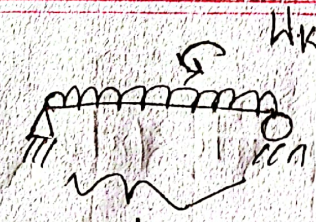
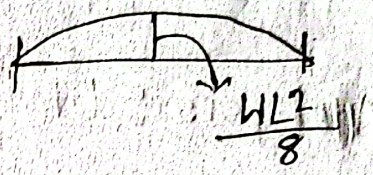
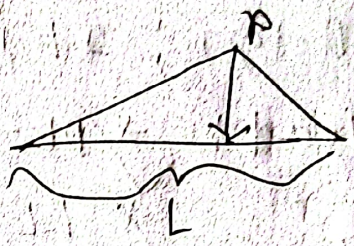
EWCE-311 (Soeb Sir) ~~Shohib~~



L/2

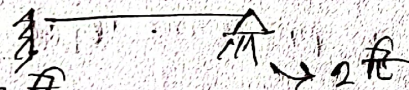
$\frac{WL}{2}$ $M = \frac{WL^2}{2}$





$M = \frac{PL}{4}$

More than 3 → indeterminate



total 5 ft



deflection, $\Delta = \frac{5WL^4}{384EI}$

$\Sigma F_V = 0$
$\Sigma F_H = 0$ } determinate
$\Sigma M = 0$

Ref Books

1. Hibbeler 4. Kassimali 5. BNBC

* Assignment, test 1 → Ch 7 to Ch 15
approximate analysis of statically indeterminate structures

Assignment & test 2 - Deflection of beams, trusses & frames by energy method (Ch 16 to Ch 26)

Assignment Review (Ch 22 & class 28)

Final Exam

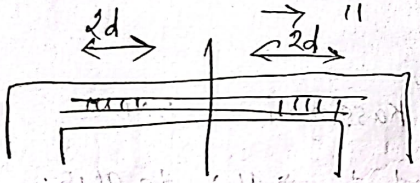
Analysis : detail examination of elements/data

Design : It is the creation

Load : * DL → dead load (change হবেনা যা beam, slab)
* LL → live load → movable
* Lateral Loads → Earthquake load
→ wind load

* Design Philosophy
→ strong column
→ weak beam

* Earthquake philosophy → EQ proof building
" resistance

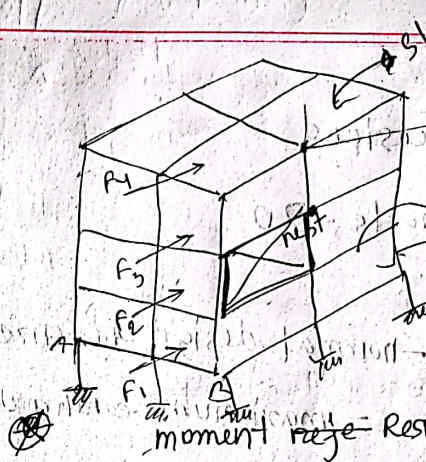


সবসময় পারি load দিতে পারবে এমনভাবে ডিজাইন করা হয়।
load বেশি হলে সেই সময় EQ এ energy absorb করে
energy is dispated

Seismic Design Methods : EQ load বের করার পদ্ধতি

→ Equivalent static force method . { part 6 chap 01
→ Dynamic response method { " 6 " 02

30.04.24



Base shear — building এর নিচে

AB floor এ column 3 টি V এসে এরা F1, F2

215 part-6 chapter-2 Para-215

$V = Sa * W$ → zone factor — building

$Sa = 2/3 \frac{2I}{R} C_s$

I = structural Importance

$C_s =$

Time period, $T = C_t (h_n)^m$ $T = \frac{1}{f}$

R = response reduction factor

Live load material এর density

earthquake load → dynamic

V = design earthquake force

minium floor live load

2.3.6. ~~[illegible]~~ - understand

Earthquake ~~loads~~ loads - 2.0

Base shear

Design earthquake - normal design এর সময়ে 2/3 multiply

= maximum earthquake

2.5.6 Earthquake Ground Motion

80 pg -

2.5.6.3 Design response

S = ~~expetnal~~ expetnal

pg-5 table: 2.1 (1, 2, 3 ছাড়া না পড়লে চলে)

material এর energy ~~for~~ যা force absorb করে। এর bridge এ R use করার জন্য 2/3 দিয়ে গুণ দিতে but building এ আরও R use করেছে।

2.5.7 -pg 90

Earthquake এর response reduction factor. R এর value for table এর 2.5.2

pg-85 table 2.1.5 (occupacy category)

ক্রিটিক্যাল না হলে সাধারণ damping 5% /

= 5 > = 0.05

~~2.5.2~~ 2.5.2.2 seismic design category

2.5.6 structure এর detailing এর প্রয়োজন

column কতটুকু খাড়া/সাধারণ করতে (সাধারণত এর site class এর উপর depend করে। SA → soil type

~~structure of building এর~~ | Sand clay

* page 29 table 2.5.1 site classification based on soil properties

* Table 2.5.4 from site, S, T_B, T_C, T_D এগুলো soil এর time period

* ~~Performance~~ → building এর একটা time period আবার soil এরও time period সমান 2টি same হলে collapse করতে।

from soil class S

~~Resonance~~ slide Eq 2.5.5

What is response spectrum → কোনো একটি acceleration নিয়ে graph

$C_s = S(1 + \frac{T}{T_B})$ (2.5.5) put.

$C_s = 2.5\,S\eta$ for $T_B \le T \le T_C$

$C_s = 2.5\,S\eta\,(\frac{T_C}{T})$ for $T_C \le T \le T_D$

$C_s = 2.5\,S\eta\,(\frac{T_C T_D}{T^2})$ for $T_D \le T \le 4$ sec

$\eta = \sqrt{10/(5+5)} \ge 0.55$ ← lowest

structural damping

structure এর energy absorb করার ক্ষমতা।

residential building ৪ – 2 এর respect ৪
I এর value 1

* damping না বলে দিলে 5% ধরিতে। আর যদি বলে কত damping 10% তাহলে 10% ই ধরিতে।

$$F_x = V \frac{w_x h_x^k}{\sum_{i=1}^{n} w_i h_i^k}$$

h → height
$w_i h_i$ → ভিন্ন ভিন্ন weight এর height x weight

* k = 1 if structure period ≤ 0.5

Natural period, $T = C_t (h_n)^m$ C_t, m from table

h_n → height of building in meters from foundation/ on from top

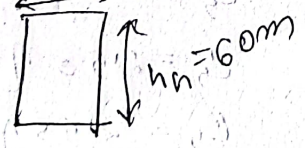
Problem:

Calculate the distribution of EQ force on the 20 storied office building shown in figure. Location – Dhaka. A soil profile consisting of a surface alluvial layer. DL including partition = 13.25 KN/sq-m, structural type IMRF. Consider 5% structural damping.

EQ force = ?

Intermediate Moment resting frames

R = 8



Given data

h_n = 60 m

Building type – II

I = 1.0

Location: Dhaka

Z = 0.2

site class = SE

S = 1.4

T_B = 0.15

T_C = 0.5

T_D = 2.0

$T = C_t (h_n)^m$ from 25.8

$= \frac{0.0466}{\text{concrete}} (60)^{0.9}$

= 1.86 sec

$C_s = 2.5 \eta (\frac{T_c}{T})$

$= 2.5 \times 1 (\frac{0.5}{1.86}) \times 1.4$

= 0.942

$C_a = \frac{2}{3} \times \frac{0.2 \times I}{R} C_s$

$= \frac{2}{3} \times \frac{0.2 \times 1}{8} \times 0.942$

= 0.0157

$\eta = \sqrt{\frac{10}{(5+5)}} = 1$ (5 → structural damping)

W = 24 × 24 × 13.25 × 20 = weight of the structure
(length × width × floor height × dead weight × floor)

= 15691.2 KN

$V = S_a \times W$

$= 0.0152 \times 19640$

$= 305.2\ KN$

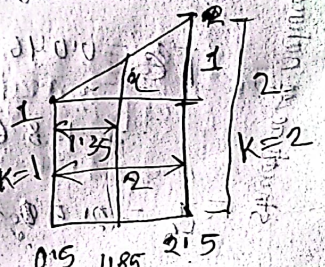
$F_x = V \dfrac{w_x h_x^k}{\sum_{i=1}^{n} w_i h_i^k}$

$= 305.2 \times \dfrac{15640}{}$

20 ফুট ফ্লোর

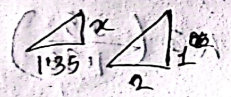
$n = 20$

$T = 1.185 < 2.5$



6-20 তলা পর্যন্ত F_x

F_{x1}, F_{x2}



$\frac{x}{1} = \frac{1.35}{2}$ $K = 1.68$

$\therefore x = 0.675$ $K = 1 + 0.625$

$W = DL + LL$

Live life load 25% $= 0.25$

DL ফিক্সড ধরা হবে

$DL = 3\ KN \times 24 \times 24 \times 20 \times$ [0.25 × live load]

সবসময় দেওয়া থাকে

Floor	h_x	W	h_x^k	F_x	Base shear (V) F_x
	3 করে বাড়বে	per floor এর total W Floor সংখ্যা			

Assignment-1

20 storied (each floor 25m × 25m) RC office building at Dhaka/Chittagong/Sylhet (Location), soil condition soft to medium stiff clay (SC). Dead load including partition wall/floor = 12 KN/m² and 25% of live load (LL) of building where LL = 4 KN/m² (BNBC, 2020), Damping 5% & R = 8

RC = IMRF → $C_t = 0.0466$, $x = 0.9$

Borishal

$Z = 0.12$

Occupancy category-2

$I = 1$

Soil type SC — $S = 1.15$

$T_B = 0.20$

$T_C = 0.66$

$T_D = 2.0$

Design basis based earthquake

$T = C_t (h_n)^{3/4}$

$= 0.085 \times (60)^{3/4}$

$= 1.85$ sec

$C_s = 2.5 \eta \left(\frac{T_c}{T}\right)$

$= 2.5 \times 1.5 \times 1 \left(\frac{0.60}{1.85}\right)$

$= 0.93$

$S_a = \frac{2}{3} \times \frac{Z I}{R} \times C_s$

$= \frac{2}{3} \times \frac{0.12 \times 1}{8} \times$

$= 9.3 \times 10^{-3}$

$\eta = \sqrt{\frac{10}{5 + \xi}} \geq 5$

$F = \frac{1}{\quad}$

$W = DL + LL$

$DL = 12 \times 25 \times 25 \times 2.0 = 150000$ KN (load)

