{12}{5} \cdot \frac{k \cdot \Delta B_{MAX}}{L^2} \cdot EI$$

$$M_C = \frac{-FL}{10} - \frac{12}{5} \cdot \frac{k}{L^2} \cdot \frac{-1}{64} \cdot \frac{FL^3}{EI} \cdot EI$$

$$M_C = \frac{FL}{80} \cdot (3k - 8)$$



2.4.3.5. 1. açıklıkta q_1 yayılı yük hali

$$M_{Cq} = \frac{qL^2}{60}$$

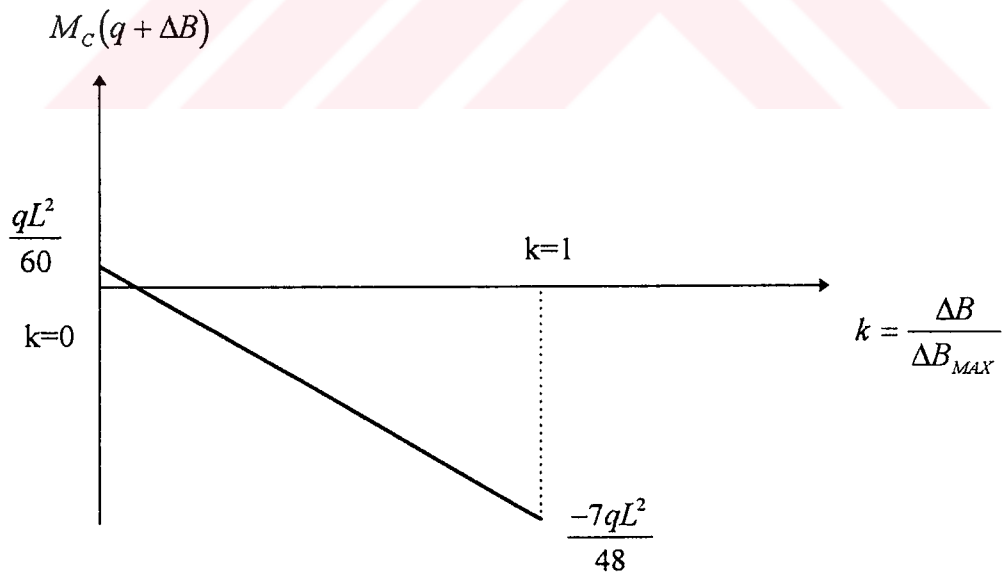
$$\Delta B_{MAX} = \frac{13}{192} \cdot \frac{qL^4}{EI}$$

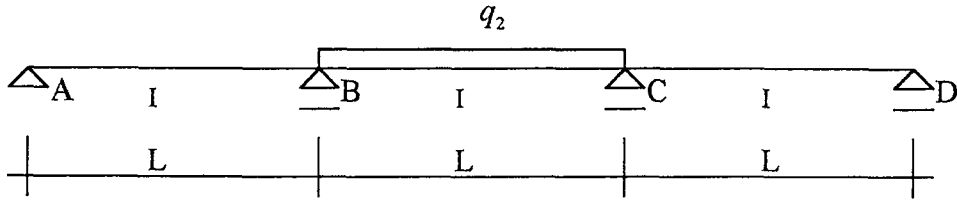
$$\Delta B = k \cdot \Delta B_{MAX}$$

$$M_C = M_{Cq} + M_{C,\Delta B} = \frac{qL^2}{60} - \frac{12}{5} \cdot \frac{\Delta B}{L^2} \cdot EI = \frac{qL^2}{60} - \frac{12}{5} \cdot \frac{k \cdot \Delta B_{MAX}}{L^2} \cdot EI$$

$$M_C = \frac{qL^2}{60} - \frac{12}{5} \cdot \frac{k}{L^2} \cdot \frac{13}{192} \cdot \frac{qL^4}{EI} \cdot EI$$

$$M_C = \frac{qL^2}{240} \cdot (4 - 39k)$$



2.4.3.6. 2. açıklıkta q_2 yayılı yük hali

$$M_{Cq} = \frac{-qL^2}{20}$$

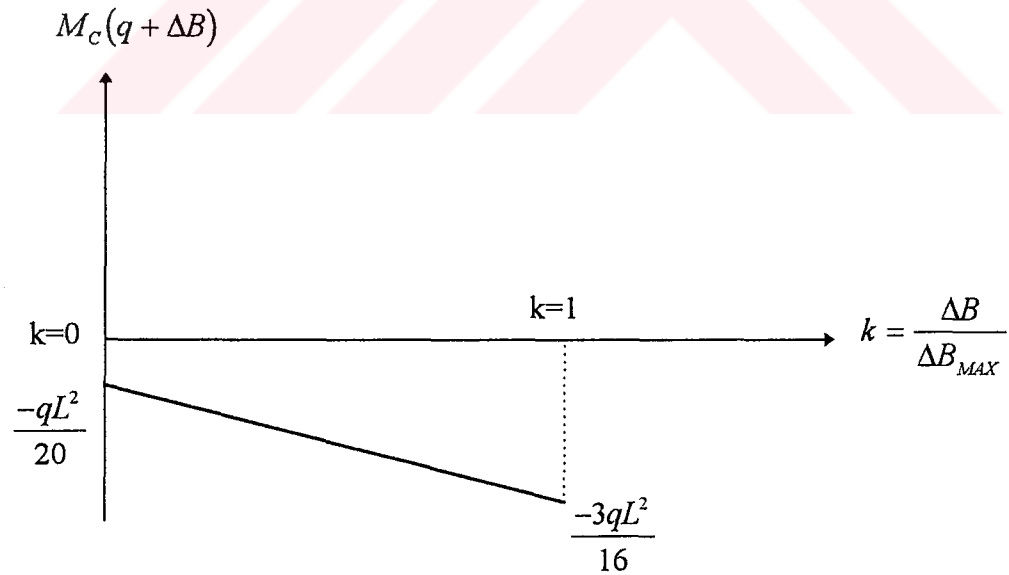
$$\Delta B_{MAX} = \frac{11}{192} \cdot \frac{qL^4}{EI}$$

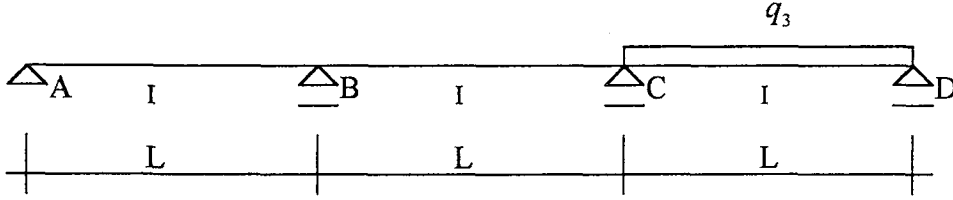
$$\Delta B = k \cdot \Delta B_{MAX}$$

$$M_C = M_{Cq} + M_{C,\Delta B} = \frac{-qL^2}{20} - \frac{12}{5} \cdot \frac{\Delta B}{L^2} \cdot EI = \frac{-qL^2}{20} - \frac{12}{5} \cdot \frac{k \cdot \Delta B_{MAX}}{L^2} \cdot EI$$

$$M_C = \frac{-qL^2}{20} - \frac{12}{5} \cdot \frac{k}{L^2} \cdot \frac{11}{192} \cdot \frac{qL^4}{EI} \cdot EI$$

$$M_C = \frac{-qL^2}{80} \cdot (11k + 4)$$



2.4.3.7. 3. açıklıkta q_3 yayılı yük hali

$$M_{Cq} = \frac{-qL^2}{15}$$

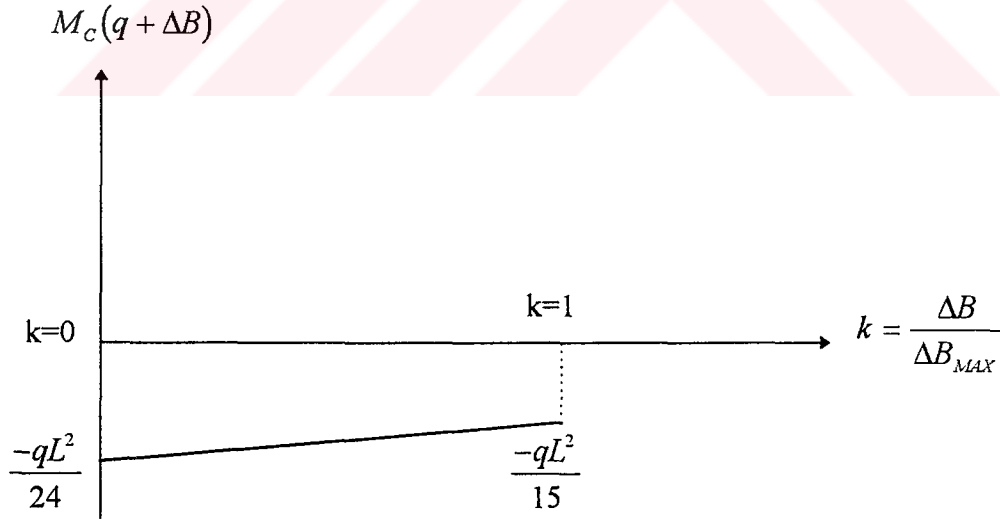
$$\Delta B_{MAX} = \frac{-1}{96} \cdot \frac{qL^4}{EI}$$

$$\Delta B = k \cdot \Delta B_{MAX}$$

$$M_C = M_{Cq} + M_{C,\Delta B} = \frac{-qL^2}{15} - \frac{12}{5} \cdot \frac{\Delta B}{L^2} \cdot EI = \frac{-qL^2}{15} - \frac{12}{5} \cdot \frac{k \cdot \Delta B_{MAX}}{L^2} \cdot EI$$

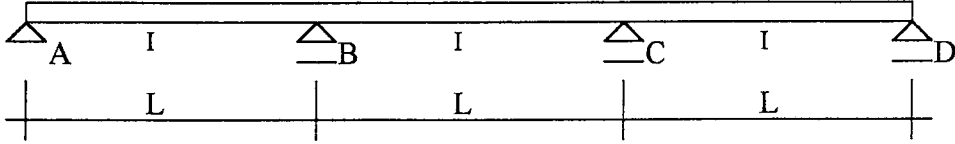
$$M_C = \frac{-qL^2}{15} - \frac{12}{5} \cdot \frac{k}{L^2} \cdot \frac{-1}{96} \cdot \frac{qL^4}{EI} \cdot EI$$

$$M_C = \frac{qL^2}{120} \cdot (3k - 8)$$

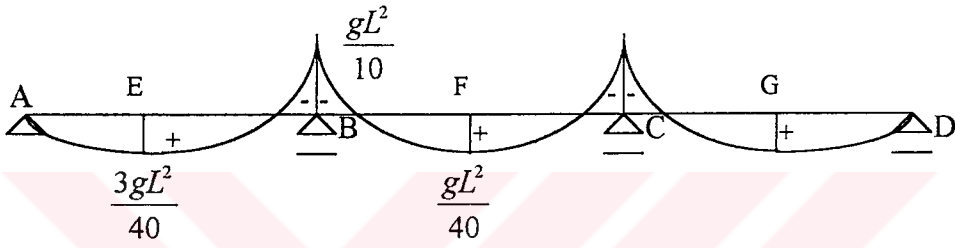


2.4.4. C mesnet eğilme momentinin A mesnedindeki maksimum mesnet hareketine bağlı değişimi

2.4.4.1. g sabit yük hali

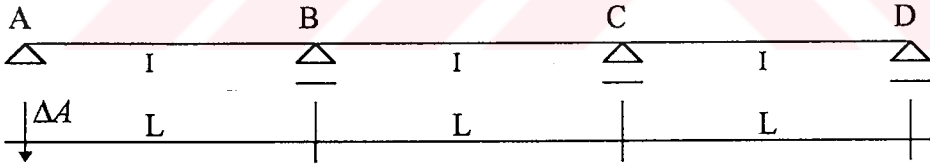


$M_{sonuç}$

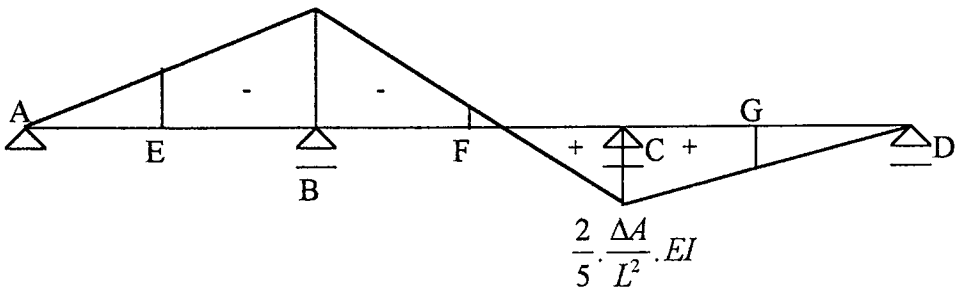


$$M_{C_s} = \frac{-gL^2}{10}$$

ΔA mesnet hareketi halinde eğilme momentleri



$$M_{\Delta A} \quad \frac{8}{5} \cdot \frac{\Delta A}{L^2} \cdot EI$$



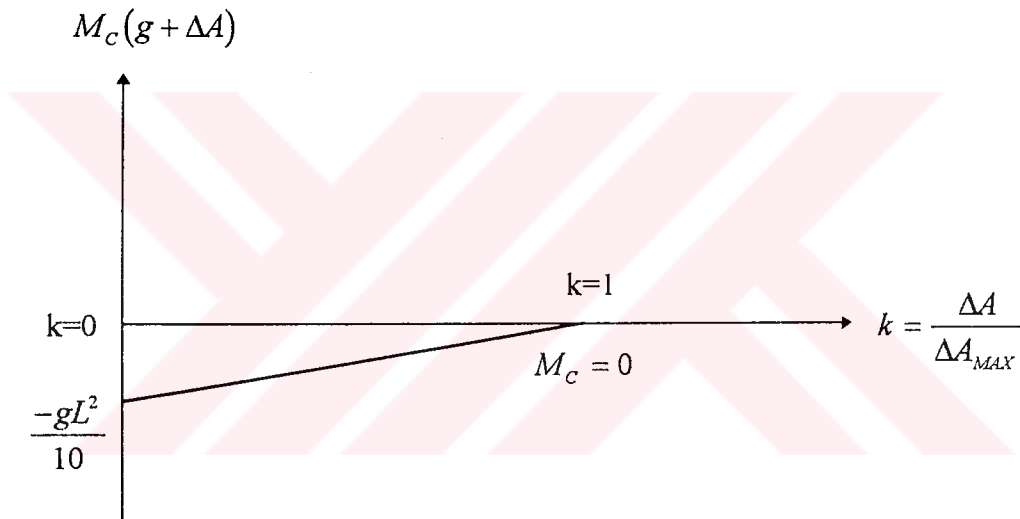
$$\Delta A_{MAX} = \frac{1}{4} \cdot \frac{gL^4}{EI}$$

