Gokaraju Rangaraju Institute of Engineering and Technology
(Autonomous)
Bachupally, Kukatpally, Hyderabad – 500 090. (040) 6686 4440

GR 22 Regulations **M.Tech I Year I semester**

MATRIX METHODS IN STRUCTURAL ANALYSIS (GR22D5001)

UNIT - I

Introduction to matrix methods of analysis - Static indeterminacy and kinematic indeterminacy - degree of freedom - coordinate system - structure idealization stiffness and flexibility matrices - suitability element stiffness equations - elements flexibility equations - mixed force - displacement equations - for truss element, beam element and tensional element. Transformation of coordinates - element stiffness matrix - and load vector - local and global coordinates

UNIT - II

Stiffness Matrix Assembly of Structures and its Applications to Simple Problems: Direct Stiffness method, Matrix in Global Coordinates, Boundary Conditions, Solution of Stiffness Matrix Equations.

UNIT - III

Analysis of Beams, Plane Trusses, Plane Rigid Jointed frames using flexibility method

UNIT - IV

Analysis of plane truss - continuous beam - plane frame and grids by stiffness matrix methods.

UNIT - V

Special analysis procedures - Static condensation and sub structuring - initial and thermal stresses. Shear walls- Necessity - structural behaviour of large frames with and without shear walls - approximate methods of analysis of shear walls.

TEXT BOOKS:

1 . William Weaver J.R and James M.Geve, Matrix Analysis of Frames structures, CBS publications, Delhi 2004.
2. Ashok.K.Jain, Advanced Structural Analysis, New Channel Brothers, 1996.
3. C.S.Reddy, Structural Analysis, 3rd edition, 2010.

REFERENCES:

1. Kanchi, Matrix Structural Analysis, 1995.
2. J.Meek, Matrix Methods of Structural Analysis, 3rd edition, 1980.
3. Ghali and Neyveli, Structural Analysis, 3rd edition , December, 1990.

DEPARTMENT OF CIVIL ENGINEERING (STRUCTURAL ENGINEERING)

I M. Tech (GR-22) - I Semester **AY: 2022-23** **wef 26-10-2022**

Day/Hour	09:00-10:00	10:00-11:00	11:00-12:00	12:00-01:00	01:00-02:00	02:00-03:00	03:00-04:00	Room No.	
MONDAY			MMSA	LUNCH				Theory/ Tutorial	4203
TUESDAY						MMSA		Lab	4205 (SD Lab) /4108&4110(ACT Lab)
WEDNESDAY	MMSA							**M.Tech Co-ordinator**	
THURSDAY	MMSA								
FRIDAY								**Dr. V Srinivasa Reddy (1117)**	
SATURDAY									

Sub. Code	Subjects	Faculty Name	Almanac	
GR22D5001	Matrix methods in structural analysis	Dr. G V V Satyanarayana (842)	1st Spell of Instruction	26-10-2022 to 22-12-2022
GR22D5002	Advanced Solid Mechanics	Dr.V.Srinivas Reddy (Dr.VSR-1117)	1st Mid-term Examinations	23-12-2022 to 29-12-2022
GR22D5004	Advanced Concrete Technology	Dr.V.Mallikarjun Reddy (Dr.VMR-807)	2nd Spell of Instruction	30-12-2022 to 28-02-2023
GR22D5006	Analytical and Numerical methods for Structural Engineering	Mr.V.Naresh Kumar Varma (1359)	2nd Mid-term Examinations	01-03-2023 to 07-03-2023
GR22D5009	Structural Design Lab	Mr.C.Vanadeep (Mr.CV-1645)/Mr.C.Vivek Kumar(1500)/Mrs.P.Sirisha(Mrs.PS-1524)	Preparation	08-03-2023 to 14-03-2023
GR22D5010	Advanced Concrete Technology Lab	Mr.Kusuma Veera Babu (Mr.KVB-1650)/Mr.V.Ramesh(1646)/Mr.PVVSSR Krishna (Mr.PVVSSRK-1562)	End Semester Examinations/ (Theory/ Practicals) Regular/Supplementary	15-03-2023 to 01-04-2023
GR22D5011	Research Methodology and IPR	Dr. Mohammed Hussain(Dr.Mohd.H-861)		
GR22D5153	English for Research Paper Writing	Dr.R.Lakshmi Kanthi (Dr.LRK-718)		

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Name of the Program: M.Tech (Structural Engineering) **Year: I**

Course/Subject: MATRIX METHODS IN STRUCTURAL ANALYSIS
Course Code: GR22D5001

Program Educational Objective's

PEO 1:

Graduates of the program will equip with professional expertise on the theories, process, methods and techniques for building high-quality structures in a cost-effective manner.