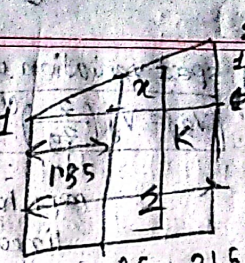
$LL = 0.25 \times 25 \times 25 \times 4 \times 2.0 = 12500$ KN

$W = 150000 + 12500 = 162500$ KN

$V = S_a \times W = 1911.25$

$h = 20$

$T = 1.85 < 2$



$\frac{1.35}{2} = \frac{x}{1.0}$

$\therefore x = 0.675$

$K = \text{arc} + \frac{1}{2} = 1.68$

Wind Loading Provisions

wind load — pressure ~~load~~ = pressure × area

pressure depend করে wind এর velocity র উপর

$q = \frac{1}{2} \rho V^2$

pressure at a point

$p = \frac{1}{2} C_p \rho V^2$

$p = \frac{1}{2} K C_p \rho V^2$

** three second gust V_{3s}

V_{FM} — BNBC ↓ wind এর speed figure — BNBC র থেকে — নাও

V_{3s} / V_{FM} — mean average

exposure — A — ~~same height~~ (building) — কাছাকাছি Market road এর building গুলো

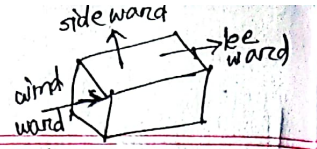
B — ছাদ থেকে building গুলো ⊥ মাটির ৯ বাড়ি ৫ টি building এর

C — বাড়ি ঘর নেই, coastal area (close + far) — কাছাকাছি বড় সমুদ্র পাশে বাড়ি ঘর এলে

1993 এ Dhaka র BNBC তে $V_{mean} = 153.3$ km/h

$V_{3s} = 232$ km/hr

Wind load math সমাধান



Wind speed variation with height

$$V_z = V_g \left(\frac{z}{z_g}\right)^{\alpha} \leq V_g$$

z_g → gradient height পর্যন্ত

linear



Method 1 – 60 ft

Method 2 – Analytical Procedure সেলসের height এর জন্য use করা যায়

Method 3 – Wind tunnel

Method-2

$q_z = q$ = level এ level এ height অনুসারে

$q_h = q$ = composed / top এর height

q_i – internal side wall এর জন্য (top এ)

G – gust effect factor 2.4.8

C_p – external pressure coefficient 6.2.6, 6.2.8

C_{pi} – internal 6.2.5

$$p = qGC_p - q_i(GC_{pi})$$

Design wind pressure

wind ward – যিনি level এ level এ lee side ward top এ

$$q_z = 0.000613\, K_z K_{zt} K_d V^2 I \ \text{KN/m}^2 \quad V \text{ in m/s}$$

K_z → velocity exposure coefficient → plane surface এর value 1

K_{zt} → topographic factor

K_d → directionality factor

V → wind speed

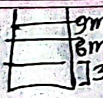
I → wind importance factor



K_z এর মান → $K_z = 2.01\left(\frac{z}{z_g}\right)^{2/\alpha}$ যদি $z < 4.57$ m

$K_z = 2.01\left(\frac{4.57}{z_g}\right)^{2/\alpha}$ যদি $z < 4.57$ m

α এবং z_g পাওয়া যায় 6.2.4 থেকে → 1st floor



I এর মান 2.4.2

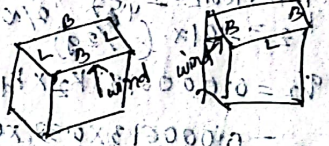
K_{zt} → $K_{zt} = (1 + K_1 K_2 K_3)^2$ সাধারণত 1

K_d → 0.85

G → $T = C_t (h_n)^m$, $f = \frac{1}{T}$, $f > 1$, $T < 1$

$T > 1$ → $G_f = 0.925\left(\frac{1 + 1.7 I_z \sqrt{g_Q^2 Q^2 + g_R^2 R^2}}{1 + 1.7 g_v I_z}\right)$

$G C_{pi}$ → open যেদিক দিয়ে বাতাস ঢোকে ও দিক দিয়ে বের হয়, void এর building – Partially enclosed, Enclosed Building



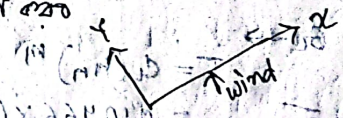
wind load case:

case 1 → accumulate করে

case 2 → X – L



accumulate করে যোগ করে



Total

C_p → wind ward & lee side wall same থাকে lee ward change হয়। lee ward যদি side – 22 পৃ.

= যদি মিল data এর মধ্যে থাকে average/interpolation করে করতে হয়।

Question:

Calculate the design load of the following building, Rectangular (24x48 m). Hospital building (6 storied). Storey height = 3m. City Dhaka, Exposure = A calculate as per BNBC-2020, Follow Method-2: Analytical Procedure. (40)

Solution:

We know, $P_z = q_z \times G_f \times C_p$ $\quad P = qGC_p = q_h(GC_p)$

for floor-1 $\quad K_z = 2.01 \times \left(\frac{4.57}{365.76}\right)^{2/\alpha} = 2.01 \times \left(\frac{4.57}{365.76}\right)^{2/9.5} = 0.57$

$q_z = 0.00613 \times K_z \times K_d \times K_{zt} \times V^2 \times I$

$= 0.00613 \times 0.57 \times 0.85 \times 1 \times 65.2^2 \times 1.15$

For floor-2

$K_z =$

$q_z =$

Location-Dhaka
Storey = 6
height = 6x3 = 18m
size = 24x48
Type - Hospital
Occupancy category IV
$I_w = 1.15$ (24.2)
Exposure: A
$K_{zt} = 1$ (24.7.3)
$K_d = 0.85$ (24.4)
Dhaka
$V = 65.2$ m/s - 66pg

$G_f \Rightarrow$

$T_1 = C_t(h_n)^x$

$= 0.0466 \times (18)^{0.9}$

$= 0.628$ sec

$f = \frac{1}{T} \times 1 = 1.59$ Hz

$f > 1$ Hz
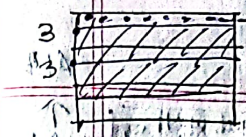
$G_f = 0.85$

Cp → L/B = 48/22 = 0.663

Windward wall, Cp = 0.80

Leeward wall, Cp = -0.5

Side wall, Cp = -0.70



Location	Height above ground (m)	z	q_z (kPa)	K_z	q_z (kPa)	G_f	C_p	$q_z G_f C_p$ (kPa)	$q_h = q_h$	$G_f C_p i$	$q_i(GC_{pi})$ (kPa)
Floor											
Windward wall											
f_1	3	x	365.76	0.57	2.122	0.85	0.8	1.44	2.122	0.68	0.40
f_2	6	x		0.62	2.299		0.8	1.56			
f_3	9	x		0.66	2.448		0.8	1.66			
f_4	12	x		0.70	2.596		0.8	1.76			
f_5	15	x		0.73	2.707		0.8	1.84			
f_6	18	x		0.76	2.818		0.8	1.91			
Leeward wall					2.122		-0.5	-1.08			
Side wall							-0.7	-1.51			

case – 1

Floor	Height above ground (m)	B (m)	Tributary Height (m)	Area	Windward wall: External Design Wind Pressure (kPa)	Windward wall: Design wind force Px (KN) A	Leeward wall: External Design wind Pressure (kPa)	Leeward wall: Design wind Pressure force, Px (KN) B	Total Design wind force Pnet x (KN) A+B
F_1				216		148		205	
F_2				216					
F_3				216					
F_4				216					
F_5				216					
			3/2 15	108					

#Calculate the design load of the following building. Rectangular (80×50m) Hospital building (10 storied), storey height = 3m, city Dhaka/Chittogong/Sylhet, Exposure = B. Calculate as per BNBC-202,

Follow Method - 2 : Analytical Procedure :

-2টি / Y axis এর Math করব

W, L change করে moment, axial force বের করতে হবে, frame এর moment distribution = $\frac{EI}{L}$ → moment of Inertia / modulus of elasticity

Σ joint Moment = 0

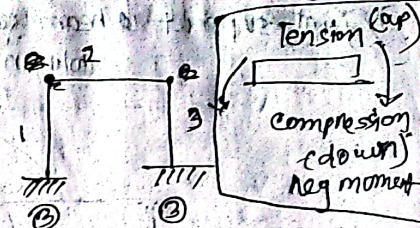
positive moment – tension – নিচে compression
neg " – tension – উপরে – " নিচে

VARTICAL LOAD

19.05.24

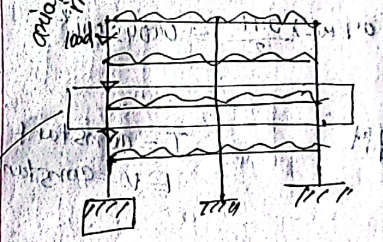
Approximate Analysis – computer ব্য

Exact analysis



slab এর DL + LL + FF + P_{wall} → Beam → Column

Dead Load, Live Load, Floor finish



C = মাঝি point
ব hinge থাকে?

Joint – এ – J

$3n = 9$

$r = 6$

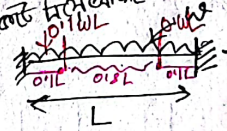
$r < 3n$

$3J + C$ ফি $= 3 \times 4 + 6$
$= 18$ না 12

$3m + r = 9 + 6$
$= 15$

$I = 15 - 12$
$= 3$

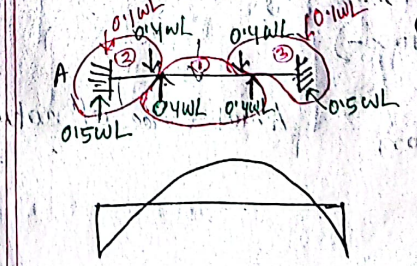
vertical load এর ক্ষেত্রে কিভাবে analysis করব তা জানা ?



beam থাকলে – moment share diagram

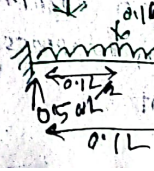
column " – "

assumption হলো – 0.1L দূরে hinge থাকে যদি না থাকে – simply supported beam



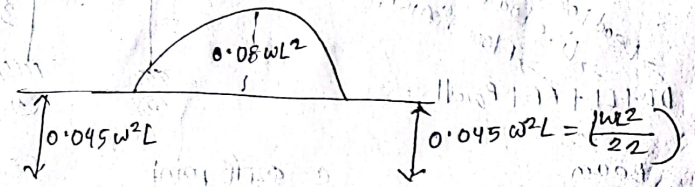
① moment $= \frac{WL^2}{8} =$ (0.8L)