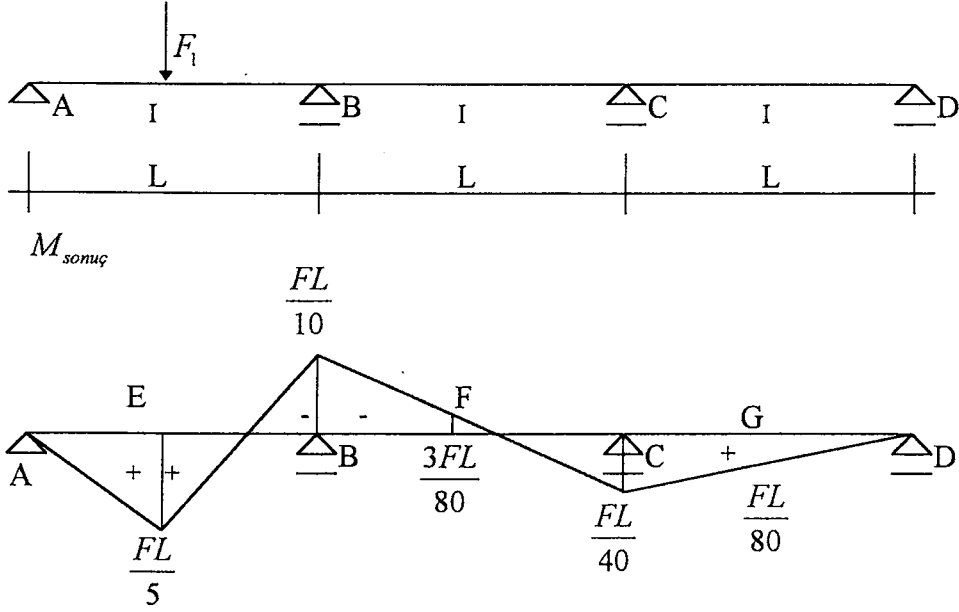
$$\Delta A = k \cdot \Delta A_{MAX}$$

$$M_C = M_{Cg} + M_{C,\Delta A} = \frac{-gL^2}{10} + \frac{2}{5} \cdot \frac{\Delta A}{L^2} \cdot EI = \frac{-gL^2}{10} + \frac{2}{5} \cdot \frac{k \cdot \Delta A_{MAX}}{L^2} \cdot EI$$

$$M_C = \frac{-gL^2}{10} + \frac{2}{5} \cdot \frac{k}{L^2} \cdot \frac{1}{4} \cdot \frac{gL^4}{EI} \cdot EI$$

$$M_C = \frac{gL^2}{10} \cdot (k - 1)$$



2.4.4.2. 1. açıklık ortasında F_1 tekil yük hali

$$M_{C_F} = \frac{FL}{40}$$

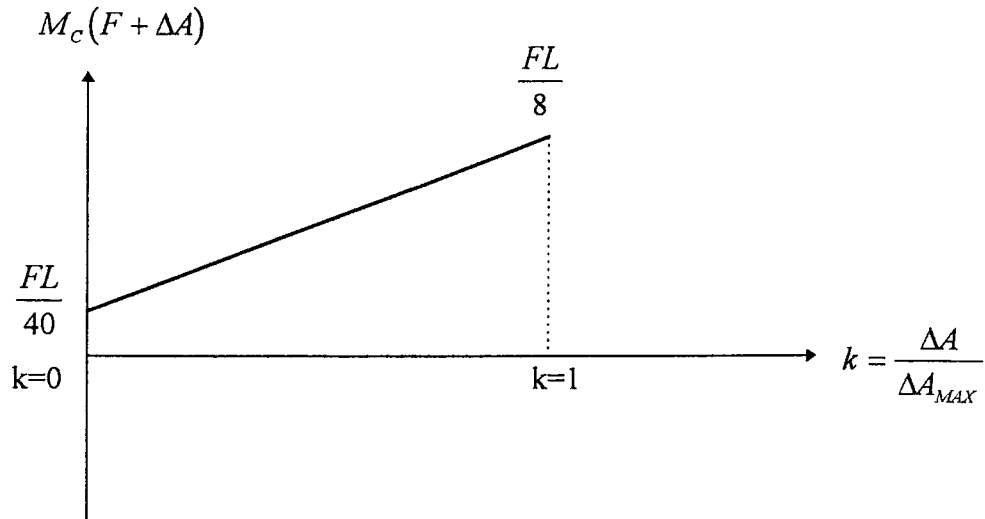
$$\Delta A_{MAX} = \frac{1}{4} \cdot \frac{FL^3}{EI}$$

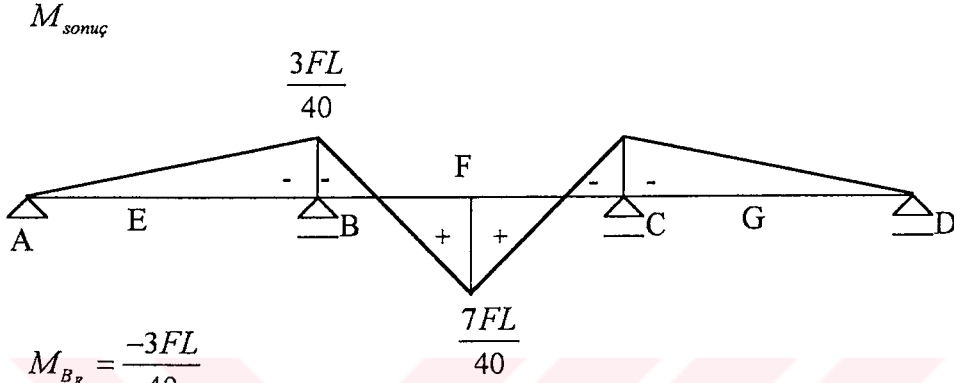
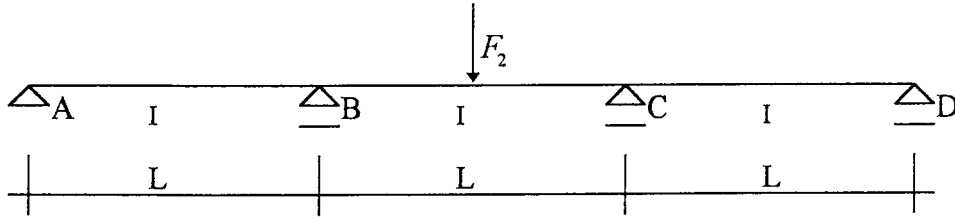
$$\Delta A = k \cdot \Delta A_{MAX}$$

$$M_C = M_{CF} + M_{C,\Delta A} = \frac{FL}{40} + \frac{2}{5} \cdot \frac{\Delta A}{L^2} \cdot EI = \frac{FL}{40} + \frac{2}{5} \cdot \frac{k \cdot \Delta A_{MAX}}{L^2} \cdot EI$$

$$M_C = \frac{FL}{40} + \frac{2}{5} \cdot \frac{k}{L^2} \cdot \frac{1}{4} \cdot \frac{FL^3}{EI} \cdot EI$$

$$M_C = \frac{FL}{40} \cdot (4k + 1)$$



2.4.4.3. 2. açıklık ortasında F_2 tekil yük hali

$$M_{B_F} = \frac{-3FL}{40}$$

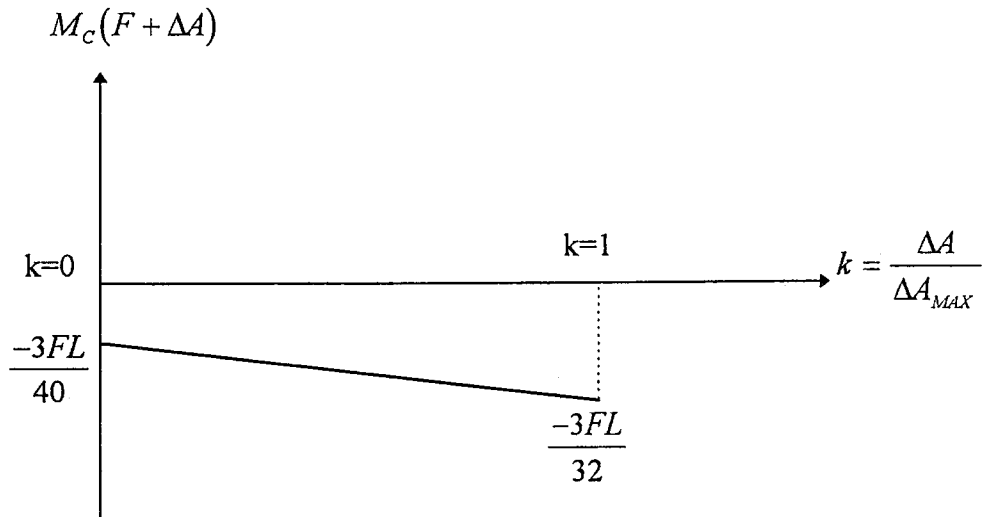
$$\Delta A_{MAX} = \frac{-3}{64} \cdot \frac{FL^3}{EI}$$

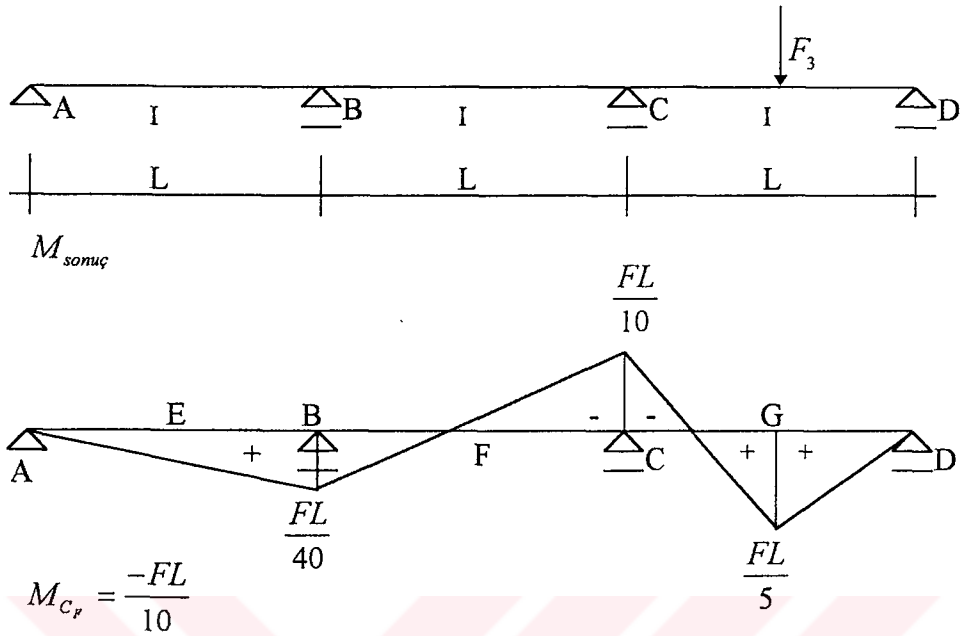
$$\Delta A = k \cdot \Delta A_{MAX}$$

$$M_C = M_{CF} + M_{C,\Delta A} = \frac{-3FL}{40} + \frac{2}{5} \cdot \frac{\Delta A}{L^2} \cdot EI = \frac{-3FL}{40} + \frac{2}{5} \cdot \frac{k \cdot \Delta A_{MAX}}{L^2} \cdot EI$$

$$M_C = \frac{-3FL}{40} + \frac{2}{5} \cdot \frac{k}{L^2} \cdot \frac{-3}{64} \cdot \frac{FL^3}{EI} \cdot EI$$

$$M_C = \frac{-FL}{160} \cdot (3k + 12)$$



2.4.4.4. 3. açıklık ortasında F_3 tekil yük hali

$$M_{C_F} = -\frac{FL}{10}$$

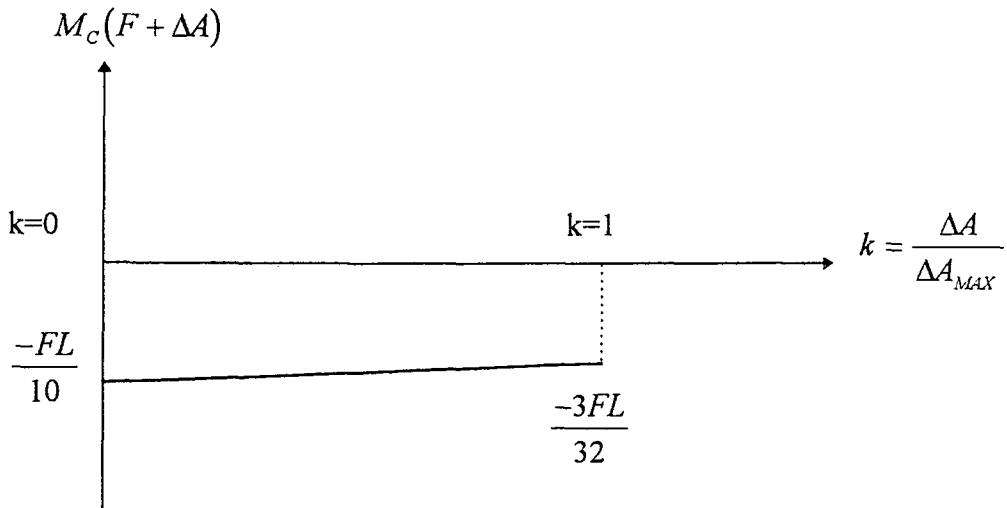
$$\Delta B_{MAX} = \frac{1}{64} \cdot \frac{FL^3}{EI}$$

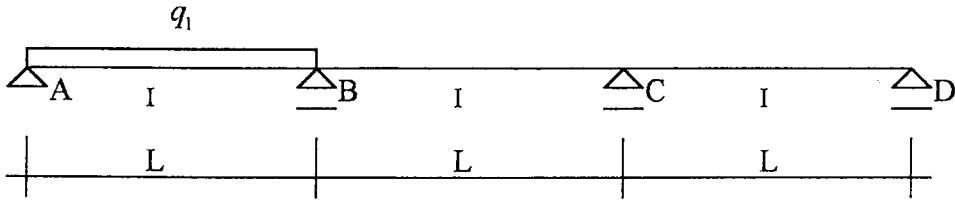
$$\Delta A = k \cdot \Delta A_{MAX}$$

$$M_C = M_{CF} + M_{C,\Delta A} = -\frac{FL}{10} + \frac{2}{5} \cdot \frac{\Delta A}{L^2} \cdot EI = -\frac{FL}{10} + \frac{2}{5} \cdot \frac{k \cdot \Delta A_{MAX}}{L^2} \cdot EI$$

$$M_C = -\frac{FL}{10} + \frac{2}{5} \cdot \frac{k}{L^2} \cdot \frac{1}{64} \cdot \frac{FL^3}{EI} \cdot EI$$

$$M_C = \frac{FL}{160} \cdot (k - 16)$$



2.4.4.5. 1. açıklıkta q_1 yayılı yük hali

$$M_{Cq} = \frac{qL^2}{60}$$

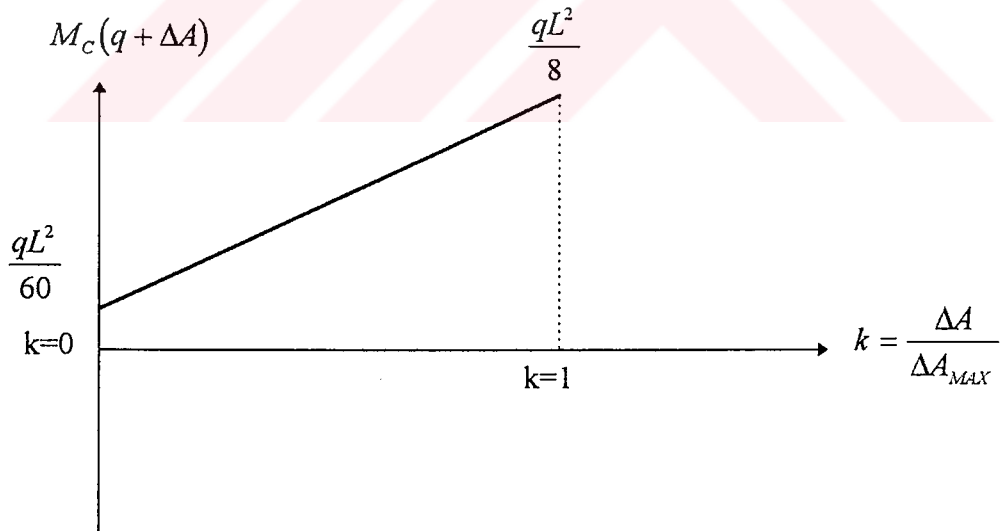
$$\Delta A_{MAX} = \frac{13}{48} \frac{qL^4}{EI}$$