PEO 2:

Graduates of the program will be able to design structural components using contempory software and professional tools with quality practices of international standards.

PEO 3:

Graduates of the program will be effective as both an individual contributor and a member of a development team with professional, ethical and social responsibilities.

PEO 4:

Graduates of the program will grow professionally through continuing education, training, research, and adapting to the rapidly changing technological trends globally in structural engineering.

Name of the Program: M.Tech (Structural Engineering) **Year: I**

Course/Subject: MATRIX METHODS IN STRUCTURAL ANALYSIS
Course Code: GR22D5001

Programme Outcomes

Graduates of the Civil Engineering programme will be able to

PO 1: An ability to independently carry out research / investigation and development to solve practical problems

PO 2: An ability to write and present a substantial technical report / document.

PO 3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor's.

PO 4: Possesses critical thinking skills and solves core, complex and multidisciplinary structural engineering problems.

PO 5: Assess the impact of professional engineering solutions in an environmental context along with societal, health, safety, legal, ethical and cultural issues and the need for sustainable development.

PO 6: Recognize the need for life-long learning to improve knowledge and competence.

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COURSE OBJECTIVES

Academic Year : 2022-23

Semester : I

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana Dept.: Civil Engineering

Designation: PROFESSOR

On completion of this Subject/Course the student shall be able to:

S.No	Objectives
1	To learn how to idealize statically and kinematically determinate and indeterminate Structures and their ill effects.
2.	To learn the difference between local and global co-ordinates systems and its role in preparation of stiffness matrix.
3	To understand the effective usage of flexibility matrix method in statically indeterminate structures.
4	To understand the effective usage of stiffness matrix method in kinematically indeterminate structures.
5	To understand about static condensation and sub structuring. To learn about shear walls and their role in multi storied structures.

Signature of HOD Signature of faculty

Date: Date:

Note: Please refer to Bloom's Taxonomy, to know the illustrative verbs that can be used to state the objectives.

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COURSE OUTCOMES

Academic **Y**ear : 2022-23

Semester : I

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana Dept.: Civil Engineering

Designation: PROFESSOR.

The expected outcomes of the Course/Subject are:

S.No	**Outcomes**
1	Evaluate the static and kinematic indeterminacy and generate stiffness and flexibility matrices.
2	Analyse the skeleton structures using stiffness method under different coordinate system.
3	Use flexibility matrix method to analyse different structures.
4	Use stiffness matrix method to analyse different structures.
5	Analyse various types of structural members using special analysis procedures and shear walls in multi storied constructions

Signature of HOD Signature of faculty

Date: Date:

Note: Please refer to Bloom's Taxonomy, to know the illustrative verbs that can be used to state the outcomes.

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M.Tech (Structural Engineering) I Year I Semester		
Academic Year 2022-23		
S.No	**Student Name**	**Roll No**
1	ADDAGATLA MAHESHKUMAR	22241D2001
2	AHMED ABDUL AZEEM	22241D2002
3	BAIRAPAKA BHARAT	22241D2003
4	BARLAPUDI ACHSAHKEERTHANA	22241D2004
5	CHAKALI SOWMYA	22241D2005
6	CHAPPIDI NARESH	22241D2006
7	DANTHALA HARIDEEPKUMAR	22241D2007
8	DEVIREDDY ANISH	22241D2008
9	DHARAVATHNAGENDAR	22241D2009
10	GANGAPURAM SUSHANTH REDDY	22241D2010
11	JEREPOTHULARAVALIKA	22241D2011
12	KADABOHINASAIPAVAN	22241D2012
13	KASUMURU BHARAT KUMAR	22241D2013
14	MACHARLA SRINIVAS	22241D2014
15	MALLI SREENIVASULU	22241D2015
16	SHAIK ABDUL MUQEED	22241D2016
17	SHAIK ZABI ULLAH	22241D2017
18	SONWANE SAHILSHIVAJIRAO	22241D2018
19	LINGAM LAKSHMI NARAYANA	22241D2019