② moment $= 0.1L \times W \times \frac{0.1L}{2} + 0.4WL \times 0.1L$



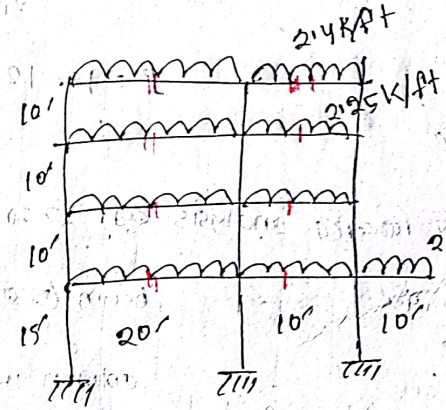
$M_A = 0.1WL \times \frac{0.1L}{2} + 0.4 \times WL \times 0.1L$

Joint / support ⓐ beam ⓐ neg moment
column ⓐ positive ⓐ — outer column ⓐ



max positive moment = $\frac{wx(0.8L)^2}{8} = 0.08\,wL^2$

max neg ⓐ = $0.4wL \times 0.4L + 0.1wL \times \frac{0.1L}{2} = 0.045\,wL^2$



I = constant
E v = constant

a) Max positive girder moment (Mmax+) — bending moment
b) Max neg girder moment (Max−)
c) Girder shear (V)
d) Exterior column compression
e) Interior column compression
f) column moment

Axial force of column

20' span

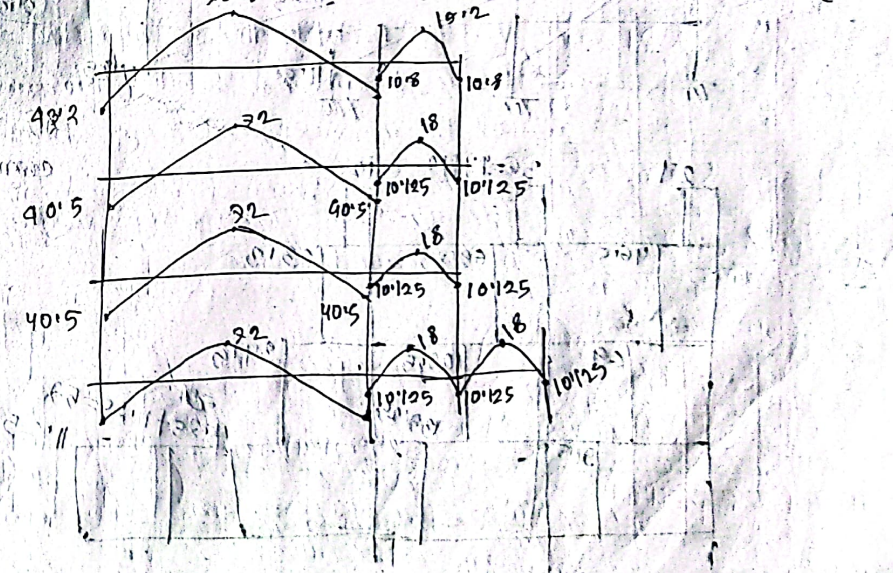
positive moment = $0.08\,wL^2 = 0.08 \times 2.4 \times 20^2 = 77$ (floor)
$= 0.08 \times 2.4 \times 20^2 = 26.8$ (roof)

neg moment = $0.045\,wL^2 = 0.045 \times 2.4 \times 20^2 = 43.2$ (roof)
$= 0.045 \times \frac{2.8}{2.125} \times 20^2 = 40.5$ (floor)

10' span

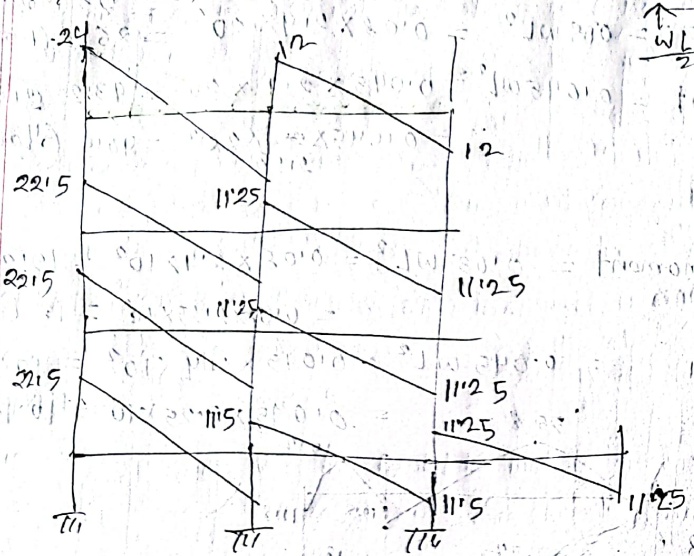
positive moment = $0.08\,wL^2 = 0.08 \times 2.4 \times 10^2 = 19.2$ (roof)
$= 0.08 \times 2.25 \times 10^2 = 18$ (floor)

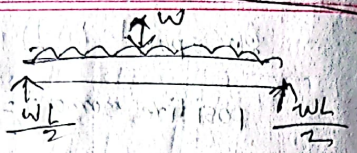
neg ⓐ = $0.045\,wL^2 = 0.045 \times 2.4 \times 10^2 = 10.8$ (roof)
$= 0.045 \times 2.25 \times 10^2 = 10.125$ (floor)



21.05.24

Vertical Load shear force





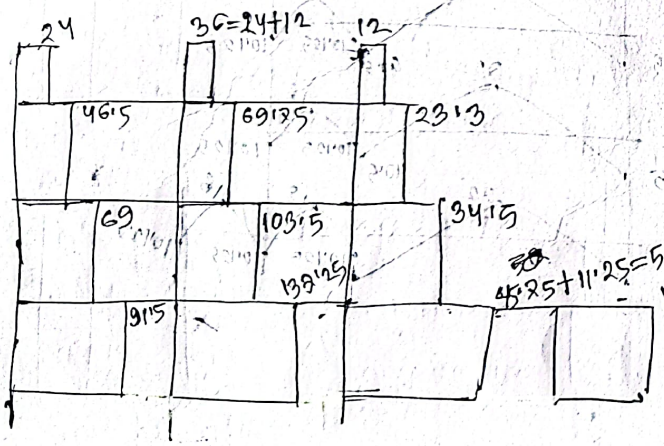
$\frac{24 \times 20}{2} = 24$

$\frac{2.2 \times 10.8}{2} = 12$

$\frac{2.25 \times 20}{2} = 22.5$

$\frac{2.25 \times 10}{2} = 11.25$

এই total load কে compression এ



Beam

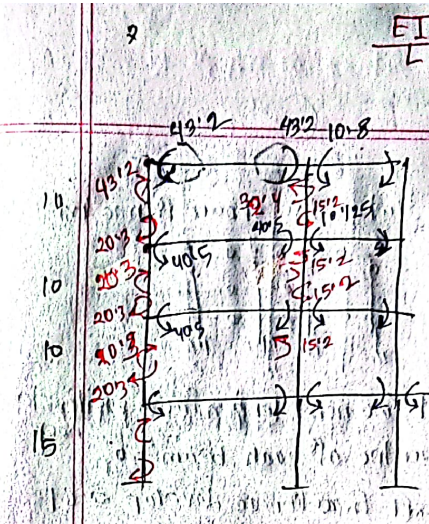
Fig- Axial force diagram

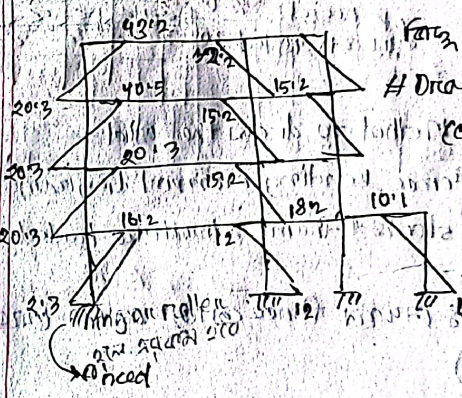
2

$\frac{EI}{L}$

blue - beam

red - column





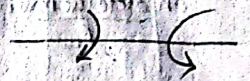
Tension

comp

neg moment

we know,

Σ Joint Moment = 0



$\frac{EI}{L} \Rightarrow \frac{1}{10}$

$\frac{EI}{L} = \frac{1}{15}$

$\frac{EI}{L} = \frac{1}{10} + \frac{1}{15} = \frac{1}{6}$

$EI/L \,/\, \frac{EI}{L} = 1/10 / \frac{1}{6} = \frac{6M}{10}$

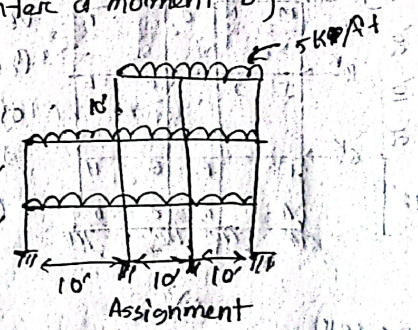
$EI/L \,/\, EI/L = 1/15 / \frac{1}{6} = \frac{6M}{15}$

28.05.24

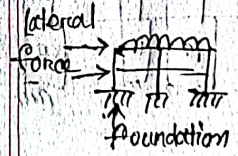
Ratio গুলা সবসময় compression phase এ থাকবে এবং

Draw moment diagram in tension phase.

(column এর center এ moment 0)



PORTAL FRAME



lateral force কে foundation এ স্থানান্তর করে frame বানানো হয় যাতে building এর কোন structure এ ভাঙে

joint → beam & colum → foundation

→ statically indeterminate

→ approximate solution

Assumption:

→ shear force in an interior column is twice the shear force in an exterior column

E → 2x force

I → 2x force

→ There is a point of inflection (hinge) at the center of each column — 0 moment / moment tension from positive to neg

→ There is a point of inflection at the centre of each beam — 0

20 K force এর floor বরাবর or frame এর দিক্ষা দিয়ে তিনটি force develop হবে।

interior & exterior ← $x+2x+2x+x = 6x = 30$

$\therefore x = 5$

20K resist করার জন্য created 30

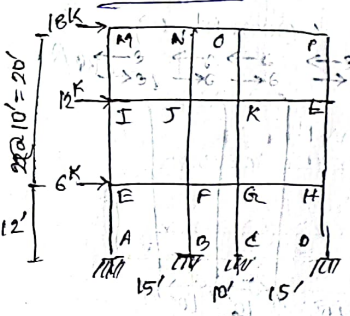


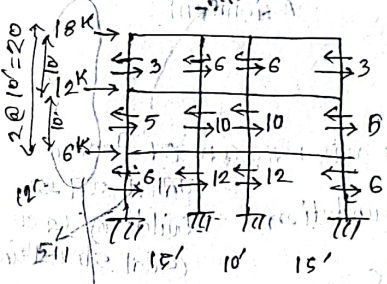
Brace created

Math

Use the Portal Method to draw the axial force, shear force, bending moment diagram of the three-storied frame structure loaded as shown below.