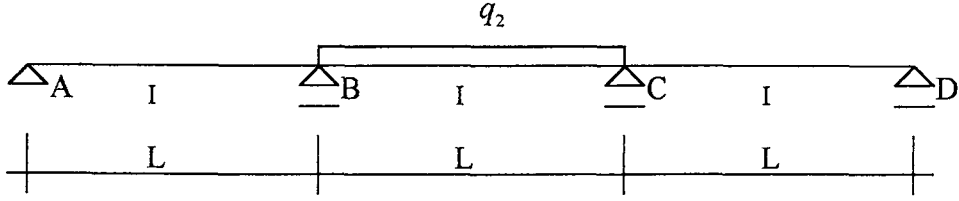
$$\Delta A = k \cdot \Delta A_{MAX}$$

$$M_C = M_{CF} + M_{C,\Delta A} = \frac{qL^2}{60} + \frac{2}{5} \cdot \frac{\Delta A}{L^2} \cdot EI = \frac{qL^2}{60} + \frac{2}{5} \cdot \frac{k \cdot \Delta A_{MAX}}{L^2} \cdot EI$$

$$M_C = \frac{qL^2}{60} + \frac{2}{5} \cdot \frac{k}{L^2} \cdot \frac{13}{48} \cdot \frac{qL^4}{EI} \cdot EI$$

$$M_C = \frac{qL^2}{120} \cdot (13k + 2)$$



2.4.4.6. 2. açıklıkta q_2 yayılı yük hali

$$M_{Bq} = \frac{-qL^2}{20}$$

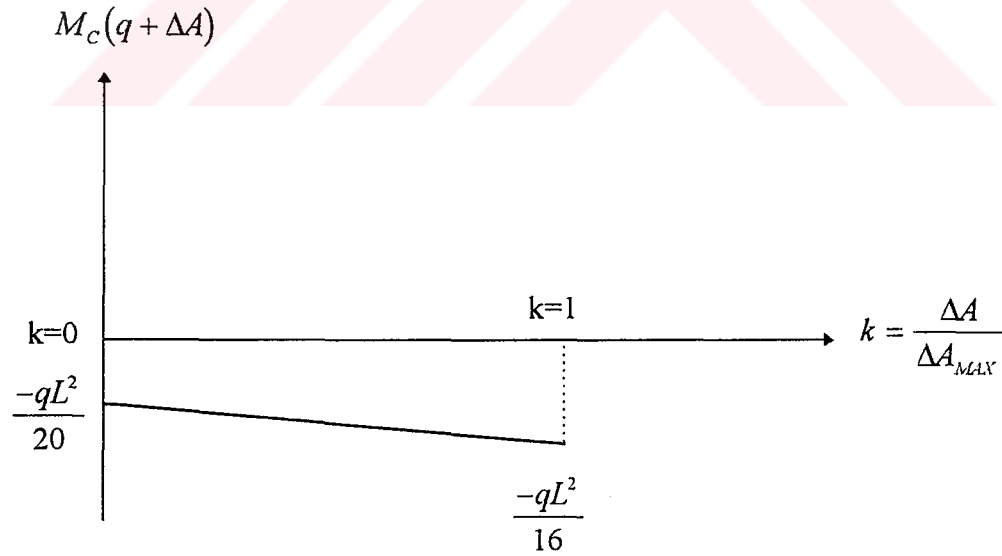
$$\Delta A_{MAX} = \frac{-1}{32} \frac{qL^4}{EI}$$

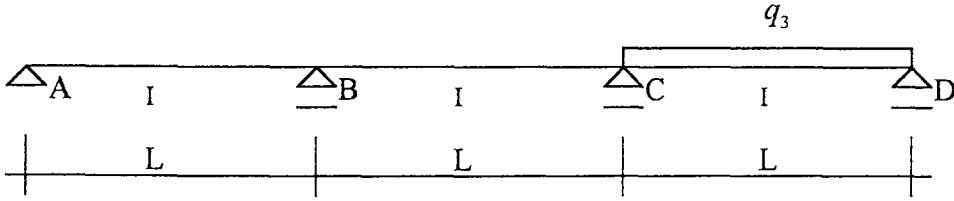
$$\Delta A = k \cdot \Delta A_{MAX}$$

$$M_C = M_{CF} + M_{C,\Delta A} = \frac{-qL^2}{20} + \frac{2}{5} \cdot \frac{\Delta A}{L^2} \cdot EI = \frac{-qL^2}{20} + \frac{2}{5} \cdot \frac{k \cdot \Delta A_{MAX}}{L^2} \cdot EI$$

$$M_C = \frac{-qL^2}{20} + \frac{2}{5} \cdot \frac{k}{L^2} \cdot \frac{-1}{32} \cdot \frac{qL^4}{EI} \cdot EI$$

$$M_C = \frac{-qL^2}{80} \cdot (k+4)$$



2.4.4.7. 3. açıklıkta q_3 yayılı yük hali

$$M_{Cq} = \frac{-qL^2}{15}$$

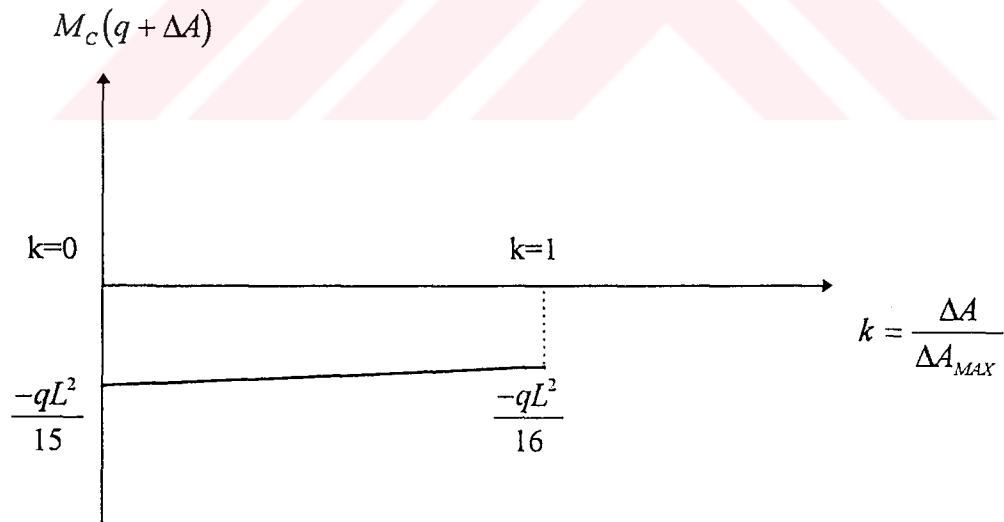
$$\Delta A_{MAX} = \frac{1}{96} \cdot \frac{qL^4}{EI}$$

$$\Delta A = k \cdot \Delta A_{MAX}$$

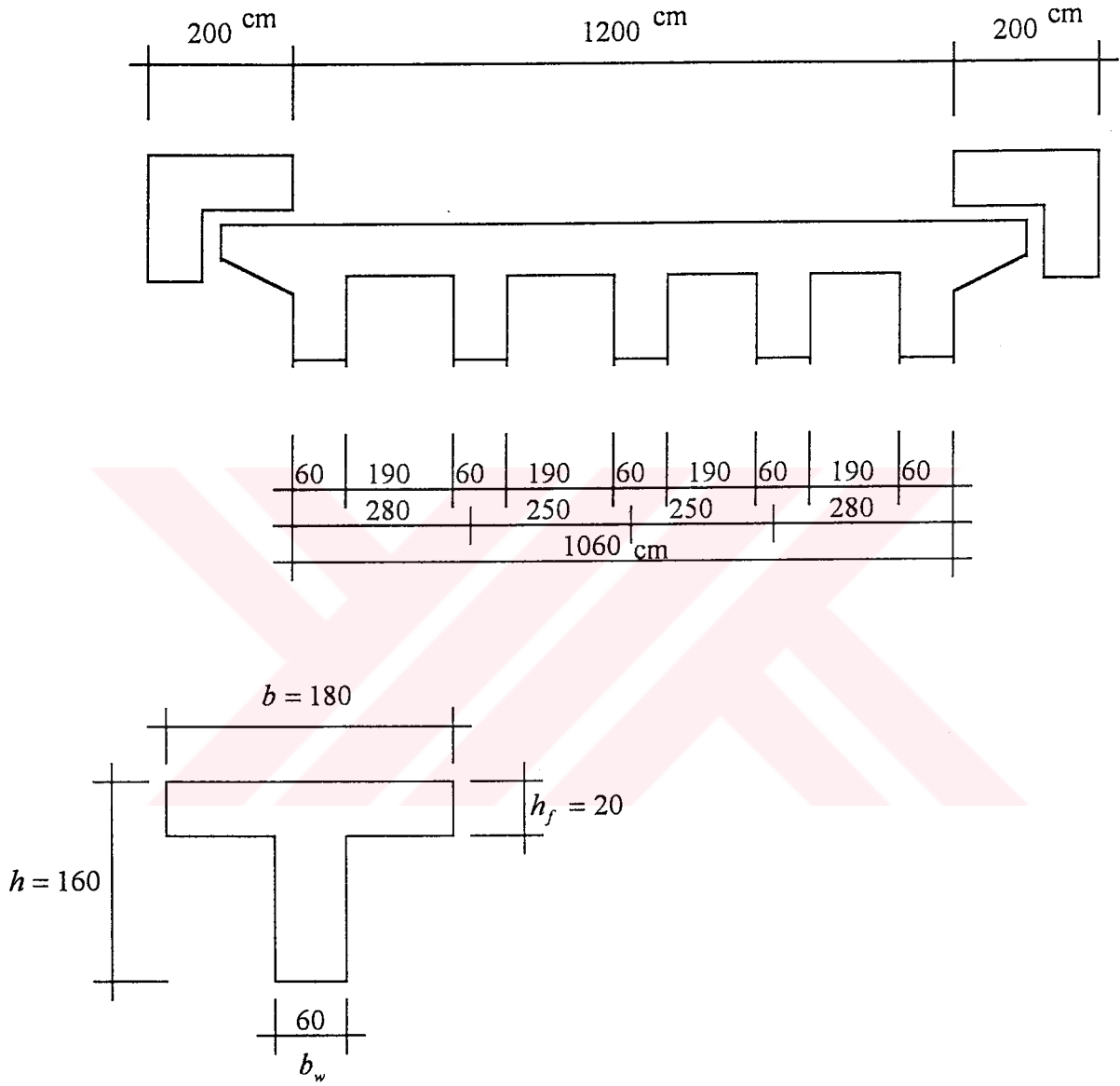
$$M_C = M_{CF} + M_{C,\Delta A} = \frac{-qL^2}{15} + \frac{2}{5} \cdot \frac{\Delta A}{L^2} \cdot EI = \frac{-qL^2}{15} + \frac{2}{5} \cdot \frac{k \cdot \Delta A_{MAX}}{L^2} \cdot EI$$

$$M_C = \frac{-qL^2}{15} + \frac{2}{5} \cdot \frac{k}{L^2} \cdot \frac{1}{96} \cdot \frac{qL^4}{EI} \cdot EI$$

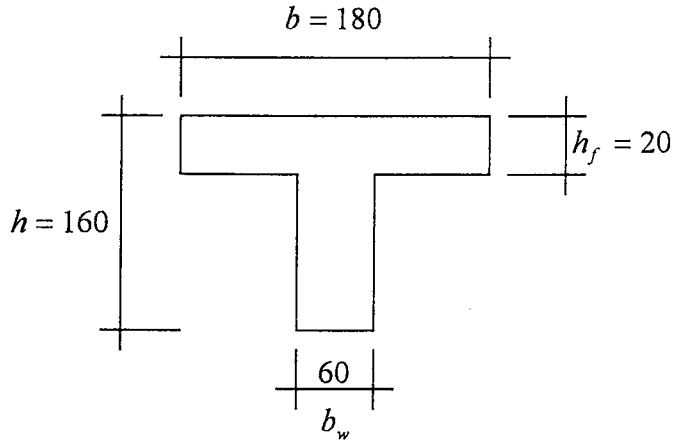
$$M_C = \frac{qL^2}{240} \cdot (k - 16)$$



2.5. Köprü enkesit özellikleri



2.6. Kiriş atalet momenti hesabı ve elverişsiz şerit sayısının bulunması



1.yol :

$$A = \frac{b}{b_w} = \frac{180}{60} = 3 \quad B = \frac{h_f}{h} = \frac{20}{160} = 0.125$$

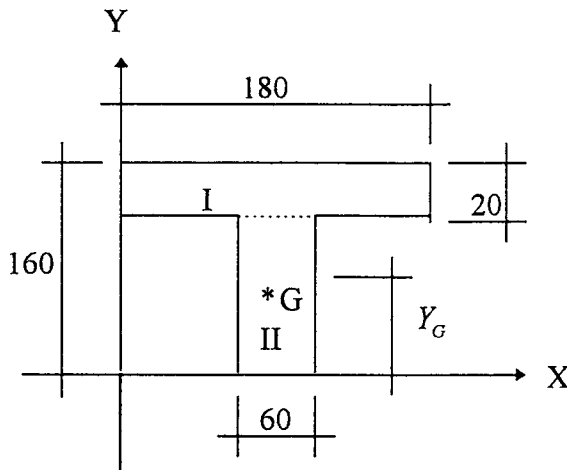
$$C = 1 + (A-1) \cdot B^3 + \frac{3 \cdot (1-B)^2 \cdot B \cdot (A-1)}{1 + B \cdot (A-1)} = 1 + (3-1) \cdot (0.125^3) + \frac{3 \cdot (1-0.125)^2 \cdot (0.125) \cdot (3-1)}{1 + (0.125) \cdot (3-1)}$$

$$C = 1.46$$

$$I = \frac{C \cdot b_w \cdot h^3}{12} = \frac{(1.46) \cdot 6 \cdot 16^3}{12} = 2990.08 \text{ dm}^4$$

$$I = 0.3 \text{ m}^4$$

2.yol



$$Y_G = \frac{18.2 \cdot 15 + 14.6 \cdot 7}{18.2 + 14.6} = 9.4 \text{ dm}$$

$$I = \frac{b \cdot h^3}{12} + b \cdot h \cdot (Y - Y_G)^2$$

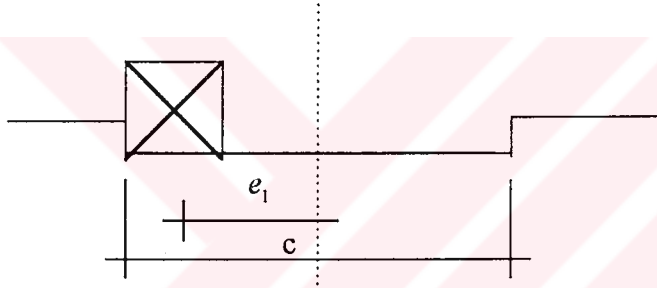
$$I = \frac{18.2^3}{12} + 18.2 \cdot (15 - 9.4)^2 + \frac{6.14^3}{12} + 6.14 \cdot (7 - 9.4)^2 = 0.299 \text{ m}^4$$

$$I = 0.3 \text{ m}^4$$

1 nolu ana kirişin eksantriklik katsayısı

$$\Delta = 1 + 6 \cdot \frac{(n+1-2i)}{n^2-1} \cdot \frac{e}{\lambda} = 1 + 6 \cdot \frac{(5+1-2 \cdot 1)}{5^2-1} \cdot \frac{e}{2.5} = 1 + 0.4e$$