(উপর থেকে 3 নিচের force গুলো কোথায় নিচে যাবে হবে।)





shear diagram

$18 = x+2x+2x+x$

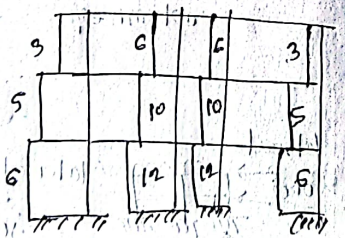
$\therefore x = 3$

$12 = x+2x+2x+x$

$\therefore x = 2$

$6 = x+2x+2x+x$

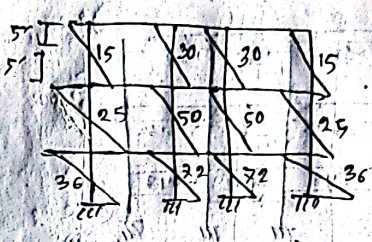
$\therefore x = 1$



column SFD (K)

frame এর সাথে ... countable ...

(compression phase এ কাজ করে) $\frac{10}{2}$ → distance



$M_1 = 3\times5 = 15$

$M_2 = 5\times5 = 25$

$M_3 = 6\times6 = 36$

(Half of moment এটা 0)

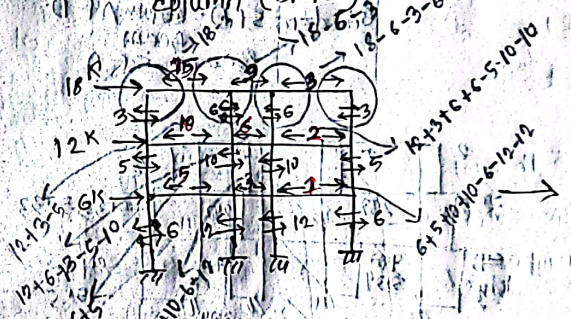
$M_1' = 6\times5 = 30$

$M_2' = 10\times5 = 50$

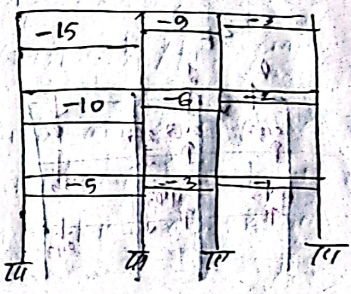
$M_3' = 12\times6 = 72$

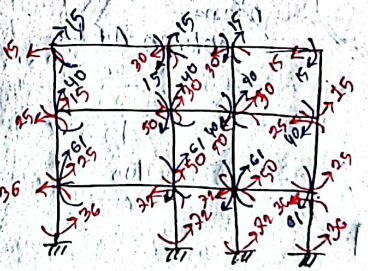
Force towards the joint ← compression হবে

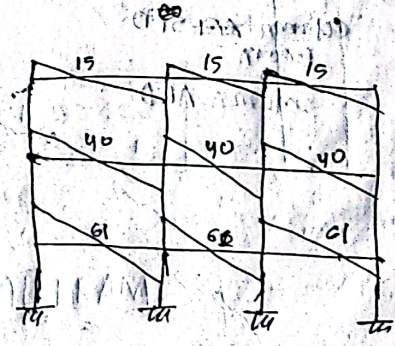
column (BMD)



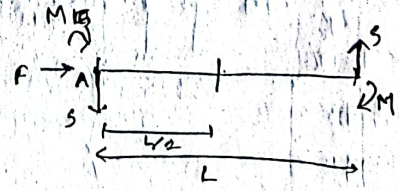
AFD beam







Beam BMD

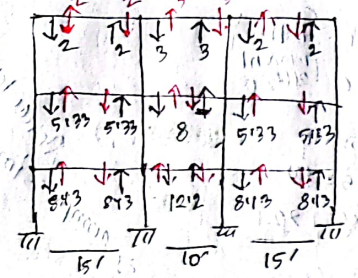


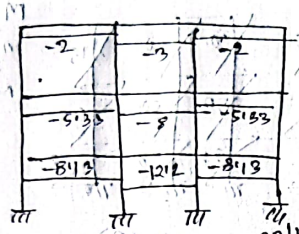
$\sum M_A = 0$

$\Rightarrow 5\times\frac{L}{2} - M = 0$ (anticlockwise positive)

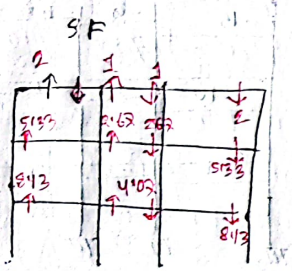
$\therefore S = \frac{2M}{L} = \frac{2\times15}{15} = 2$ kip (MN

neg shear column এর জন্য positive হবে

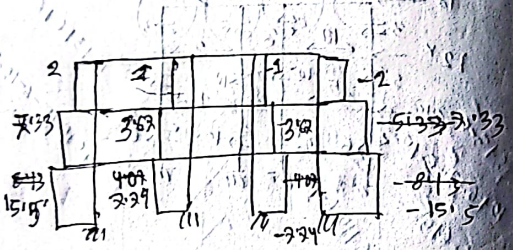




Beam SFD



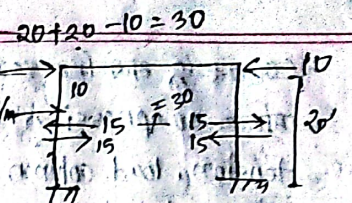
column AFD



column AFD

Deflected shape এমন হবে।

3A & 2A দিয়ে করলে এত বড় হবে, তাই ছোট করতে তারা (১৩৭) দিয়েছে।

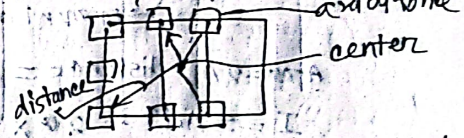


CANTILEVER Method

এ column কতটা load নিবে এটা size এর উপর depend করে। portal এ column size এর lack of consideration of size effect. তাই এই method apply করা হয়েছে।

Assumption – প্রতেকটি storey distance & size এর উপর depend করে।

→ axial force in each column of a storey is proportional to its horizontal distance from the CG of all the column.



এই lateral load wind থেকে আসে।

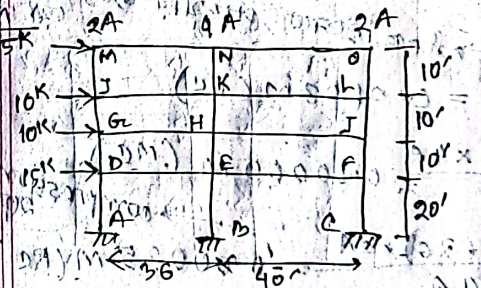
Question:

Beam – AFD, BMD, SFD

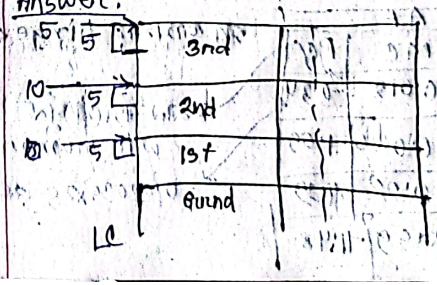
Column – AFD, BMD, SFD

Draw using cantilever method.

Math



Answer:



মাঝের থেকে load যেদিকে বেশি সেদিকে হবে।

$$\bar{x} = \frac{a_1x_1 + \dots + a_nx_n}{a_1 + \dots + a_n}$$

a = area

A = column এর sectional area

$$\bar{x} = \frac{2A \times 0 + 4A \times 36 + 2A \times 96}{2A + 4A + 2A}$$

যে সেকশন বার দিয়ে যেতে আমরা সর্বোচ্চ compression এবং সর্বোচ্চ tension load column যে সেকশন stress develop করে।

stress ∝ distance from CC (but আমরা inversely proportional এবং stress ↑ distance ↓)

$\sigma \propto y$

$\Rightarrow \sigma = Ky$

$\Rightarrow \sigma = \frac{M}{I} y$

$\therefore \sigma = \frac{Mc}{I}$ → distance from CC

M → moment

I → moment of inertia

stress × Area = force

Area = 2A, distance CC = 32 − 36 =

$I = \Sigma Ad^2 = 2 \times A \times 32^2 + 4A(32-36)^2 + 2A \times (32-26)^2$

$= 5284\,A$

$6 \propto y \Rightarrow 6 = k\,y = \frac{My}{I}$ → force নিজের পাওয়ার জন্য Area গুণ করা হয়েছে।

left colum = $\frac{M \times 32 \times 2A}{5284\,A} = 0.0128\,M$ (LC)

middle A = $\frac{M(32-36) \times 4A}{5284\,A} = 0.00069\,M$ (MC)

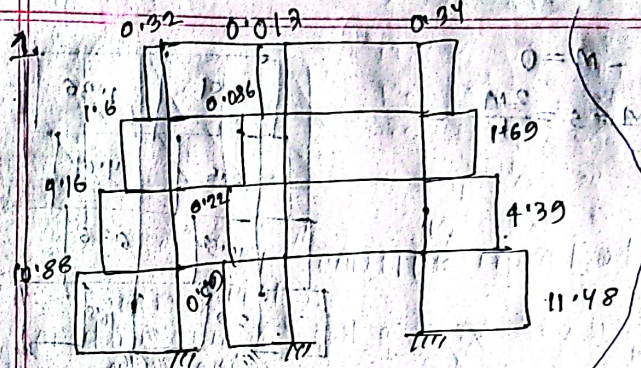
Right = $\frac{M \times (32-26) \times 2A}{5284\,A} = -0.00035\,M$ (RC) → compression এসেছে

এর কারণে hinge এর মান বসিয়ে গুণ with moment = 0.00035 × 25 এবং

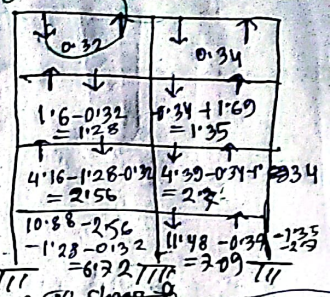
Floor	Moment		AF LC	MC	RC
3rd	5×5=25		0.32	0.012	−0.34
2nd	5×15+10×5 = 125		1.6	0.086	−1.69
1st	5×25+10×15 +10×5=325		4.16	0.22	−4.39
Ground	5×40+10×30 +10×25+15×10 = 550		10.88	0.59	−11.48

Axial force of column = force × total distance

column এর axial force বের Beam এর shear force থেকে compression এবং express neg moment এর moment নিয়ে বের



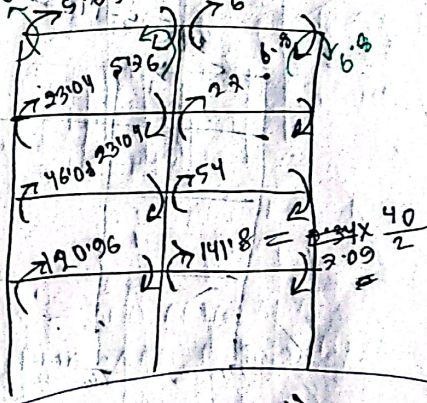
1. Beam এর Axial force



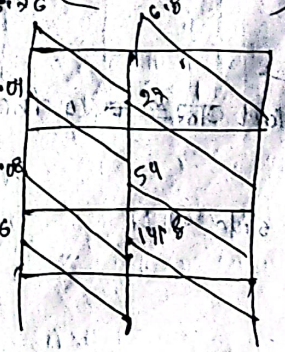
3.