a) 1 şeridin dolu olması hali

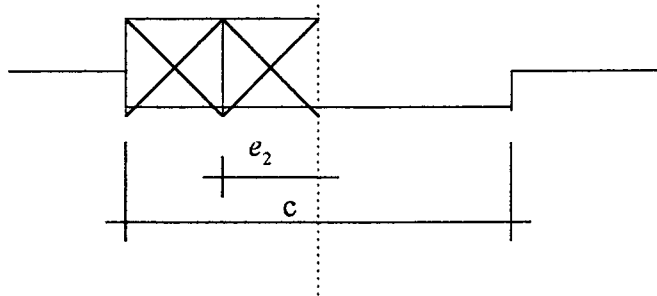


$$\Delta_{1,1} = 1 + 0.4e_1 = 1 + (0.4) \cdot (4.5) = 2.8$$

$$e_1 = \frac{c}{2} - 1.5 = \frac{12}{2} - 1.5 = 4.5 \text{ m}$$

$$1 \cdot \Delta_{1,1} = 1 \cdot (2.8) = 2.8$$

b) 2 şeridin dolu olması hali

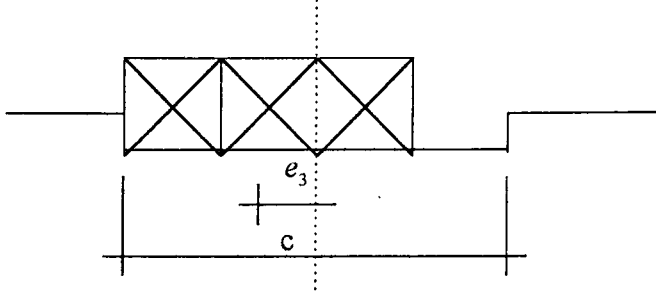


$$\Delta_{1,2} = 1 + 0.4e_2 = 1 + (0.4) \cdot (3.0) = 2.2$$

$$e_2 = \frac{c}{2} - 3 = \frac{12}{2} - 3 = 3 \text{ m}$$

$$2. \Delta_{1,2} = 2.(2.2) = 4.4$$

c) 3 şeridin dolu olması hali

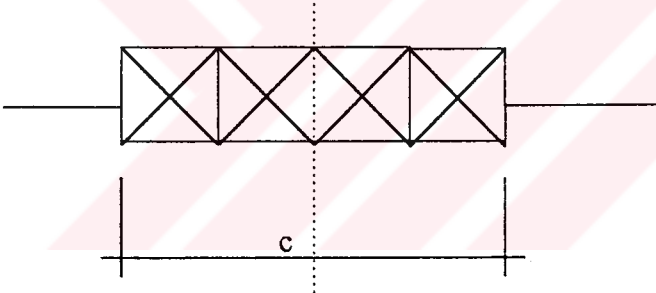


$$\Delta_{1,3} = 1 + 0.4e_3 = 1 + (0.4).(1.5) = 1.6$$

$$e_3 = \frac{c}{2} - 4.5 = \frac{12}{2} - 4.5 = 1.5 \text{ m}$$

$$3. \Delta_{1,3} = 3.(1.6) = 4.8 * 0.9 = 4.32$$

d) 4 şeridin dolu olması hali



$$\Delta_{1,4} = 1 + 0.4e_4 = 1 + (0.4).0 = 0$$

$$e_4 = 0 \text{ m}$$

$$4. \Delta_{1,4} = 4.1 = 4 * 0.75 = 3$$

Köprü 3 şeritle yüklendiğinde yükler %10 ve 4şeritle yüklendiğinde %25 azaltılır. En elverişsiz durumun , birden çok trafik şeridinin aynı zamanda yüklenmesi ile elde edildiği hallerde tam yük ihtimalinin zayıf olduğu dikkate alınarak hareketli yükten doğan etkiler azaltılır. 1 veya 2 şerit için azaltma yapılmaz , 3 şerit için %10 , 4 ve daha fazla şerit için %25 oranında azaltma yapılır.

2.7. Üç açıklıklı köprü kirişlerinde kenar ana kirişin çeşitli kesitlerinde eğilme momentlerinin mesnet deplasmanlarına bağlı değişimi

2.7.1. Kenar ana kiriş B mesnet kesiti eğilme momenti

Sayısal değerler : $H_{30} - S_{24}$ için $F_{sm} = 135$ kN , $q_s = 15$ kN/m , $g = 350$ kN/m
 $L = 20$ m Yukarıdaki değerler köprünün tamamı için geçerlidir. Kenar ana kiriş için gerekli değerler ise aşağıdaki gibidir.

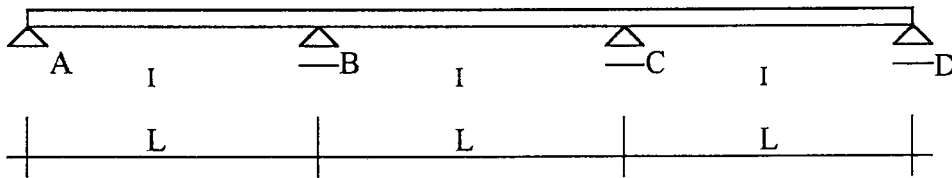
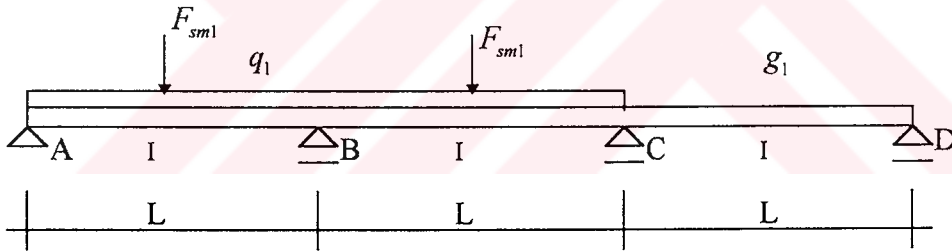
$$\varphi = 1 + \frac{15}{L + 37} = 1 + \frac{15}{20 + 37} = 1.263 \text{ sadme katsayısı}$$

$$M_i = \frac{1}{n} \cdot M_{Fs,qs} \cdot (\Delta_{ij} \cdot j)_{\max} \cdot \varphi$$

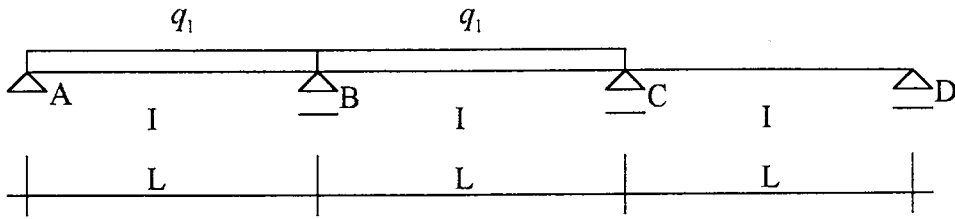
$$g_1 = \frac{g}{5} = \frac{350}{5} = 70 \text{ kN/m}$$

$$q_1 = \frac{q_s}{n} \cdot (\Delta_{ij} \cdot j)_{\max} \cdot \varphi = \frac{15}{5} \cdot (4.4) \cdot (1.263) = 16.67 \text{ kN/m}$$

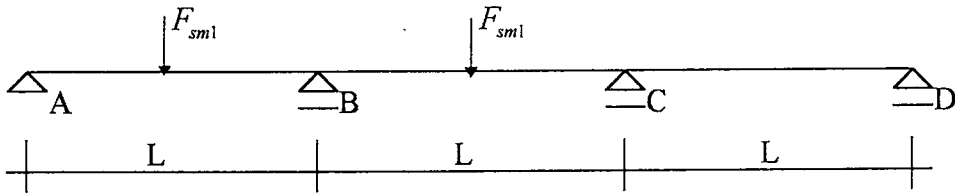
$$F_{sm1} = \frac{F_{sm}}{n} \cdot (\Delta_{ij} \cdot j)_{\max} \cdot \varphi = \frac{135}{5} \cdot (4.4) \cdot (1.263) = 150.04 \text{ kN}$$



$$M_{Bg_1} = \frac{-gL^2}{10} = \frac{-70 \cdot 20^2}{10} = -2800 \text{ kNm}$$



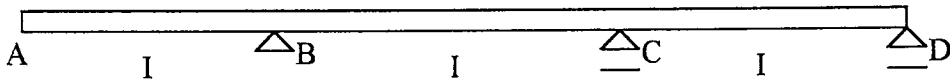
$$M_{q_1} = \frac{-qL^2}{15} + \frac{-qL^2}{20} = \frac{-7qL^2}{60} = \frac{-7 \cdot (16.67) \cdot 20^2}{60} = -778.01 \text{ kNm}$$



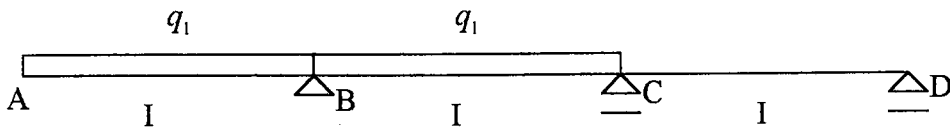
$$M_{BF_1} = \frac{-FL}{10} + \frac{-3FL}{40} = \frac{-7FL}{40} = \frac{-7 \cdot (150.04) \cdot 20}{40} = -525.15 \text{ kNm}$$

$$M_{B\Sigma} = M_{Bg_1} + M_{Bq_1} + M_{BF_1} = (-2800) + (-778.01) + (-525.15) = -4103.16 \text{ kNm}$$

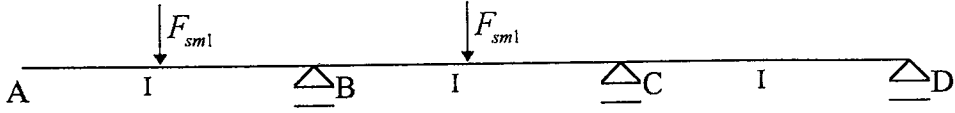
A mesnedindeki maksimum mesnet deplasmanının söz konusu yükleme hali için toplam değeri



$$\Delta A_{MAX} = \frac{1}{4} \cdot \frac{gL^4}{EI} = \frac{1}{4} \cdot \frac{70 \cdot 20^4}{3 \cdot 10^7 \cdot (0.3)} = 0.311 \text{ m}$$



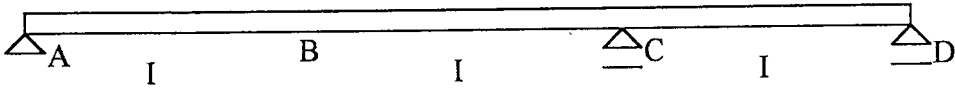
$$\Delta A_{MAX} = \frac{13}{48} \cdot \frac{qL^4}{EI} + \frac{-1}{32} \cdot \frac{qL^4}{EI} = \frac{13}{48} \cdot \frac{(16.67) \cdot 20^4}{3 \cdot 10^7 \cdot (0.3)} + \frac{-1}{32} \cdot \frac{(16.67) \cdot 20^4}{3 \cdot 10^7 \cdot (0.3)} = 0.071 \text{ m}$$



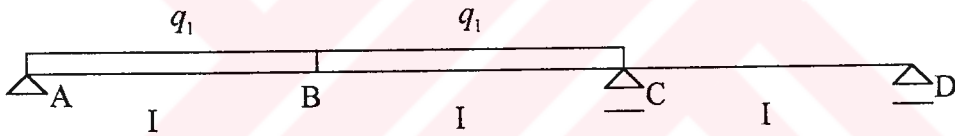
$$\Delta A_{MAX} = \frac{1}{4} \cdot \frac{FL^3}{EI} + \frac{-3}{64} \cdot \frac{FL^3}{EI} = \frac{1}{4} \cdot \frac{(150.04) \cdot 20^3}{3 \cdot 10^7 \cdot (0.3)} - \frac{3}{64} \cdot \frac{(150.04) \cdot 20^3}{3 \cdot 10^7 \cdot (0.3)} = 0.0271 \text{ m}$$

$$\Delta A_{MAX\Sigma} = \Delta A_{MAXg1} + \Delta A_{MAXq1} + \Delta A_{MAXF1} = 0.311 + 0.071 + 0.0271 = 0.4092 \text{ m}$$

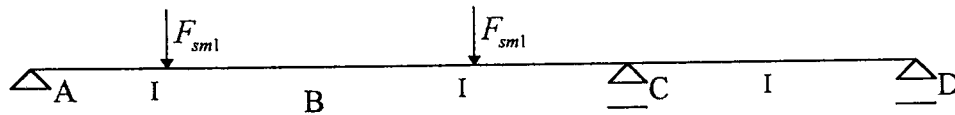
B mesnedindeki maksimum mesnet deplasmanının söz konusu yükleme hali için toplam değeri



$$\Delta B_{MAX} = \frac{11}{96} \cdot \frac{gL^4}{EI} = \frac{11}{96} \cdot \frac{70 \cdot 20^4}{3 \cdot 10^7 \cdot (0.3)} = 0.1426 \text{ m}$$



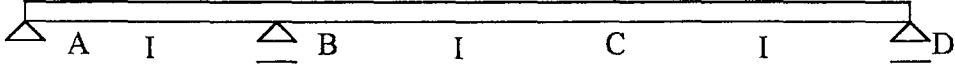
$$\Delta B_{MAX} = \frac{13}{192} \cdot \frac{qL^4}{EI} + \frac{11}{192} \cdot \frac{qL^4}{EI} = \frac{24}{192} \cdot \frac{qL^4}{EI} = \frac{24}{192} \cdot \frac{(16.67) \cdot 20^4}{3 \cdot 10^7 \cdot (0.3)} = 0.03714 \text{ m}$$



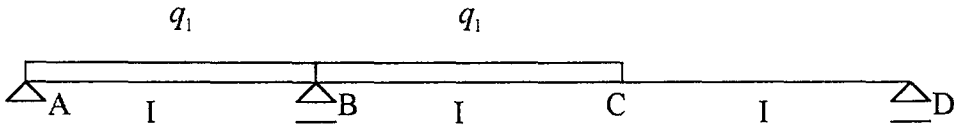
$$\Delta B_{MAX} = \frac{29}{384} \cdot \frac{FL^3}{EI} + \frac{23}{384} \cdot \frac{FL^3}{EI} = \frac{52}{384} \cdot \frac{FL^3}{EI} = \frac{52}{384} \cdot \frac{(150.04) \cdot 20^3}{3 \cdot 10^7 \cdot (0.3)} = 0.01806 \text{ m}$$

$$\Delta B_{MAX\Sigma} = \Delta B_{MAXg1} + \Delta B_{MAXq1} + \Delta B_{MAXF1} = 0.1426 + 0.03704 + 0.01806 = 0.1977 \text{ m}$$

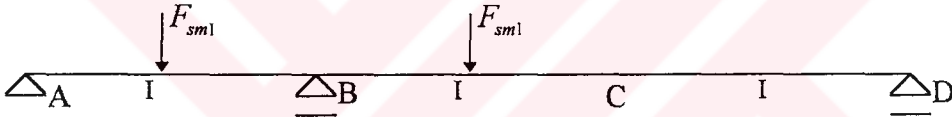
C mesnedindeki maksimum mesnet deplasmanının söz konusu yükleme hali için toplam değeri



$$\Delta C_{MAX} = \frac{11}{96} \cdot \frac{gL^4}{EI} = \frac{11}{96} \cdot \frac{70 \cdot 20^4}{3 \cdot 10^7 \cdot (0.3)} = 0.1426 \text{ m}$$



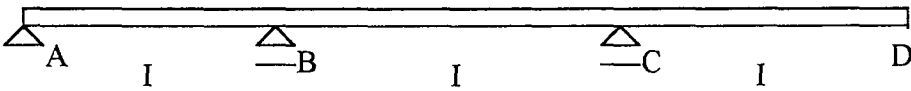
$$\Delta C_{MAX} = \frac{-1}{96} \cdot \frac{qL^4}{EI} + \frac{11}{192} \cdot \frac{qL^4}{EI} = \frac{-1}{96} \cdot \frac{(16.67) \cdot 20^4}{3 \cdot 10^7 \cdot (0.3)} + \frac{11}{192} \cdot \frac{(16.67) \cdot 20^4}{3 \cdot 10^7 \cdot (0.3)} = 0.0139 \text{ m}$$