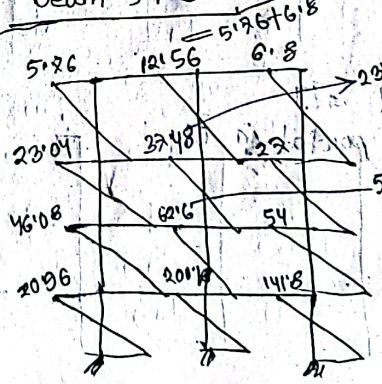
4.



5. (Beam moment)



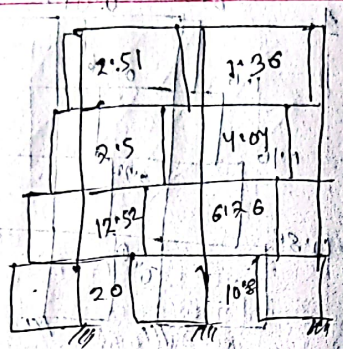
6.



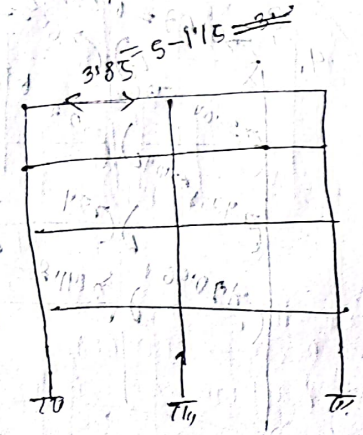
column এর BMD

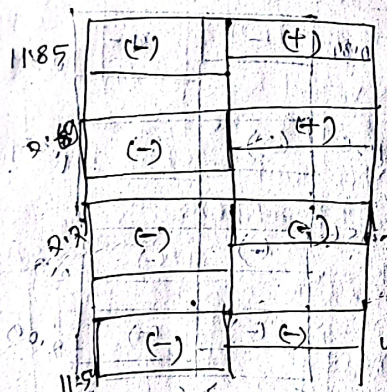
$S \times \frac{L}{2} - M = 0$

$\therefore M = S = \frac{2M}{L}$



column SFD

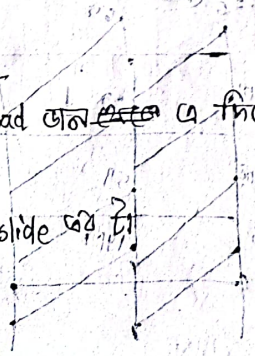


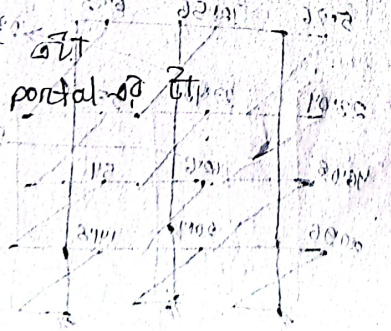


BEAM AFD

HW

1. load অন্য কোন দিকে করে হবে তাই
2. portal কত টি
3. slide কত টি





Bridge Portal

Approximate Analysis of Bridge Portal and Mili Bent

2 ft member এলে যার moment নেয়, তাকেও truss দিয়ে join করে single force member ⇐ truss এ force এলে ⊖ 1 ft (either tension or compression) It ~~et~~ doesn't take any moment.

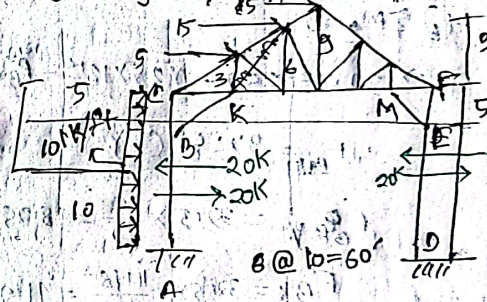
Bending moment —— X

axial force & এলে খালি truss এর।

shear force ~~first~~ —— X



এখানে hinge দিব A to B এর এলে। $\Rightarrow \frac{L}{2}$ (hinge point) L = unsupported length



ABC column: Axial, Shear, Bending moment

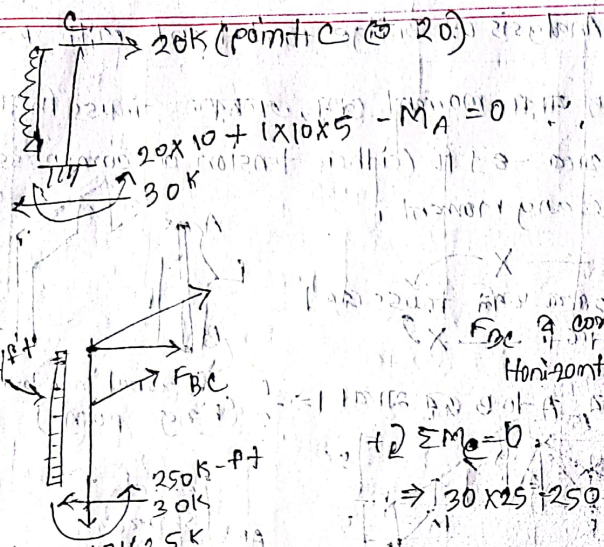
Bar force → BK, ME

Total Horizontal Force = 5 + 15 + 15 + 15 × 1 = 40 K

Each point = $\frac{40}{2} = 20$ K

$V_b \times 12 - 5 \times (15+9) + 15 \times (6+15) + 5 \times (3+15) + 1 \times 15 \times 2.5 - V_E \times 60 = 0$

$\Rightarrow V_b = 10.625$ (↑)



F_BC ৭ component ৭ ভাগ
Horizontal টানে নিয়ে চলে এসে।

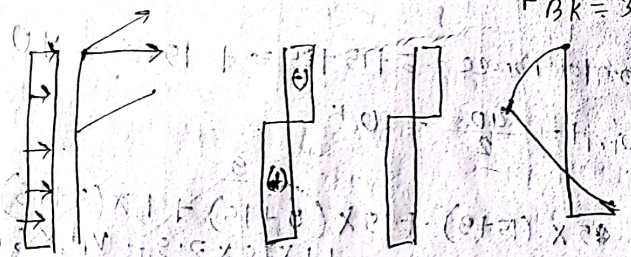
$+\circlearrowleft \Sigma M_C = 0$

$\Rightarrow 30 \times 25 + 250 - 1 \times 25 \times 12.5 - F_{BH} \times 5 = 0$

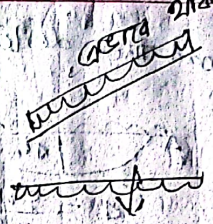
$\therefore F_{BH} = 32.5K$ (T)

$F_{BV} = 32.5 \times \frac{25}{110} = 8.25K$

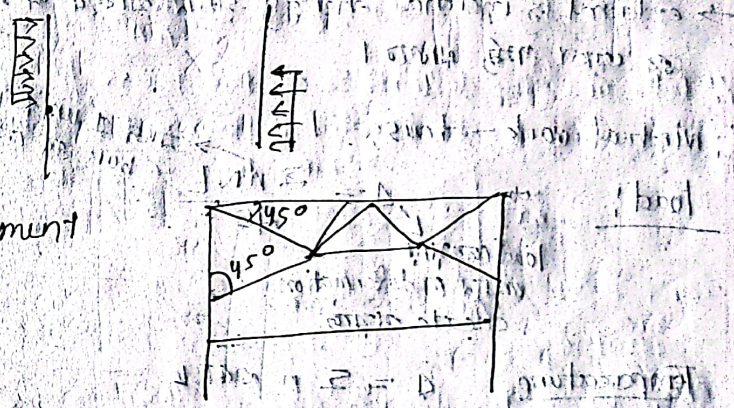
$F_B = 32.5 \times \frac{11.18}{10} = 41.93K$



(1) ME force ৭ solve (Assignment)
(2) এই math ৭ load ভিন্ন side ৭ হত

(3) 

(4) C ৭ force vertically, এভাবে

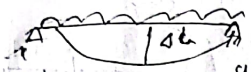
(5) 

3 Assignment

External work & Strain Energy 09.০৪.২৫

load দিলে deflection create হয়।





$\Delta = \frac{5WL^4}{384EI}$

$U_e = U_i$

→ external & internal energy সমান থাকবে যখন elastic limit এর ভেতর থাকে।

virtual work – truss

load; $\Delta = \frac{\Sigma nNL}{AE}$ → যখন 1 unit load দেওয়ার পরে bar এর যে force হয়

load দেওয়ার কারণে যে deformation create হয়েছে

Temperature $\Delta = \Sigma n \alpha \Delta T L$

Fabrication $\Delta = \Sigma n \Delta L$

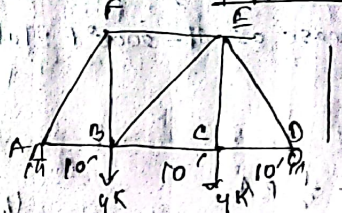
steel structure factory তে বানানো হয়, সাইটে গিয়ে এসেম্বল করে হয় then connect করার হয়। বড় হলে sag হবে (deflection)

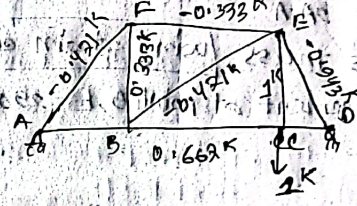
ছোট হলে উপরে (upward deflection)

↳ stress থেকে যাবে যাকে residual stress বলে।

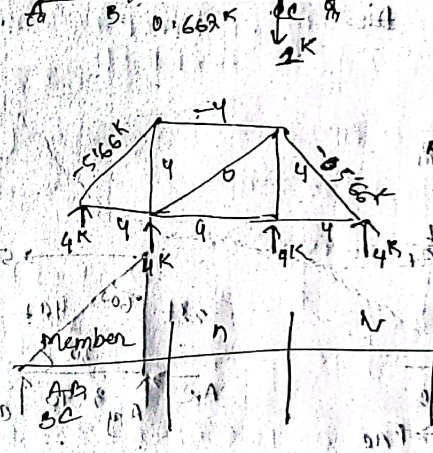
যা বাড়তি stress (load ছাড়াও stress আছে)

Q: Determine the vertical displacement of joint C of the steel truss shown in fig. The cross-sectional area of each member $A = 0.5\ in^2$ & $E = 29(10^3)$ ksi





i) C তে 1kip load দেওয়া (virtual load)

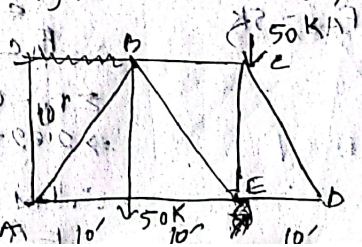


Real load (N)

Member	n	N	L	nNL
AB				
BC				

Assignment-1

compute the vertical deflection of joint B of the truss shown in fig. $A = 2\ in^2$ $E = 30,000$ ksi



Assignment-2 → slide

Assignment-3

Determine the vertical displacement of joint A if member AB and BC experience a temp increase of $\Delta T = 200°F$. Take $A = 2in^2$ & $E = 29(10^3)$ ksi. Also $\alpha = 6.60(10^{-6})/°F$

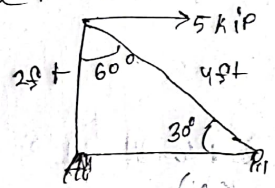
16.02.24

external energy, $U_e = \frac{1}{2} P \Delta_i$ $\quad U_e = U_i$

internal strain energy, $U_i = \frac{N^2 L}{2AE}$

Q: # Determine the deflection of this truss, using strain energy.

Q: Determine the horizontal displacement at point B, $E = 29000$ ksi, $A = 0.12 in^2$



Ans: $W_e = \frac{PQ}{2}$ $\quad U_i = \sum \frac{P^2 L}{2AE}$

$\sum M_A = 0$

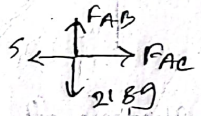
$\Rightarrow -5 \times 2 + C_y \times 3.46 = 0$

$\Rightarrow C_y = 2.89 K \uparrow$

$A_y = -2.89 K \downarrow$

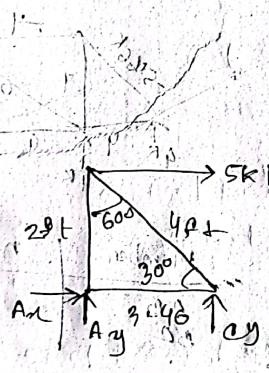
$A_x = -5 K$

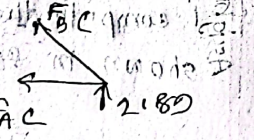
Joint A



$F_{AB} = 2.89 K$

$F_{AC} = 5 K$





$\sum F_y = 0$

$\Rightarrow 2.89 + F_{BC} \sin 30° = 0$

$\therefore F_{BC} = -5.78 K$

$EA = 5800 K/in$

$U_e = U_i$ (horizontal force, vertical)

$\Rightarrow \frac{1}{2} P_1 \Delta_{AB} = \sum \int_0^{L_i} \frac{P_i^2}{2E_i A_i} dx = \sum \frac{P_i^2 L_i}{2E_i A_i}$

$\Rightarrow \frac{1}{2} \times 5 \times \Delta_{AB} = \frac{1}{2EA} \left(F_{AB}^2 L_{AB} + F_{BC}^2 L_{BC} + F_{CA}^2 L_{CA} \right)$

$= \frac{1}{2 \times 5800} \left(2.89^2 \times 2 + (-5.78)^2 \times 4 + 5^2 \times 3.46 \right)$

$\therefore \Delta_B = 8.12 \times 10^{-3} ft = 0.0698 m$ $\quad$ +ve → same direction of the load

Vertical displacement ক্ষেত্রে একই ভাবে করতে হবে।

Example-5

Calculate the horizontal displacement at joint C, each member has an area of $2 in^2$ and a modulus of elasticity, $E = 30,000$ ksi.

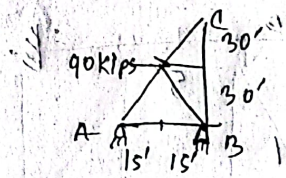
a) Due to loads applied

b) Due to members AB & AD 3/4 in too long

c) Due to member AB & BC are subjected to temp increase $\Delta T = +100°F$. The co-efficient of thermal expansion, $\kappa = 6.5 \times 10^{-6}/°F$

d) Due to 3/5 in support settlement at A

e) Due to all the above,



→ কোনো point এ deflection বের করতে হলে, ঐ point এ 1 unit load দিবো, then এর moment diagram আঁকব। or Virtual moment (m)

→ real load এর জন্য যে bending moment or M (real moment)

$$\Delta = \int_0^L \frac{mM}{EI}\,dx$$

m = internal virtual moment in the beam caused by virtual load

E = modulus of elasticity

I = moment of Inertia

Δ = external displacement caused by real loads

M = internal moment caused by real load

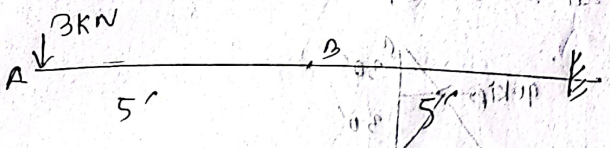
→ কোনো point এ rotation বের করতে হলে ঐ point এ বের করতে হবে ঐ point এ unit moment দিয়ে the process the analysis

$$\theta = \int_0^L \frac{m_\theta M}{EI}\,dx$$

M = real load

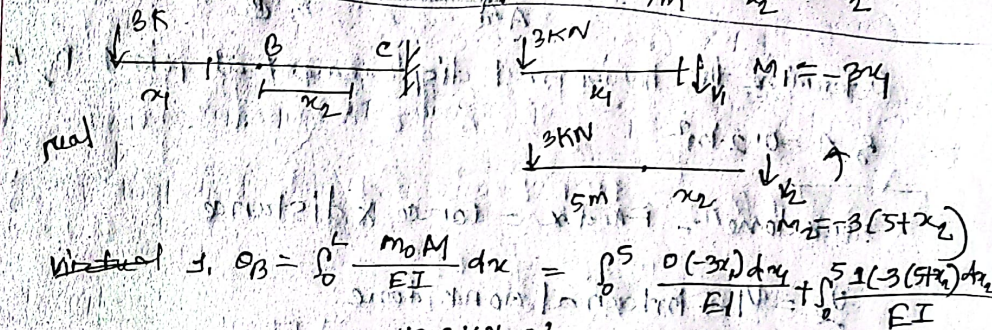
m = virtual load

Q; Determine the slope θ at point B of the steel beam shown in fig - Take E = 200 GPa, I = 60(10⁶) mm⁴



B point এ 1 unit moment দিয়ে।

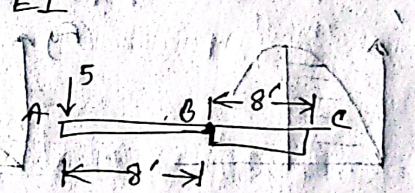




virtual ∴ $\theta_B = \int_0^L \frac{m_\theta M}{EI}\,dx = \int_0^5 \frac{0(-3x_1)\,dx_1}{EI} + \int_0^5 \frac{1(-3(5+x_2))\,dx_2}{EI}$

$$\Rightarrow \theta_B = \frac{-112.5\ KN\text{-}m^2}{EI}$$

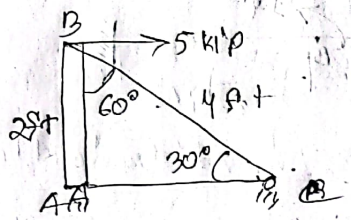
$I_1 = 200\ in^4$ $I_2 = 400\ in^4$





3 sept 2024

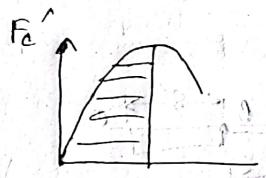
Example-1

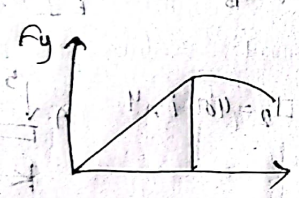


Determine the horizontal displacement at point B, E = 29000 ksi & A = 0.2 in²

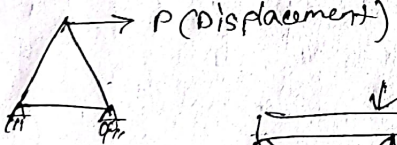
Work done = $\int F \, dx$ = force x distance

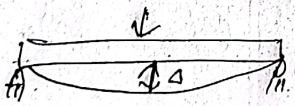
$U_e = U_i$ → internal work done
↳ external work done





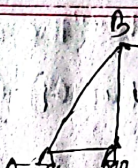
$U_e = \frac{1}{2} \Delta P$ $U_e = \frac{1}{2} \Delta P$ $U_i = \frac{N^2 L}{2AE} = \int_0^L \frac{P^2}{2AE} dx$





$U_i = \int_0^L \frac{M^2 dx}{2EI}$

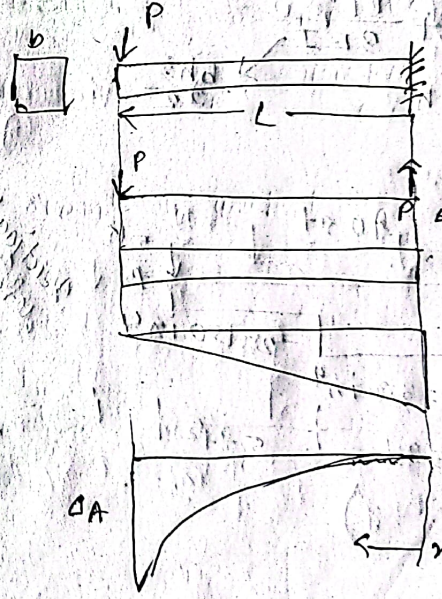
Assignment



Dis^p at B, E = 29 x 10^3 ksi, A = 0.5 □", using strain energy

Example-2

Determine the vertical displacement at point A. The beam is made of a material that has a modulus of elasticity E and a shear modulus (or) elasticity G