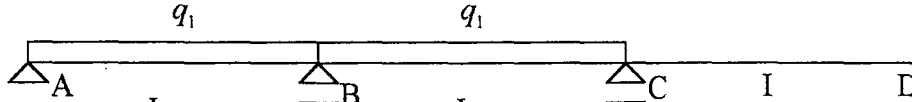
$$\Delta C_{MAX} = \frac{-1}{64} \cdot \frac{FL^3}{EI} + \frac{23}{384} \cdot \frac{FL^3}{EI} = \frac{-1}{64} \cdot \frac{(150.04) \cdot 20^3}{3 \cdot 10^7 \cdot (0.3)} + \frac{23}{384} \cdot \frac{(150.04) \cdot 20^3}{3 \cdot 10^7 \cdot (0.3)} = 0.0059 \text{ m}$$

$$\Delta C_{MAX\Sigma} = \Delta C_{MAXg1} + \Delta C_{MAXq1} + \Delta C_{MAXF1} = 0.1426 + 0.0139 + 0.0059 = 0.1624 \text{ m}$$

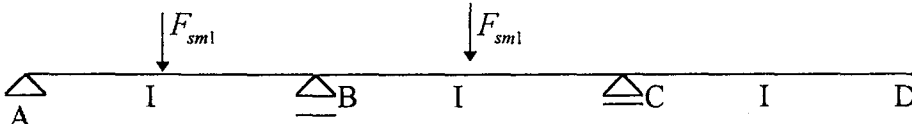
D mesnedindeki maksimum mesnet deplasmanının söz konusu yükleme hali için toplam değeri



$$\Delta D_{MAX} = \frac{1}{4} \cdot \frac{gL^4}{EI} = \frac{1}{4} \cdot \frac{70 \cdot 20^4}{3 \cdot 10^7 \cdot (0.3)} = 0.311 \text{ m}$$



$$\Delta D_{MAX} = \frac{1}{96} \cdot \frac{qL^4}{EI} + \frac{-1}{32} \cdot \frac{qL^4}{EI} = \frac{1}{96} \cdot \frac{(16.67) \cdot 20^4}{3.10^7 \cdot (0.3)} + \frac{-1}{32} \cdot \frac{(16.67) \cdot 20^4}{3.10^7 \cdot (0.3)} = -0.006173 \text{ m}$$



$$\Delta D_{MAX} = \frac{1}{64} \cdot \frac{FL^3}{EI} + \frac{-3}{64} \cdot \frac{FL^3}{EI} = \frac{1}{64} \cdot \frac{(150.04) \cdot 20^3}{3.10^7 \cdot (0.3)} - \frac{3}{64} \cdot \frac{(150.04) \cdot 20^3}{3.10^7 \cdot (0.3)} = -0.00417 \text{ m}$$

$$\Delta D_{MAX\Sigma} = \Delta D_{MAXg1} + \Delta D_{MAXq1} + \Delta D_{MAXF1} = 0.311 - 0.006173 - 0.00417 = 0.300767 \text{ m}$$

2.7.1.1. Kenar ana kiriş B mesnet kesiti eğilme momentinin ΔA mesnet deplasmanına göre değişimi

$$\Delta A_{MAX} = 0.4092 \text{ m} \quad M_{B,\Delta A} = \frac{-8}{5} \cdot \frac{\Delta A}{L^2} \cdot EI = \frac{-8}{5} \cdot \frac{\Delta A}{20^2} \cdot 3.10^7 \cdot (0.3) = -36000 \cdot \Delta A$$

ΔA (cm)	0	1	2	3	4	5
M_B (kNm)	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16
$M_{B,\Delta A}$ (kNm)	0	-360	-720	-1080	-1440	-1800
M_{Bson} (kNm)	-4103.16	-4463.16	-4823.16	-5183.16	-5543.16	-5903.16

11
-4103.16
-3960
-8063.16

17
-4103.16
-6120
-10223.16

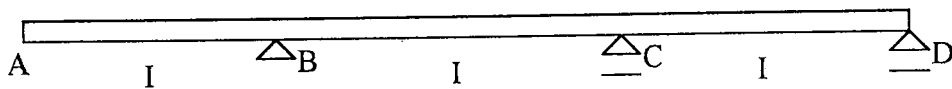
23
-4103.16
-8280
6 -12383.16

29
-4103.16
-10440
6 -14543.16

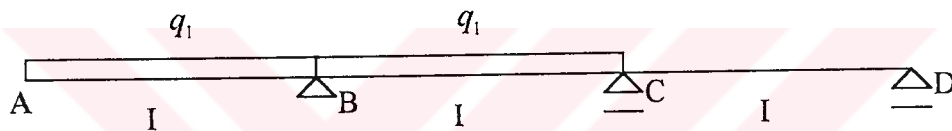
35
-4103.16
-12600
6 -16703.16

ΔA	36	37	38	39	40	40.92
M_B	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16
$M_{B,\Delta A}$	-12960	-13320	-13680	-14040	-14440	-14727.6
M_{Bson}	-17063.16	-17423.16	-17783.16	-18143.16	-18503.16	-18834.36

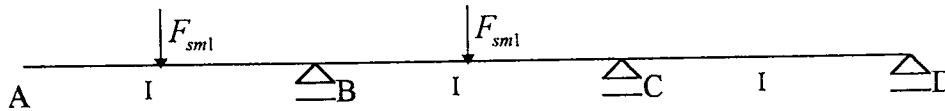
ΔA hali kontrol



$$M_{B,q_1} = \frac{-gL^2}{2} = \frac{-70.20^2}{2} = -14000 \text{ kNm}$$



$$M_{B,q_1} = \frac{-qL^2}{2} + 0 = \frac{-(16.67) \cdot 20^2}{2} + 0 = -3334 \text{ kNm}$$



$$M_{B,F_1} = \frac{-FL}{2} + 0 = \frac{(-150.04) \cdot 20}{2} + 0 = -1500.4 \text{ kNm}$$

$$M_{B\Sigma} = M_{B,q_1} + M_{B,q_1} + M_{B,F_1} = (-14000) + (-3334) + (-1500.4) = -18834.4 \text{ kNm}$$

2.7.1.2. Kenar ana kiriş B mesnet kesiti eğilme momentinin ΔB mesnet deplasmanına göre değişimi

$$\Delta B_{MAX} = 0.1977 \text{ m} \quad M_{B,\Delta B} = \frac{18}{5} \cdot \frac{\Delta B}{L^2} \cdot EI = \frac{18}{5} \cdot \frac{\Delta B}{20^2} \cdot 3.10^7 \cdot (0.3) = 81000 \cdot \Delta B$$

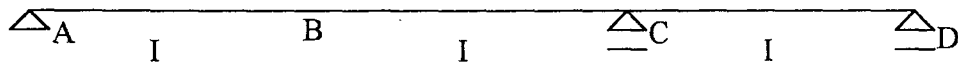
ΔB (cm)	0	1	2	3	4	5
M_B (kNm)	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16
$M_{B,\Delta B}$ (kNm)	0	810	1620	2430	3240	4050
$M_{B_{son}}$ (kNm)	-4103.16	-3293.16	-2483.16	-1673.16	-863.16	-53.16

ΔB	6	7	8	9	10	11
M_B	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16
$M_{B,\Delta B}$	4860	5670	6480	7290	8100	8910
$M_{B_{son}}$	756.84	1566.84	2376.84	3186.84	3996.84	4806.84

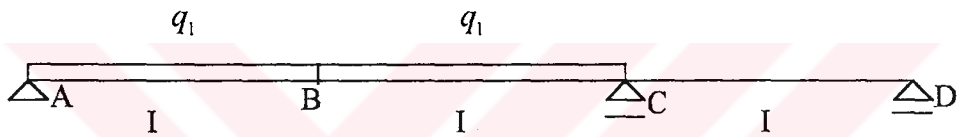
ΔB	12	13	14	15	16	17
M_B	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16
$M_{B,\Delta B}$	9720	10530	11340	12150	12960	13770
$M_{B_{son}}$	5616.84	6426.84	7236.84	8046.84	8856.84	9666.84

ΔB	18	19	19.77
M_B	-4103.16	-4103.16	-4103.16
$M_{B,\Delta B}$	14580	15390	16013.7
M_{Bson}	10476.84	11286.84	11910.84

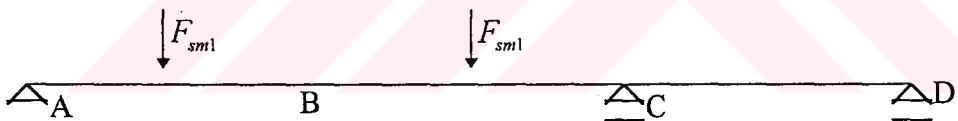
ΔB hali kontrol



$$M_{B,g_1} = \frac{10}{32} \cdot gL^2 = \frac{10}{32} \cdot 70 \cdot 20^2 = 8750 \text{ kNm}$$



$$M_{B,q_1} = \frac{68}{384} \cdot qL^2 + \frac{60}{384} \cdot qL^2 = \frac{128}{384} \cdot qL^2 = \frac{128}{384} \cdot (16.67) \cdot 20^2 = 2222.67 \text{ kNm}$$



$$M_{B,F_1} = \frac{22}{128} FL + \frac{18}{128} FL = \frac{40}{128} FL = \frac{40}{128} \cdot (150.04) \cdot 20 = 937.75 \text{ kNm}$$

$$M_{B\Sigma} = M_{B,g_1} + M_{B,q_1} + M_{B,F_1} = 8750 + 2222.67 + 937.75 = 11910.42 \text{ kNm}$$

2.7.1.3. Kenar ana kiriş B mesnet kesiti eğilme momentinin ΔC mesnet deplasmanına göre değişimi

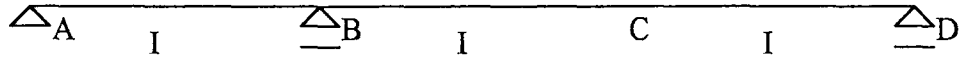
$$\Delta C_{MAX} = 0.1624 \text{ m} \quad M_{B,\Delta C} = \frac{-12}{5} \cdot \frac{\Delta C}{L^2} \cdot EI = \frac{-12}{5} \cdot \frac{\Delta C}{20^2} \cdot 3 \cdot 10^7 \cdot (0.3) = -54000 \cdot \Delta C$$

ΔC (cm)	0	1	2	3	4	5
M_B (kNm)	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16
$M_{B,\Delta C}$ (kNm)	0	-540	-1080	-1620	-2160	-2700
M_{Bson} (kNm)	-4103.16	-4643.16	-5183.16	-5723.16	-6263.16	-6803.16

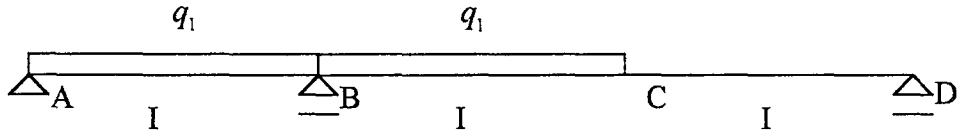
ΔC	6	7	8	9	10	11
M_B	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16
$M_{B,\Delta C}$	-3240	-3780	-4320	-4860	-5400	-5940
M_{Bson}	-7343.16	-7883.16	-8423.16	-8963.16	-9503.16	-10043.16

ΔC	12	13	14	15	16	16.24
M_B	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16
$M_{B,\Delta C}$	-6480	-7020	-7560	-8100	-8640	-8769.6
M_{Bson}	-10583.16	-11123.16	-11663.16	-12203.16	-12743.16	-12872.76

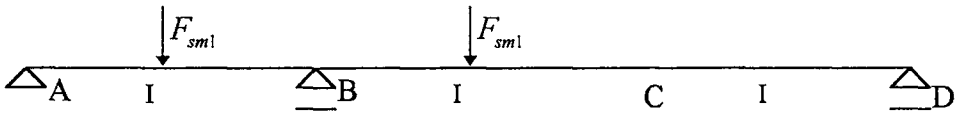
ΔC hali kontrol



$$M_{B,g_1} = \frac{-3}{8} \cdot gL^2 = \frac{-3}{8} \cdot 70 \cdot 20^2 = -10500 \text{ kNm}$$



$$M_{B,q_1} = \frac{-1}{24} \cdot qL^2 + \frac{-3}{16} \cdot qL^2 = \frac{-1}{24} \cdot (16.67) \cdot 20^2 + \frac{-3}{16} \cdot (16.67) \cdot 20^2 = 1528.08 \text{ kNm}$$



$$M_{B,F_1} = \frac{-1}{16} FL + \frac{-7}{32} FL = \frac{-1}{16} \cdot (150.04) \cdot 20 + \frac{-7}{32} \cdot (150.04) \cdot 20 = 843.974 \text{ kNm}$$

$$M_{B\Sigma} = M_{B,g_1} + M_{B,q_1} + M_{B,F_1} = -10500 - 1528.08 - 843.974 = -12872.05 \text{ kNm}$$

2.7.1.4. Kenar ana kiriş B mesnet kesiti eğilme momentinin ΔD mesnet deplasmanına göre değişimi

$$\Delta D_{MAX} = 0.3007 \text{ m} \quad M_{B,\Delta D} = \frac{2}{5} \cdot \frac{\Delta D}{L^2} \cdot EI = \frac{2}{5} \cdot \frac{\Delta D}{20^2} \cdot 3 \cdot 10^7 \cdot (0.3) = 9000 \cdot \Delta D$$

ΔD (cm)	0	1	2	3	4	5
M_B (kNm)	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16
$M_{B,\Delta D}$ (kNm)	0	90	180	270	360	450
M_{Bson} (kNm)	-4103.16	-4013.16	-3923.16	-3833.16	-3743.16	-3653.16

ΔD	6	7	8	9	10	11
M_B	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16
$M_{B,\Delta D}$	540	630	720	810	900	990
M_{Bson}	-3563.16	-3473.16	-3383.16	-3293.16	-3203.16	-3113.16

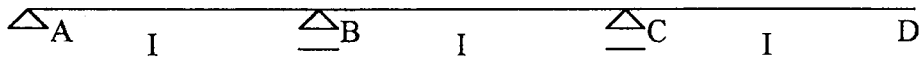
ΔD	12	13	14	15	16	17
M_B	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16
$M_{B,\Delta D}$	1080	1170	1260	1350	1440	1530
M_{Bson}	-3023.16	-2933.16	-2843.16	-2753.16	-2668.16	-2573.16

ΔD	18	19	20	21	22	23
M_B	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16
$M_{B,\Delta D}$	1620	1710	1800	1890	1980	2070
M_{Bson}	-2483.16	-2393.16	-2303.16	-2213.16	-2123.16	-2033.16

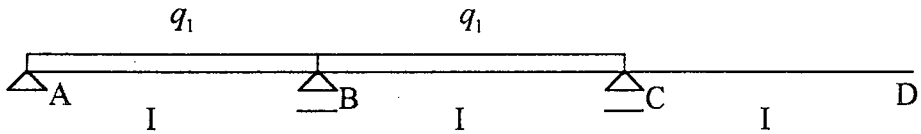
ΔD	24	25	26	27	28	29
M_B	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16	-4103.16
$M_{B,\Delta D}$	2160	2250	2340	2430	2520	2610
M_{Bson}	-1943.16	-1853.16	-1763.16	-1673.16	-1583.16	-1493.16

ΔD	30	30.07
M_B	-4103.16	-4103.16
$M_{B,\Delta D}$	2700	2706.9
M_{Bson}	-1403.16	-1396.2