PL হলো সবচেয়ে last limit সর্বশেষ যাওয়া যাবে → সবচেয়ে বেশি moment point

$U_e = U_i$

Formula $\Rightarrow \frac{1}{2} P(\Delta_A) = \int_0^L \frac{f_s V^2}{2GA}\,dx + \int_0^L \frac{M^2}{2EI}\,dx$ (shear, bending moment)

$= \int_0^L \frac{1{\cdot}2(-P^2)}{2GA}\,dx + \int_0^L \frac{(-Px)^2}{2EI}\,dx$

$= \left[\frac{1{\cdot}2P^2x}{2GA}\right]_0^L + \frac{P^2}{2EI}\left[\frac{x^3}{3}\right]_0^L$

$f_s = 1{\cdot}2$ for rectangular shape factor

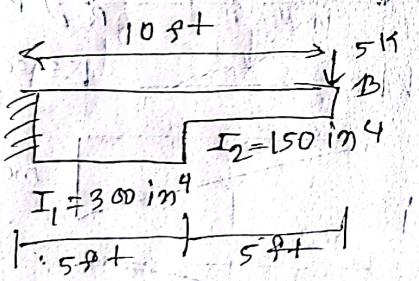
$\Rightarrow \frac{1}{2} P(\Delta_A) = \frac{1{\cdot}2P^2L}{2GA} + \frac{P^2L^3}{6EI}$

$\therefore \Delta_A = \frac{1{\cdot}2PL}{GA} + \frac{PL^3}{3EI}$

$\frac{1{\cdot}2PL}{GA}$: $b \times h$, সেকশন এরিয়া A

$\frac{PL^3}{3EI}$: $\frac{bh^3}{12}$

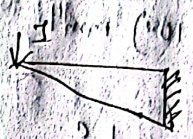
Assignment



Vertical deformation at B.

10.09.24

Virtual work method for beam & frames



যে point এ তার্ক করতে হবে সেখানে unit load দিতে হবে

moment diagram small m for virtual



M for real load

$1 \cdot \Delta = \int_0^L \frac{mM}{EI}\,dx$

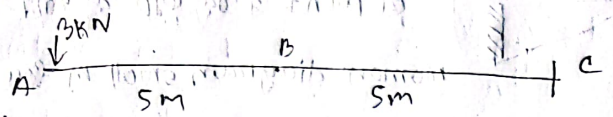
determine deflection at any point of beam.

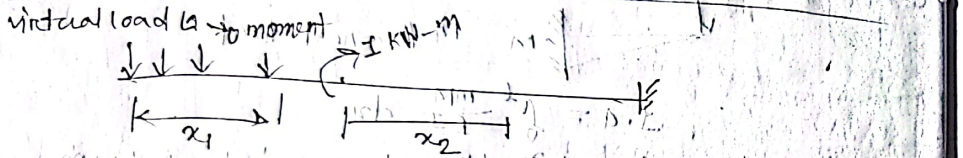
graphical method (table পদ্ধতি)

→ PTO

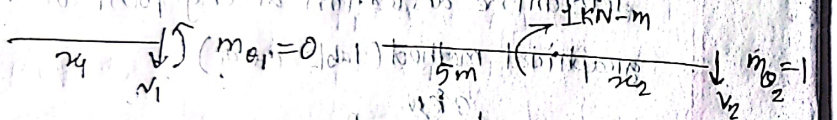
10.09.24

Determine the slope θ at point B of the steel beam shown in Fig - Take $E = 200$ GPa, $I = 60(10^6)$ mm^4.



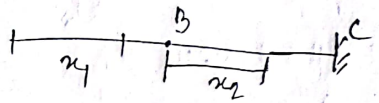


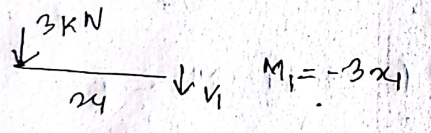
virtual load

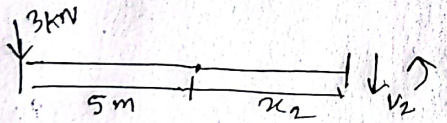


virtual unit couple (6)

real load







$M_2 = -3(5+x_2)$

(cantilever beam or2 neg)

The slope at B,

$$\theta_B = \int_0^L \frac{m_\theta M}{EI}\, dx$$

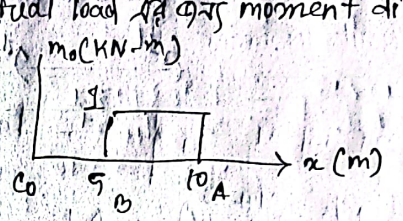
$$= \int_0^5 \frac{0 \times (-3x_1)\, dx_1}{EI} \to 0 + \int_0^5 \frac{(1)[-3(5+x_2)]\, dx_2}{EI}$$

$$\therefore \theta_B = \frac{-112.5\ \text{KN-m}^2}{EI}$$

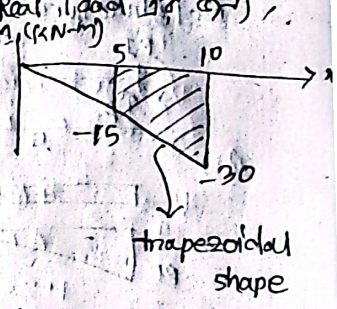
EI = rotation
= ঘূর্ণন angle
= Gaus Radia

Graphical Method

Virtual load এর জন্য moment diagram



Real load এর জন্য,



~~graphical method~~ এর জন্য

Table after evaluating $\int_0^L m_m M\, dx$ (formula ব্যবহার table করে intersect করে)

$$\int_5^{10} m_\theta M\, dx = \frac{1}{2} m_\theta (M_1 + M_2) L$$

$$= \frac{1}{2}(1)(-15-30)5$$

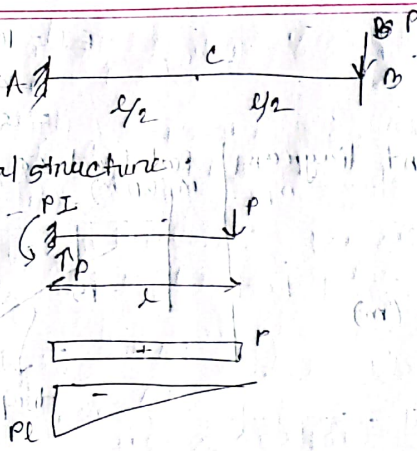
$$= -112.5\ \text{KN}^2, \text{m}^3$$

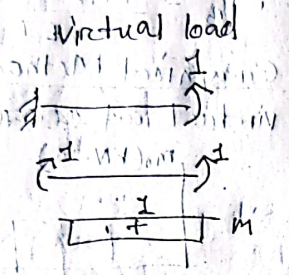
$$\theta_B = \frac{-112.5}{20(10^6)\ \text{KN/m}^2 \left[60 \times (10^6)\ \text{mm}^4\right] (10^{-12}\ \text{m}^4/\text{mm}^4)}$$

$$\theta = -0.00938\ \text{rad}$$

Assignment

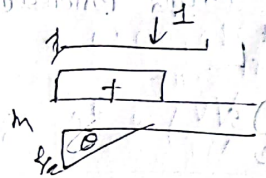
Determine the deflection at point B using virtual method & Graphical method.





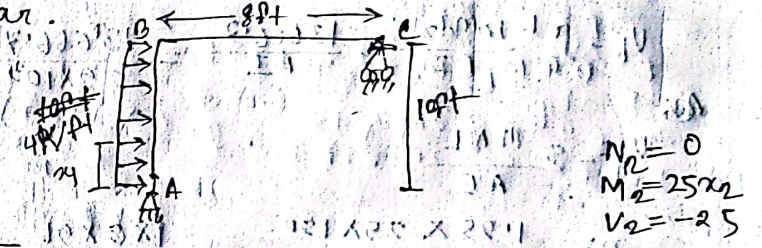
$$\theta_B = \int_0 \frac{M\,m}{EI}$$

Deflection at point C,



Assignment — C point A rotation, B point a deflection

Determine the horizontal displacement of point C on the frame shown in Fig -9.25a. Take $E = 29(10^3)$ ksi, $G = 12(10^3)$ ksi, $I = 600$ in^4, $A = 80$ in^2 for both members. The cross-sectional area is rectangular. Include the internal strain energy due to axial load & shear.



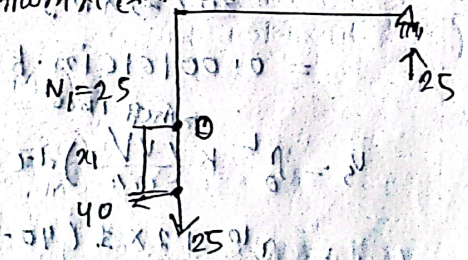
Real load

Point C moment from A

$M_1 = 40 \times x_1 - 4x_1 \times x_1/2$

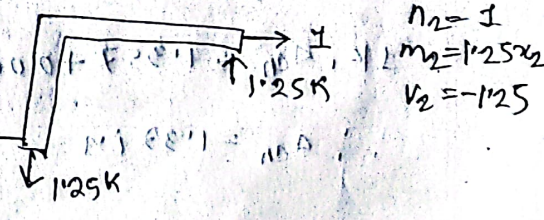
A to B shear force,

$V_1 = 40 + 4x_1$



Virtual load

Horizontal displacement, C point এ 1 kip load নিলে



axial force ← $n_1 = 1.25$

$m_1 = 1x_1$

$V_1 = 1$ k

$$V_b = \int_0^L \frac{mM\,dx}{EI} = \frac{1}{EI}\int_0^{10} (1)(40x_1 - 2x_1^2)\,dx_1 + \int_0^8 \frac{12.5x_2 \times 2.5x_2\,dx_2}{EI}$$

$$\Delta_{Ch} = \frac{8333.3}{EI} + \frac{5333.3}{EI} = \frac{13666.7\ \text{k-ft}^3}{EI}$$

$$V_b = \int_0^L \frac{mM\,dx}{EI} = \frac{13666.7}{EI} = \frac{13666.7}{29\times10^3} = 1.3509\ \text{in-k}$$

$$V_h = \sum \frac{nNL}{AE}$$

$$= \frac{1.25 \times 25 \times 120}{80(29\times10^3)} + \frac{1\times0\times96}{18\times29\times10^3}$$

$$= 0.001616\ \text{in-k}$$

$$V_s = \int_0^L K\left(\frac{VV}{GA}\right)dx$$

$$= \int_0^{10} \frac{1.2\times1(40-4x_1)\,dx_1}{GA} + \int_0^8 \frac{1.2(-1.25)(-25)\,dx_2}{GA}$$

$$= \frac{1540\times12}{12\times10^3\times80} = 0.00625$$

$$\therefore 1K.\ \Delta_{Ch} = 1.357 + 0.001616 + 0.00625$$

$$\therefore \Delta_{Ch} = 1.364\ \text{in}$$

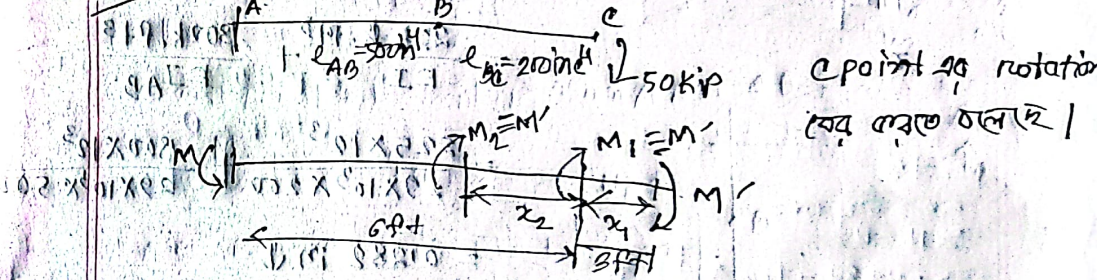
Castigliano's Theorem for beams & frames