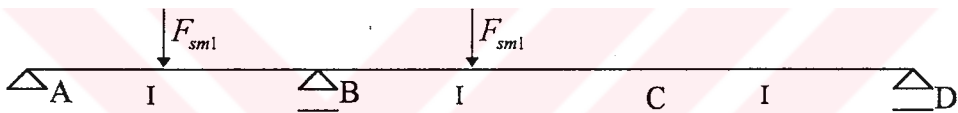
ΔD hali kontrol



$$M_{B,q_1} = 0$$



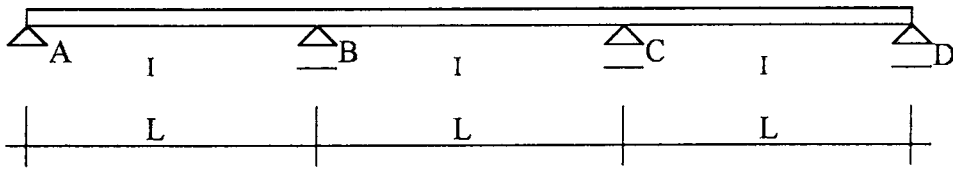
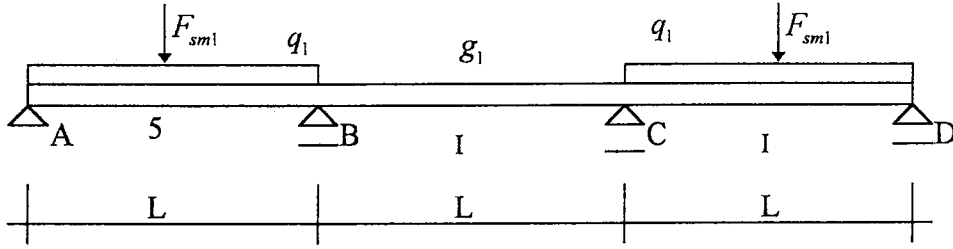
$$M_{B,q_1} = \frac{-1}{16} \cdot qL^2 + \frac{-1}{16} \cdot qL^2 = \frac{-1}{16} \cdot (16.67) \cdot 20^2 + \frac{-1}{16} \cdot (16.67) \cdot 20^2 = 833.5 \text{ kNm}$$



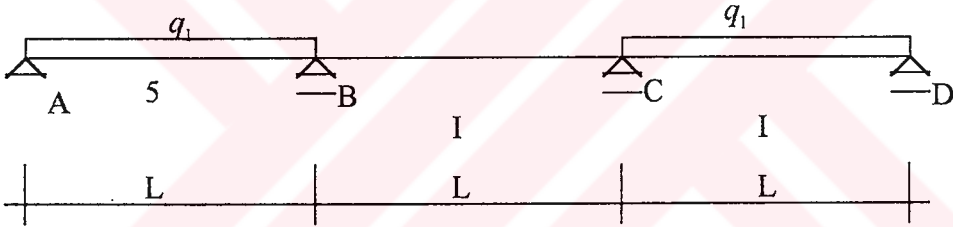
$$M_{B,F_1} = \frac{-3}{32} FL + \frac{-3}{32} FL = \frac{-3}{16} \cdot (150.04) \cdot 20 + \frac{-3}{32} \cdot (150.04) \cdot 20 = 562.65 \text{ kNm}$$

$$M_{B\Sigma} = M_{B,q_1} + M_{B,F_1} = 0 - 833.5 - 562.5 = -1396.15 \text{ kNm}$$

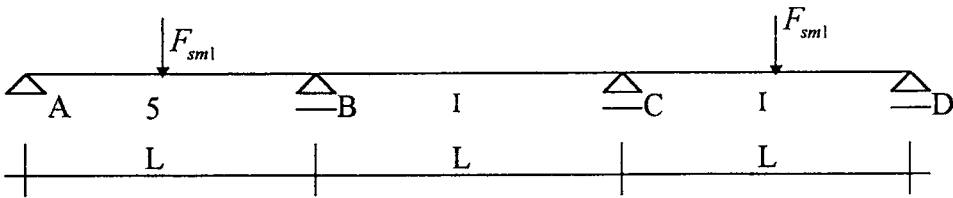
2.7.2. Kenar ana kiriş 5 kesiti eğilme momenti



$$M_{5g_1} = \frac{3gL^2}{40} = \frac{3 \cdot 70 \cdot 20^2}{40} = 2100 \text{ kNm}$$



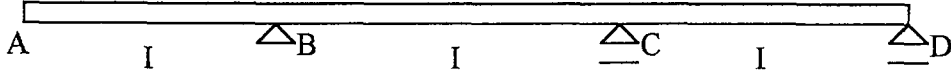
$$M_{5q_1} = \frac{11qL^2}{120} + \frac{qL^2}{120} = \frac{12qL^2}{120} = \frac{12 \cdot (16.67) \cdot 20^2}{120} = 666.8 \text{ kNm}$$



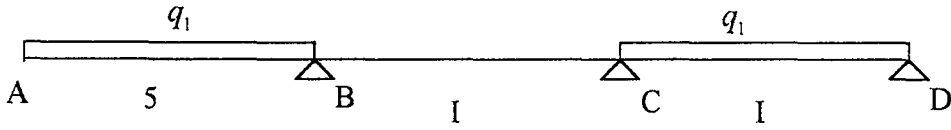
$$M_{5F_1} = \frac{FL}{5} + 0 = \frac{FL}{5} = \frac{(150.04) \cdot 20}{5} = 600.16 \text{ kNm}$$

$$M_{5\Sigma} = M_{5g_1} + M_{5q_1} + M_{5F_1} = (2100) + (666.8) + (600.16) = 3366.96 \text{ kNm}$$

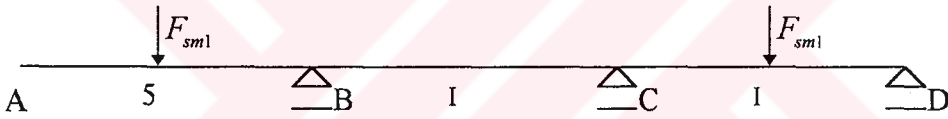
A mesnedindeki maksimum mesnet deplasmanının söz konusu yükleme hali için toplam değeri



$$\Delta A_{MAX} = \frac{1}{4} \cdot \frac{gL^4}{EI} = \frac{1}{4} \cdot \frac{70 \cdot 20^4}{3 \cdot 10^7 \cdot (0.3)} = 0.311 \text{ m}$$



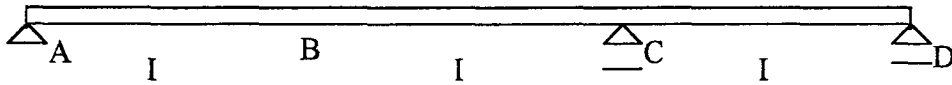
$$\Delta A_{MAX} = \frac{13}{48} \cdot \frac{qL^4}{EI} + \frac{1}{96} \cdot \frac{qL^4}{EI} = \frac{13}{48} \cdot \frac{(16.67) \cdot 20^4}{3 \cdot 10^7 \cdot (0.3)} + \frac{1}{96} \cdot \frac{(16.67) \cdot 20^4}{3 \cdot 10^7 \cdot (0.3)} = 0.08335 \text{ m}$$



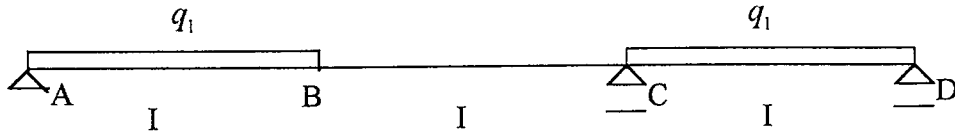
$$\Delta A_{MAX} = \frac{1}{4} \cdot \frac{FL^3}{EI} + 0 = \frac{1}{4} \cdot \frac{(150.04) \cdot 20^3}{3 \cdot 10^7 \cdot (0.3)} + 0 = 0.03334 \text{ m}$$

$$\Delta A_{MAX \Sigma} = \Delta A_{MAXg1} + \Delta A_{MAXq1} + \Delta A_{MAXF1} = 0.311 + 0.08335 + 0.03334 = 0.4278 \text{ m}$$

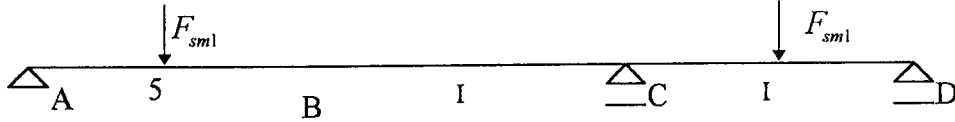
B mesnedindeki maksimum mesnet deplasmanının söz konusu yükleme hali için toplam değeri



$$\Delta B_{MAX} = \frac{11}{96} \cdot \frac{gL^4}{EI} = \frac{11}{96} \cdot \frac{70 \cdot 20^4}{3 \cdot 10^7 \cdot (0.3)} = 0.1426 \text{ m}$$



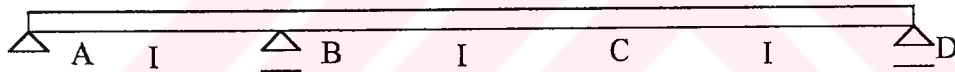
$$\Delta B_{MAX} = \frac{13}{192} \cdot \frac{qL^4}{EI} + \frac{-1}{96} \cdot \frac{qL^4}{EI} = \frac{13}{192} \cdot \frac{(16.67) \cdot 20^4}{3 \cdot 10^7 \cdot (0.3)} - \frac{1}{96} \cdot \frac{(16.67) \cdot 20^4}{3 \cdot 10^7 \cdot (0.3)} = 0.016973 \text{ m}$$



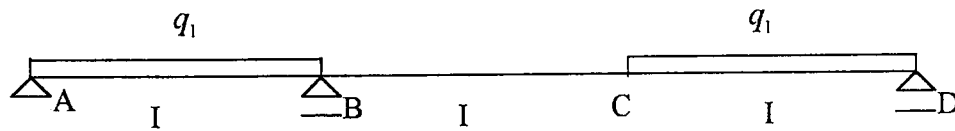
$$\Delta B_{MAX} = \frac{29}{384} \cdot \frac{FL^3}{EI} + 0 = \frac{29}{384} \cdot \frac{(150.04) \cdot 20^3}{3 \cdot 10^7 \cdot (0.3)} = 0.01007 \text{ m}$$

$$\Delta B_{MAX \Sigma} = \Delta B_{MAXg1} + \Delta B_{MAXq1} + \Delta B_{MAXF1} = 0.1426 + 0.016973 + 0.01007 = 0.1696 \text{ m}$$

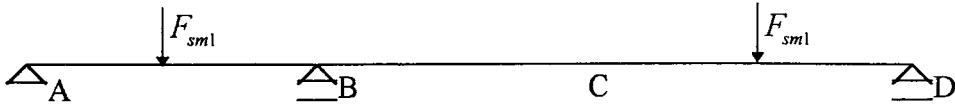
C mesnedindeki maksimum mesnet deplasmanının söz konusu yükleme hali için toplam değeri



$$\Delta C_{MAX} = \frac{11}{96} \cdot \frac{gL^4}{EI} = \frac{11}{96} \cdot \frac{70 \cdot 20^4}{3 \cdot 10^7 \cdot (0.3)} = 0.1426 \text{ m}$$



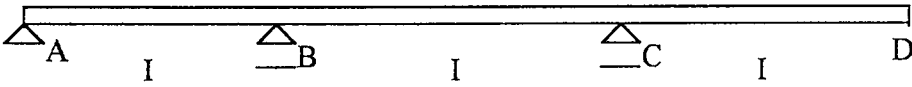
$$\Delta C_{MAX} = \frac{-1}{96} \cdot \frac{qL^4}{EI} + \frac{13}{192} \cdot \frac{qL^4}{EI} = \frac{-1}{96} \cdot \frac{(16.67) \cdot 20^4}{3 \cdot 10^7 \cdot (0.3)} + \frac{13}{192} \cdot \frac{(16.67) \cdot 20^4}{3 \cdot 10^7 \cdot (0.3)} = 0.016979 \text{ m}$$



$$\Delta C_{MAX} = \frac{-1}{64} \cdot \frac{FL^3}{EI} + 0 = \frac{-1}{64} \cdot \frac{(150.04) \cdot 20^3}{3.10^7 \cdot (0.3)} = -0.0020838 \text{ m}$$

$$\Delta C_{MAX\Sigma} = \Delta C_{MAXg_1} + \Delta C_{MAXq_1} + \Delta C_{MAXF_1} = 0.1426 + 0.016979 - 0.0020838 = 0.1575 \text{ m}$$

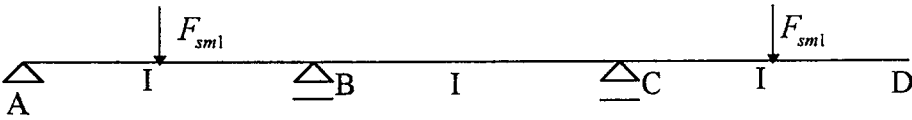
D mesnedindeki maksimum mesnet deplasmanının yukarıdaki yükleme hali için toplam değeri



$$\Delta D_{MAX} = \frac{1}{4} \cdot \frac{gL^4}{EI} = \frac{1}{4} \cdot \frac{70 \cdot 20^4}{3.10^7 \cdot (0.3)} = 0.311 \text{ m}$$



$$\Delta D_{MAX} = \frac{1}{96} \cdot \frac{qL^4}{EI} + \frac{13}{48} \cdot \frac{qL^4}{EI} = \frac{1}{96} \cdot \frac{(16.67) \cdot 20^4}{3.10^7 \cdot (0.3)} + \frac{13}{48} \cdot \frac{(16.67) \cdot 20^4}{3.10^7 \cdot (0.3)} = 0.083353 \text{ m}$$



$$\Delta D_{MAX} = \frac{1}{64} \cdot \frac{FL^3}{EI} + 0 = \frac{1}{64} \cdot \frac{(150.04) \cdot 20^3}{3.10^7 \cdot (0.3)} = 0.002084 \text{ m}$$

$$\Delta D_{MAX\Sigma} = \Delta D_{MAXg_1} + \Delta D_{MAXq_1} + \Delta D_{MAXF_1} = 0.311 + 0.083347 + 0.002084 = 0.3965 \text{ m}$$

2.7.2.1. Kenar ana kiriş 5 kesiti eğilme momentinin ΔA mesnet deplasmanına göre değişimi

$$\Delta A_{MAX} = 0.4278 \text{ m} \quad M_{5,\Delta A} = \frac{-4}{5} \cdot \frac{\Delta A}{L^2} \cdot EI = \frac{-4}{5} \cdot \frac{\Delta A}{20^2} \cdot 3.10^7 \cdot (0.3) = -18000 \cdot \Delta A$$

ΔA (cm)	0	1	2	3	4	5
M_5 (kNm)	3366.96	3366.96	3366.96	3366.96	3366.96	3366.96
$M_{5,\Delta A}$ (kNm)	0	-180	-360	-540	-720	-900
M_{5son} (kNm)	3366.96	3186.96	3006.96	2826.96	2646.96	2466.96

ΔA	6	7	8	9	10	11
M_5	3366.96	3366.96	3366.96	3366.96	3366.96	3366.96
$M_{5,\Delta A}$	-1080	-1260	-1440	-1620	-1800	-1980
M_{5son}	2286.96	2106.96	1926.96	1746.96	1566.96	1386.96

ΔA	12	13	14	15	16	17
M_5	3366.96	3366.96	3366.96	3366.96	3366.96	3366.96
$M_{5,\Delta A}$	-2160	-2340	-2520	-2700	-2880	-3060
M_{5son}	1206.96	1026.96	846.96	666.96	486.96	306.96