Point এবং direction বরাবর deformation বের করার জন্য, $\Delta = \int_0^L \frac{\partial U}{\partial P}$

$$\theta = \int_0^L M\left(\frac{\partial M}{\partial M'}\right)\frac{dx}{EI}$$

যে point এ rotation বের করতে চাই ⇒ point এ M moment দিতে

B:



C point এ rotation বের করতে চলেছি।

$$\frac{\partial M_1}{\partial M'} = \frac{\partial M_2}{\partial M'} = -1 \quad \text{(differentiation করে)}$$

$M' = 50\text{k-ft}$ $\quad M_1 = M_2 = 50\text{k-ft}$

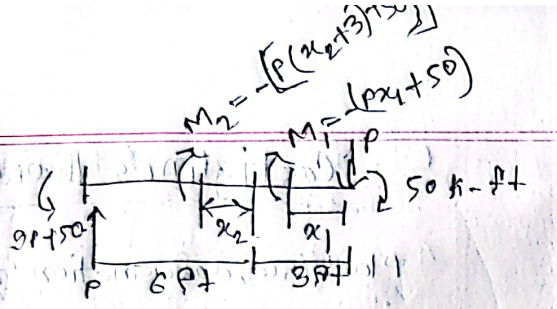
$$\theta_C = \int_0^L M\left(\frac{\partial M}{\partial M'}\right)\frac{dx}{EI} = \int_0^{3ft} \frac{-50(-1)\,dx}{EI_{BC}} + \int_0^{6ft} \frac{-50(-1)\,dx}{EI_{AB}}$$

$$= \frac{150\ \text{k-ft}^2}{EI_{BC}} + \frac{300\ \text{k-ft}^2}{EI_{AB}}$$

$$= \frac{150\times12^2\ \text{k-in}^2}{29\times10^3\times200} + \frac{300\times12^2}{29\times10^3\text{k/in}^2\times500\text{in}^4}$$

$$= 0.01070$$

C point a deflection,



$$\frac{\partial M_1}{\partial P} = -x_1$$

$$\frac{\partial M_2}{\partial P} = -(x_2+3)$$

$P = 0$, $M_1 = M_2 = -50$ k.ft

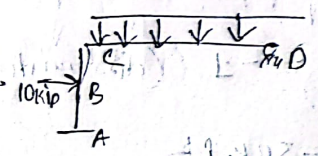
$$\Delta_C = \int_0^L M\left(\frac{\partial M}{\partial P}\right)\frac{dx}{EI} = \int_0^3 \frac{(-50)\times(-x)\,dx}{EI_{BC}} + \int_0^{6ft} \frac{-50\times(-x_2-3)\,dx}{EI_{AB}}$$

$$= \frac{225\ k\text{-}ft^3}{EI} + \frac{1800\ k.ft^3}{EI_{AB}}$$

$$= \frac{225\times12^3}{29\times10^3\times200} + \frac{1800\times12^3}{29\times10^3\times500}$$

$$= 0.1282\ in \downarrow$$

Assignment

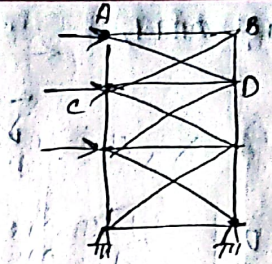


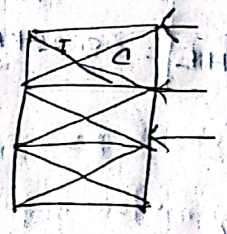
24.09.24

Method-1 (Assumption)

load বসিয়ে দেখে আমরা BC Tension এবং AD compression ধরে।

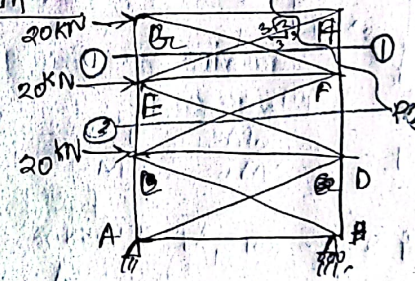
compression = 0





Determine the forces of different members of this truss.

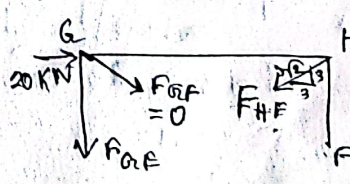
Math



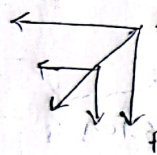
Method:
following method I:

I. $DF = CG = BH = GF = ED = CB = 0$

(1-1) section নিলে,



P-P বরাবর কাটলে,



$\Sigma F_x = 0$

$\Rightarrow 20 - F_{HE} \times \frac{3}{3\sqrt{2}} = 0$

$\therefore F_{HE} = 28.28 KN(T)$

A তে H, $\Sigma F_y = 0$

$\Rightarrow F_{HF} + 28.28 \times \frac{3}{3\sqrt{2}} = 0$

$\therefore F_{HF} = -20 KN$

At point G,

$\Sigma V = 0$

$\therefore F_{GE} = 0$

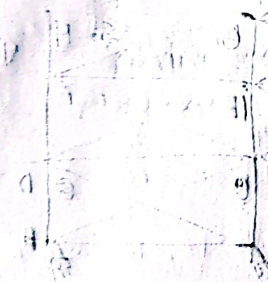
panel 2

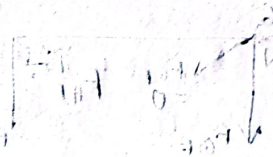
(2-2) কাটলে,

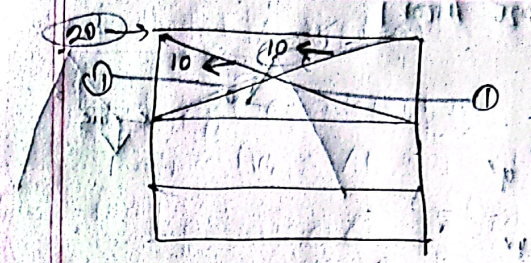
$\Sigma H = 0$

$\Rightarrow 20 + 20 - F_{FC} \times \frac{1}{\sqrt{2}} = 0$

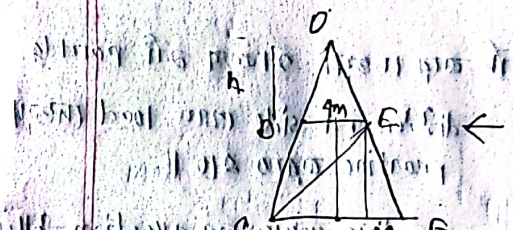
$\Rightarrow F_{FC} = 40\sqrt{2} KN(T)$







Ans: method 2 তারে 20 & opposite এ force দিলে



ΔODE & ΔOCF এ,

$\frac{h}{4} = \frac{h+3}{5}$

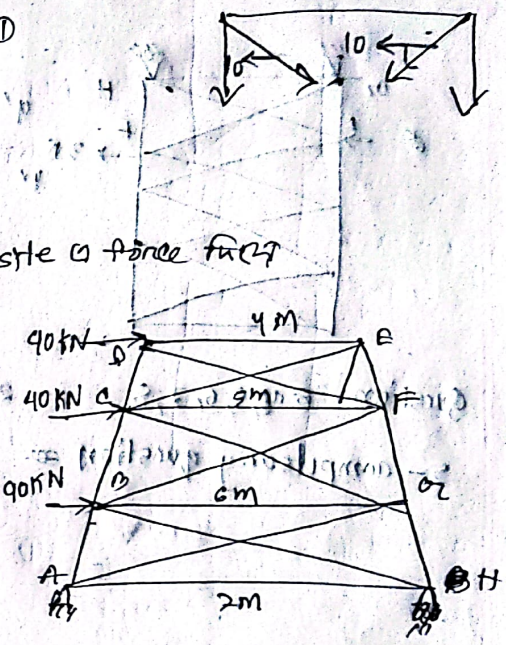
$\therefore h = 12m$

$CE = CM^2 + EM^2$

$= 3^2 + 4.5^2 = 5.41$ $(CM = 2.5 + \frac{4}{2} = 4.5)$

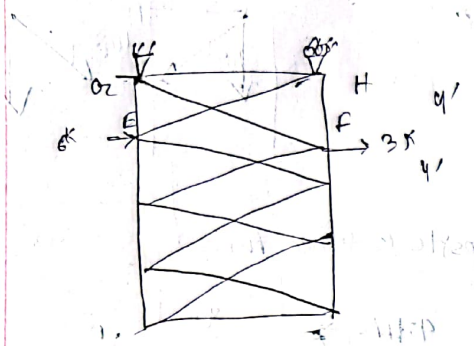
$EF^2 = 3^2 + 0.5^2 = 3.04$

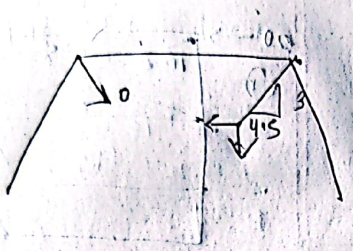
$MF = 0.5$



DE বরাবর প্রান্তে বাড়ানো হচ্ছে যাতে O point এ moment ধরলে হরে কষতে পারি।

bar এর
সেটির মধ্যে বলবে কোন্টি বেশি।





Question – ৪ টা 4, 5, 6, 7, 8 ... — 2 টা করে দেওয়া থাকবে 2 টি part-এ

5- compulsory question

> different side থেকে load দেওয়া practice করতে হবে।

previous year-এর question follow করতে হবে।