ΔA	18	19	20	21	22	23
M_5	3366.96	3366.96	3366.96	3366.96	3366.96	3366.96
$M_{5,\Delta A}$	-3240	-3420	-3600	-3780	-3960	-4140
M_{5son}	126.96	-53.04	-233.04	-413.04	-593.04	-773.04

ΔA	24	25	26	27	28	29
M_5	3366.96	3366.96	3366.96	3366.96	3366.96	3366.96
$M_{5,\Delta A}$	-4320	-4500	-4680	-4860	-5040	-5220
M_{5son}	-953.04	-1133.04	-1313.04	-1493.04	-1673.04	-1853.04

ΔA	30	31	32	33	34	35
M_5	3366.96	3366.96	3366.96	3366.96	3366.96	3366.96
$M_{5,\Delta A}$	-5400	-5580	-5760	-5940	-6120	-6300
M_{5son}	-2033.04	-2213.04	-2393.04	-2573.04	-2753.04	-2933.04

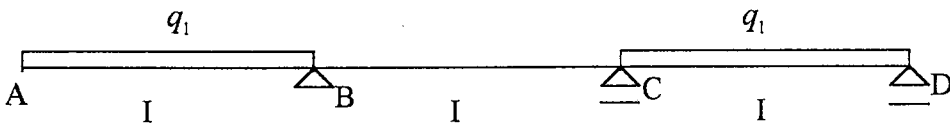
ΔA	36	37	38	39	40	41
M_5	3366.96	3366.96	3366.96	3366.96	3366.96	3366.96
$M_{5,\Delta A}$	-6480	-6660	-6840	-7020	-7200	-7380
M_{5son}	-3113.04	-3293.04	-3473.04	-3653.04	-3833.04	-4013.04

ΔA	42	42.78
M_5	3366.96	3366.96
$M_{5,\Delta A}$	-7560	-7700.4
M_{5son}	-4193.04	-4333.04

ΔA hali kontrol



$$M_{s,g_1} = \frac{-gL^2}{8} = \frac{-70 \cdot 20^2}{8} = -3500 \text{ kNm}$$



$$M_{s,q_1} = \frac{-qL^2}{8} + 0 = \frac{-(16.67) \cdot 20^2}{8} + 0 = -833.5 \text{ kNm}$$



$$M_{s,F_1} = 0 + 0 = 0 \text{ kNm}$$

$$M_{s\Sigma} = M_{s,g_1} + M_{s,q_1} + M_{s,F_1} = (-3500) + (-833.5) + 0 = -4333.5 \text{ kNm}$$

2.7.2.2. Kenar ana kiriş 5 kesiti eğilme momentinin ΔB mesnet deplasmanına göre değişimi

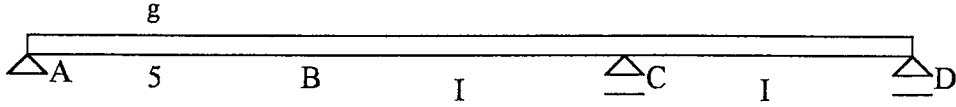
$$\Delta B_{MAX} = 0.16964 \text{ m} \quad M_{5,\Delta B} = \frac{9}{5} \cdot \frac{\Delta B}{L^2} \cdot EI = \frac{9}{5} \cdot \frac{\Delta B}{20^2} \cdot 3.10^7 \cdot (0.3) = 40500 \cdot \Delta B$$

ΔB (cm)	0	1	2	3	4	5
M_5 (kNm)	3366.96	3366.96	3366.96	3366.96	3366.96	3366.96
$M_{5,\Delta B}$ (kNm)	0	405	810	1215	1620	2025
M_{5son} (kNm)	3366.96	3771.96	4176.96	4581.96	4986.96	5391.96

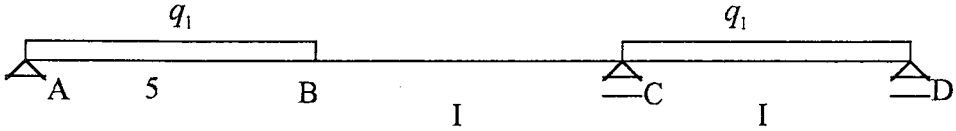
ΔB	6	7	8	9	10	11
M_5	3366.96	3366.96	3366.96	3366.96	3366.96	3366.96
$M_{5,\Delta B}$	2430	28350	3240	3645	4050	4445
M_{5son}	5796.96	6201.96	6606.96	7011.96	7416.96	7821.96

ΔB	12	13	14	15	16	16.964
M_5	3366.96	3366.96	3366.96	3366.96	3366.96	3366.96
$M_{5,\Delta B}$	4860	5265	5670	6075	6480	6885
M_{5son}	8226.96	8631.96	9036.96	9441.96	9846.96	10237.41

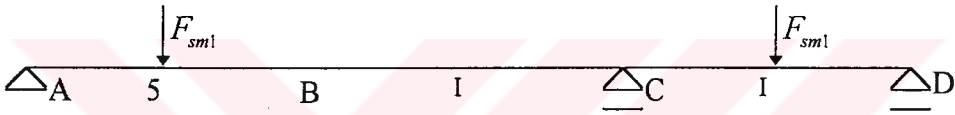
ΔB hali kontrol



$$M_{5,g_1} = \frac{9}{32} \cdot gL^2 = \frac{9}{32} \cdot 70 \cdot 20^2 = 7875 \text{ kNm}$$



$$M_{5,q_1} = \frac{82}{384} \cdot qL^2 - \frac{1}{96} \cdot qL^2 = \frac{82}{384} \cdot (16.67) \cdot 20^2 - \frac{1}{96} \cdot (16.67) \cdot 20^2 = 1354.44 \text{ kNm}$$



$$M_{5,F_1} = \frac{43}{128} FL = 1008.08 \text{ kNm}$$

$$M_{5\Sigma} = M_{5,g_1} + M_{5,q_1} + M_{5,F_1} = 7875 + 1354.44 + 1008.08 = 10237.51 \text{ kNm}$$

2.7.2.3. Kenar ana kiriş 5 kesiti eğilme momentinin ΔC mesnet deplasmanına göre değişimi

$$\Delta C_{MAX} = 0.1575 \text{ m} \quad M_{5,\Delta C} = \frac{-6}{5} \cdot \frac{\Delta C}{L^2} \cdot EI = \frac{-6}{5} \cdot \frac{\Delta C}{20^2} \cdot 3.10^7 \cdot (0.3) = -27000 \cdot \Delta C$$

ΔC (cm)	0	1	2	3	4	5
M_5 (kNm)	3366.96	3366.96	3366.96	3366.96	3366.96	3366.96
$M_{5\Delta C}$ (kNm)	0	-270	-540	-810	-1080	-1350
M_{5son} (kNm)	3366.96	3096.96	2826.96	2556.96	2286.96	2016.96

ΔC	6	7	8	9	10	11
M_s	3366.96	3366.96	3366.96	3366.96	3366.96	3366.96
$M_{s,\Delta C}$	-1620	-1890	-2160	-2430	-2700	-2970
$M_{s_{son}}$	1746.96	1476.96	1206.96	936.96	666.96	396.96

ΔC	12	13	14	15	15.75
M_s	3366.96	3366.96	3366.96	3366.96	3366.96
$M_{s,\Delta C}$	-3240	-3510	-3780	-4050	-4252.5
$M_{s_{son}}$	126.96	-143.04	-413.04	-683.04	-885.54

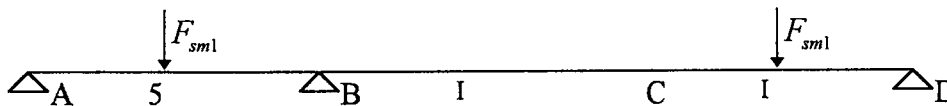
ΔC hali kontrol



$$M_{s,g_1} = \frac{-1}{16} \cdot gL^2 = \frac{-1}{16} \cdot 70 \cdot 20^2 = -1750 \text{ kNm}$$



$$M_{s,q_1} = \frac{5}{48} \cdot qL^2 - \frac{7}{96} \cdot qL^2 = \frac{5}{48} \cdot (16.67) \cdot 20^2 - \frac{7}{96} \cdot (16.67) \cdot 20^2 = 208.372 \text{ kNm}$$



$$M_{s,F_1} = \frac{7}{32} FL = 656.425 \text{ kNm}$$

$$M_{s_{\Sigma}} = M_{s,g_1} + M_{s,q_1} + M_{s,F_1} = -1750 + 208.372 + 656.425 = -885.2 \text{ kNm}$$

2.7.2.4. Kenar ana kiriş 5 kesiti eğilme momentinin ΔD mesnet deplasmanına göre değişimi

$$\Delta D_{MAX} = 0.3965 \text{ m} \quad M_{5,\Delta D} = \frac{1}{5} \cdot \frac{\Delta D}{L^2} \cdot EI = \frac{1}{5} \cdot \frac{\Delta D}{20^2} \cdot 3.10^7 \cdot (0.3) = 4500 \cdot \Delta D$$

ΔD (cm)	0	1	2	3	4	5
M_5 (kNm)	3366.96	3366.96	3366.96	3366.96	3366.96	3366.96
$M_{5,\Delta D}$ (kNm)	0	45	90	135	180	225
M_{5son} (kNm)	3366.96	3411.96	3456.96	3501.96	3546.96	3591.96

ΔD	6	7	8	9	10	11
M_5	3366.96	3366.96	3366.96	3366.96	3366.96	3366.96
$M_{5,\Delta D}$	270	315	360	405	450	495
M_{5son}	3636.96	3681.96	3726.96	3771.96	3816.96	3861.96

ΔD	12	13	14	15	16	17
M_5	3366.96	3366.96	3366.96	3366.96	3366.96	3366.96
$M_{5,\Delta D}$	540	585	630	675	720	765
M_{5son}	3906.96	3951.96	3996.96	4041.96	4086.96	4131.96

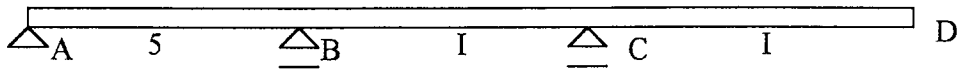
ΔD	18	19	20	21	22	23
M_5	3366.96	3366.96	3366.96	3366.96	3366.96	3366.96
$M_{5,\Delta D}$	810	855	900	945	990	1035
M_{5son}	4176.96	4221.96	4266.96	4311.96	4356.96	4401.96

ΔD	24	25	26	27	28	29
M_5	3366.96	3366.96	3366.96	3366.96	3366.96	3366.96
$M_{5,\Delta D}$	1080	1125	1170	1215	1260	1305
M_{5son}	4446.96	4491.96	4536.96	4581.96	4626.96	4671.96

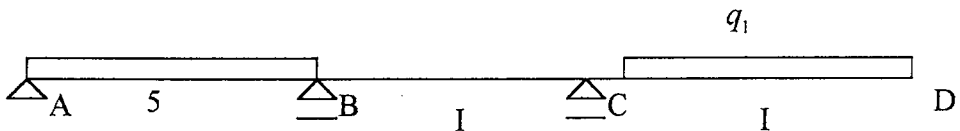
ΔD	30	31	32	33	34	35
M_5	3366.96	3366.96	3366.96	3366.96	3366.96	3366.96
$M_{5,\Delta D}$	1350	1395	1440	1485	1530	1575
M_{5son}	4716.96	4761.96	4806.96	4851.96	4896.96	4941.96

ΔD	36	37	38	39	39.65
M_5	3366.96	3366.96	3366.96	3366.96	3366.96
$M_{5,\Delta D}$	1620	1665	1710	1755	1784.4
M_{5son}	4986.96	5031.96	5076.96	5121.96	5151.4

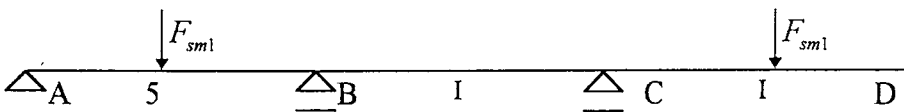
ΔD hali kontrol



$$M_{s,g_1} = \frac{1}{8} \cdot gL^2 = \frac{1}{8} \cdot 70 \cdot 20^2 = 3500 \text{ kNm}$$



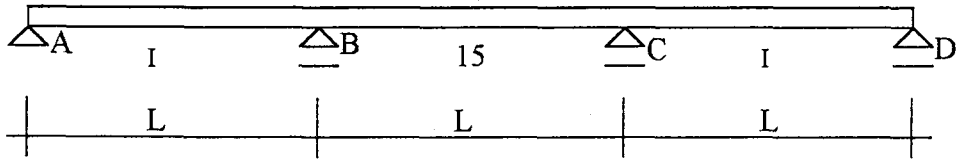
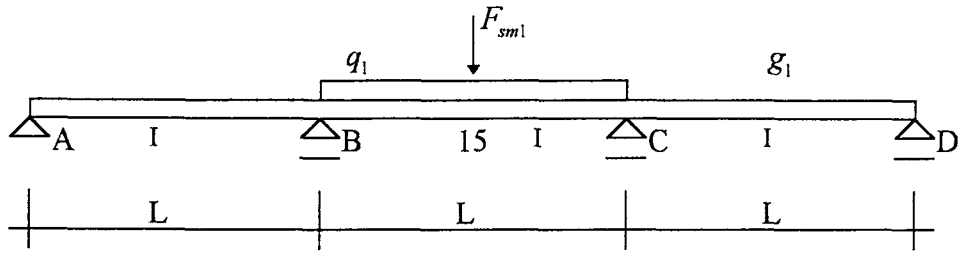
$$M_{s,q_1} = \frac{3}{32} \cdot qL^2 + \frac{1}{16} \cdot qL^2 = \frac{3}{32} \cdot (16.67) \cdot 20^2 + \frac{1}{16} \cdot (16.67) \cdot 20^2 = 1041.88 \text{ kNm}$$



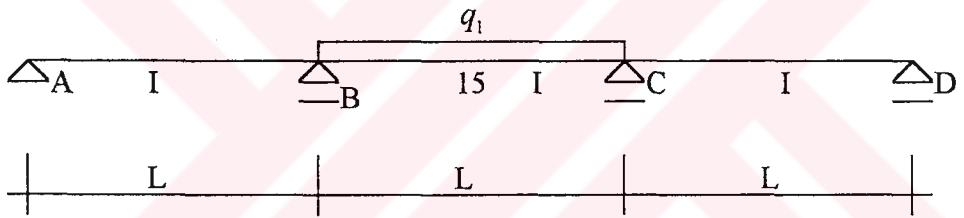
$$M_{s,F_1} = \frac{13}{64} FL = 609.54 \text{ kNm}$$

$$M_{s\Sigma} = M_{s,g_1} + M_{s,q_1} + M_{s,F_1} = 3500 + 1041.88 + 609.54 = 5151.4 \text{ kNm}$$

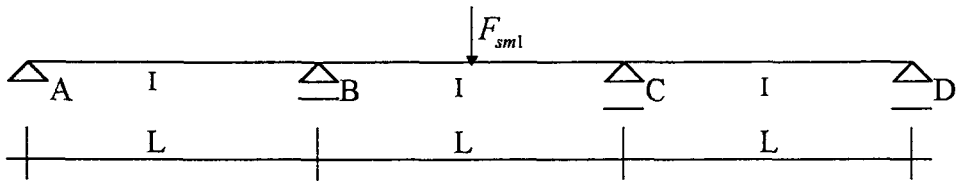
2.7.3. Kenar ana kiriş 15 kesiti eğilme momenti



$$M_{15g_1} = \frac{gL^2}{40} = \frac{70 \cdot 20^2}{40} = 700 \text{ kNm}$$



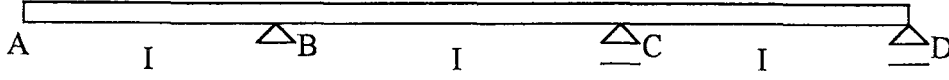
$$M_{15q_1} = \frac{3qL^2}{40} = \frac{3 \cdot (16.67) \cdot 20^2}{40} = 500.1 \text{ kNm}$$



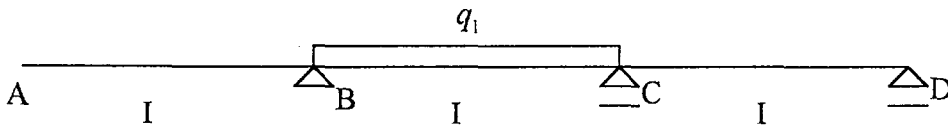
$$M_{15F_1} = \frac{7FL}{40} = \frac{7 \cdot (150.04) \cdot 20}{40} = 525.14 \text{ kNm}$$

$$M_{15\Sigma} = M_{15g_1} + M_{15q_1} + M_{15F_1} = (700) + (500.1) + (525.14) = 1725.24 \text{ kNm}$$

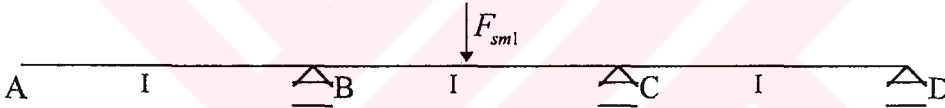
A mesnedindeki maksimum mesnet deplasmanının yukarıdaki yükleme hali için toplam değeri



$$\Delta A_{MAX} = \frac{1}{4} \cdot \frac{gL^4}{EI} = \frac{1}{4} \cdot \frac{70 \cdot 20^4}{3 \cdot 10^7 \cdot (0.3)} = 0.311 \text{ m}$$



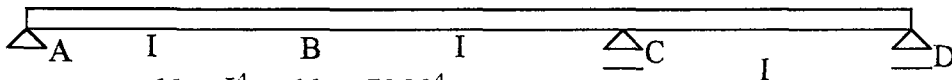
$$\Delta A_{MAX} = \frac{-1}{32} \cdot \frac{qL^4}{EI} = \frac{-1}{32} \cdot \frac{(16.67) \cdot 20^4}{3 \cdot 10^7 \cdot (0.3)} = -0.00926 \text{ m}$$



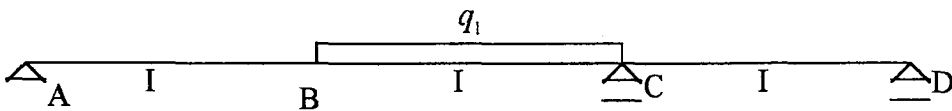
$$\Delta A_{MAX} = \frac{-3}{64} \cdot \frac{FL^3}{EI} = \frac{-3}{64} \cdot \frac{(150.04) \cdot 20^3}{3 \cdot 10^7 \cdot (0.3)} = -0.00625 \text{ m}$$

$$\Delta A_{MAX \Sigma} = \Delta A_{MAXg1} + \Delta A_{MAXq1} + \Delta A_{MAXF1} = 0.311 - 0.00926 - 0.00625 = 0.2956 \text{ m}$$

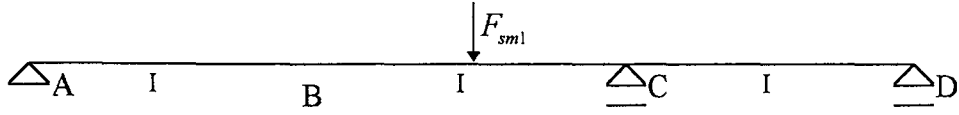
B mesnedindeki maksimum mesnet deplasmanının yukarıdaki yükleme hali için toplam değeri



$$\Delta B_{MAX} = \frac{11}{96} \cdot \frac{gL^4}{EI} = \frac{11}{96} \cdot \frac{70 \cdot 20^4}{3 \cdot 10^7 \cdot (0.3)} = 0.1426 \text{ m}$$



$$\Delta B_{MAX} = \frac{11}{192} \cdot \frac{qL^4}{EI} = \frac{11}{192} \cdot \frac{(16.67) \cdot 20^4}{3 \cdot 10^7 \cdot (0.3)} = 0.01698 \text{ m}$$



$$\Delta B_{MAX} = \frac{23}{384} \cdot \frac{FL^3}{EI} = \frac{23}{384} \cdot \frac{(150.04) \cdot 20^3}{3 \cdot 10^7 \cdot (0.3)} = 0.00799 \text{ m}$$

$$\Delta B_{MAX\Sigma} = \Delta B_{MAXg1} + \Delta B_{MAXq1} + \Delta B_{MAXF1} = 0.1426 + 0.01698 + 0.00799 = 0.16757 \text{ m}$$

2.7.3.1. Kenar ana kiriş 15 kesiti eğilme momentinin ΔA mesnet deplasmanına göre değişimi

$$\Delta A_{MAX} = 0.2956 \text{ m} \quad M_{15,\Delta A} = \frac{-3}{5} \cdot \frac{\Delta A}{L^2} \cdot EI = \frac{-3}{5} \cdot \frac{\Delta A}{20^2} \cdot 3 \cdot 10^7 \cdot (0.3) = -13500 \cdot \Delta A$$

ΔA (cm)	0	1	2	3	4	5
M_{15} (kNm)	1725.24	1725.24	1725.24	1725.24	1725.24	1725.24
$M_{15,\Delta A}$ (kNm)	0	-135	-270	-405	-540	-675
M_{15son} (kNm)	1725.24	1590.24	1455.24	1320.24	1185.24	1050.24

ΔA	6	7	8	9	10	11
M_{15}	1725.24	1725.24	1725.24	1725.24	1725.24	1725.24
$M_{15,\Delta A}$	-810	-945	-1080	-1215	-1350	-1485
M_{15son}	915.24	780.24	645.24	510.24	375.24	240.24

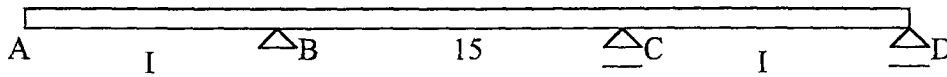
ΔA	12	13	14	15	16	17
M_{15}	1725.24	1725.24	1725.24	1725.24	1725.24	1725.24
$M_{15,\Delta A}$	-1620	-1755	-1890	-2025	-2160	-2295
M_{15son}	105.24	-29.76	-164.76	-299.76	-434.76	-569.76

ΔA	18	19	20	21	22	23
M_{15}	1725.24	1725.24	1725.24	1725.24	1725.24	1725.24
$M_{15,\Delta A}$	-2430	-2565	-2700	-2835	-2970	-3105
M_{15son}	-704.76	-839.76	-974.76	-1109.76	-1244.76	-1379.76

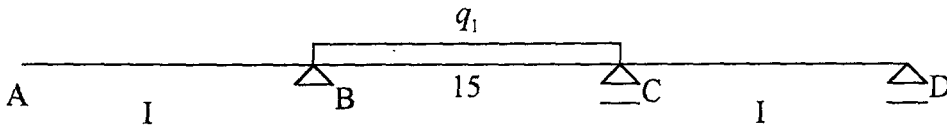
ΔA	24	25	26	27	28	29
M_{15}	1725.24	1725.24	1725.24	1725.24	1725.24	1725.24
$M_{15,\Delta A}$	-3240	-3375	-3510	-3645	-3780	-3915
M_{15son}	-1514.76	-1649.76	-1784.76	-1919.76	-2054.76	-2189.76

ΔA	29.56
M_{15}	1725.24
$M_{15,\Delta A}$	-3990.6
M_{15son}	-2265.36

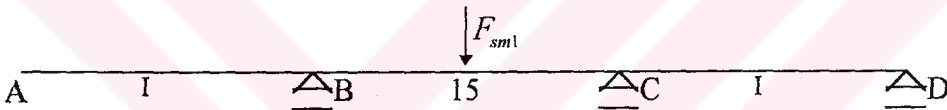
ΔA hali kontrol



$$M_{15, g_1} = \frac{-gL^2}{8} = \frac{-70 \cdot 20^2}{8} = -3500 \text{ kNm}$$



$$M_{15, q_1} = \frac{3qL^2}{32} = \frac{3 \cdot (16.67) \cdot 20^2}{32} = 625.125 \text{ kNm}$$



$$M_{15, F_1} = \frac{16FL}{64} = \frac{13 \cdot (-150.04) \cdot 20}{64} = 609.54 \text{ kNm}$$

$$M_{15 \Sigma} = M_{15, g_1} + M_{15, q_1} + M_{15, F_1} = (-3500) + (625.125) + (609.54) = -2265.34 \text{ kNm}$$

2.7.3.2. Kenar ana kiriş 15 kesiti eğilme momentinin ΔB mesnet deplasmanına göre değişimi

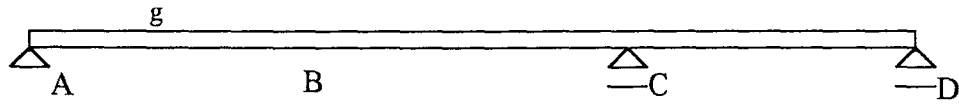
$$\Delta B_{MAX} = 0.16757 \text{ m} \quad M_{15,\Delta B} = \frac{3}{5} \cdot \frac{\Delta B}{L^2} \cdot EI = \frac{3}{5} \cdot \frac{\Delta B}{20^2} \cdot 3 \cdot 10^7 \cdot (0.3) = 13500 \cdot \Delta B$$

ΔB (cm)	0	1	2	3	4	5
M_{15} (kNm)	1725.24	1725.24	1725.24	1725.24	1725.24	1725.24
$M_{15,\Delta B}$ (kNm)	0	135	270	405	540	675
M_{15son} (kNm)	1725.24	1860.24	1995.24	2130.24	2265.24	2400.24

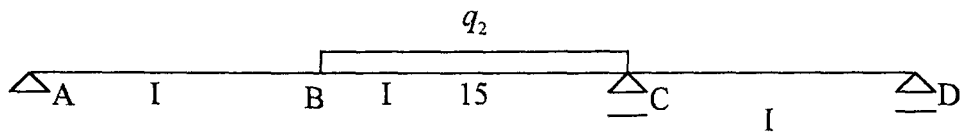
ΔB	6	7	8	9	10	11
M_{15}	1725.24	1725.24	1725.24	1725.24	1725.24	1725.24
$M_{15,\Delta B}$	810	945	1080	1215	1350	1485
M_{15son}	2535.24	2670.24	2805.24	2940.24	3075.24	3210.24

ΔB	12	13	14	15	16	16.757
M_{15}	1725.24	1725.24	1725.24	1725.24	1725.24	1725.24
$M_{15,\Delta B}$	1620	1755	1890	2025	2160	2262.20
M_{15son}	3345.24	3480.24	3615.24	3750.24	3885.24	3987.44

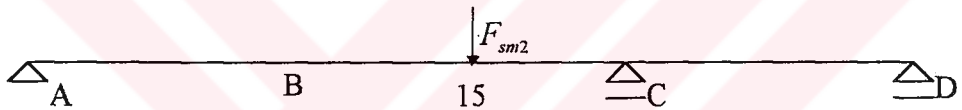
ΔB hali kontrol



$$M_{15,g} = \frac{3}{32} \cdot gL^2 = \frac{3}{32} \cdot 70 \cdot 20^2 = 2625 \text{ kNm}$$



$$M_{15,q_2} = \frac{42}{384} \cdot qL^2 = \frac{42}{384} \cdot (16.67) \cdot 20^2 = 729.31 \text{ kNm}$$



$$M_{15,F_2} = \frac{27}{128} FL = 632.98 \text{ kNm}$$

$$M_{15\Sigma} = M_{15,g_2} + M_{15,q_2} + M_{15,F_2} = 2625 + 729.31 + 632.98 = 3987.29 \text{ kNm}$$

3.SONUÇLAR

Betonarme karayolu köprülerinin boyutlandırılmasında aşağıda gösterilen yük ve etkilerden varolanlar dikkate alınmalı her yük veya etki altında bulunacak tesirler ayrı ayrı hesaba katılmalıdır. Genel olarak yükler, A grubu yükler (zati yük, hareketli yükler, boyuna kuvvetler, mesnet şartlarındaki değişme, merkezkaç kuvveti, rüzgar yükü, ısı tesiri, kar yükü, rötre, sünme, zemin itkisi, suyun kaldırma kuvveti, su akıntısının etkisi, buz itkisi, atalet etkisi, öngerilme etkisi) ve B grubu yükler (yapım safhalarından ötürü etkiler, deprem etkisi, çarpma) olarak 2 çeşittir. Mesnet şartlarındaki değişme temel zeminindeki hareketten ötürü mesnetlerde meydana gelebilecek öteleme ve dönmeler, beklenen büyüklükleri ile gözönüne alınmalıdır. Ancak, yapı rijit mesnetlendirilmiş olduğu (kaya üzerine) veya mesnet şartlarındaki değişiklikler az ise bu tetkik yapılmayabilir. Köprü en kesit özellikleri, yapının üzerindeki yoldan geçen hareketli yükler standart kamyon veya standart kamyon katarına eşdeğer olan şerit yükleri $H_{30} - S_{24}$ için verilmiştir. Kiriş atalet momenti, elverişsiz şerit sayısı ve titreşim katsayısı belirlenmiştir. En elverişsiz durumun, birden çok trafik şeridinin aynı zamanda yüklenmesi ile elde edildiği hallerde, tam yük olasılığının zayıf olduğu dikkate alınarak hareketli yükten doğan etkiler azaltılır.

Son olarak kenar ana kirişin B,5,15 kesitlerinde eğilme momentleri, bu eğilme momenti değerlerini maksimum yapan yüklemeler için ayrı ayrı hesaplanmıştır.

Bu yükleme halleri için ΔA , ΔB , ΔC , ΔD deplasmanları durumlarında $\Delta A_{MAX\Sigma} = \Delta A_{MAXg} + \Delta A_{MAXq1} + \Delta A_{MAXq2} + \Delta A_{MAXF1} + \Delta A_{MAXF2}$ ve benzer şekilde $\Delta B_{MAX\Sigma}$, $\Delta C_{MAX\Sigma}$, $\Delta D_{MAX\Sigma}$ ve $M_{MAX\Sigma}$ değerleri bulunur. Bulunan değerler tablo değerleri ile desteklenmiş ve kontrol edilmiştir.

Bu inceleme sonucunda 5,15,B kesitlerinde ΔA , ΔB , ΔC , ΔD deplasmanlarının her bir cm.'si için aynı kesitteki eğilme momentlerinin ulaştığı değerler tablo olarak verilmiştir. Eğilme momentleri dış yükten doğan mevcut eğilme momenti değeri ile mesnet hareketlerinden doğan ve ΔA , ΔB , ΔC , ΔD mesnet deplasman değerlerine bağlı olan

eğilme momenti değerlerinin toplamı şeklindedir. Dolayısıyla sıfırdan maksimum mesnet deplasmanına kadar deplasman değerlerinin her bir cm.'si M_{Σ} büyüklükleri bulunur.

ΔA_{max} , ΔB_{max} , ΔC_{max} , ΔD_{max} değerlerine karşılık gelen eğilme momenti değerleri belirlenmiştir.



KAYNAKLAR

- [1] akirođlu, A., etmeli, E., 1983. " Yapı Statiđi ", İstanbul
- [2] Ekiz, İ., 1981. " özümlü Köprü Problemleri ", İstanbul
- [3] Göğüş, İ., 1978. " Yapı Statiđi, İzostatik Sistemlerde Şekil Deđiřtirmeler, Hiperstatik Sistemlerin Kuvvet Metoduyla özümü ", İstanbul Devlet Mühendislik ve Mimarlık Akademisi Yayını, İstanbul



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