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GUIDELINES TO STUDY THE COURSE / SUBJECT

Academic **Y**ear : 2022-23

Semester : I

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana Dept.: Civil Engineering

Designation: PROFESSOR

Guidelines to study the Course/ Subject: Structural Analysis

Course Design and Delivery System (CDD):

- The Course syllabus is written into number of learning objectives and outcomes.
- These learning objectives and outcomes will be achieved through lectures, assessments, assignments, experiments in the laboratory, projects, seminars, presentations, etc.
- Every student will be given an assessment plan, criteria for assessment, scheme of evaluation and grading method.
- The Learning Process will be carried out through assessments of Knowledge, Skills and Attitude by various methods and the students will be given guidance to refer to the text books, reference books, journals, etc.

The faculty be able to –

- Understand the principles of Learning
- Understand the psychology of students
- Develop instructional objectives for a given topic
- Prepare course, unit and lesson plans
- Understand different methods of teaching and learning
- Use appropriate teaching and learning aids
- Plan and deliver lectures effectively
- Provide feedback to students using various methods of Assessments and tools of Evaluation
- Act as a guide, advisor, counselor, facilitator, motivator and not just as a teacher alone

Signature of HOD Signature of faculty

Date: Date:

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COURSE SCHEDULE

Academic **Y**ear : 2022-23

Semester : I

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana Dept.: Civil Engineering

Designation: PROFESSOR

The Schedule for the whole Course / Subject is:

S. No.	Description	Duration (Date)		Total No. Of Periods
		From	To	
1.	Unit – I Introduction to Matrix methods of Analysis	26-10-22	15-11-22	12
2.	Unit- II Assembly of stiffness matrices	16-11-22	29-11-22	08
3.	Unit-III Introduction about Flexibility matrix method(Force Method) And application to indeterminate beams	30-11-22	19-12-22	11
4.	Unit-IV Introduction about stiffness matrix method(Displacement Method) And application to indeterminate beams	20-12-22	12-01-23	11
5.	Unit-V Special analysis procedures Introduction about special analysis procedures, static condensation and sub structuring in structures	17-01-23	13-02-23	15

Total No. of Instructional periods available for the course: 57 Hours / Periods

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SCHEDULE OF INSTRUCTIONS
COURSE PLAN

Academic Year : 2022-23

Semester : I UNIT NO.: I TO V

Name of the Program: M.Tech Year: I

Course/Subject: **Matrix Methods in Structural Analysis** Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana Dept.: Civil Engineering

Designation: PROFESSOR

Unit No.	Lesson No.	Date	No. of Periods	Topics / Sub-Topics	Objectives & Outcomes Nos.	References (Text Book, Journal…) Page Nos.:____to ____
1.	1.	26-10-2022	1	**Unit – I Introduction to Matrix methods of Analysis** - Introduction about Matrix Methods in Structural analysis	1 & 1	Structural Analysis by S.S.Bhavikati , Advanced Structural Analysis by Asohk.K.Jainn and Structural analysis by C.S.Reddy
	2.	27-10-2022	1	Determination of Static indeterminacy of structures	1 & 1	
	3.	31-10-2022	1	Determination of Kinematic indeterminacy of structures	1 & 1	
	4.	01-11-2022	1	Determination of DOF of given structures	1 & 1	
	5.	02-11-2022	1	Explain the co-ordinate system	1 & 1	
	6.	03-11-2022	1	Structure idealization	1 & 1	
	7.	07-11-2022	1	Differentiate & relation between Stiffness & Flexibility Matrix methods	1 & 1	
	8.	08-11-2022	1	Explain general equations for Flexibility & stiffness matrix methods	1 & 1	
	9	09-11-2022	1	Derivation of displacement equations for truss element	1 & 1	

	10	10-11-2022	1	Discuss on element stiffness matrix, local and Global coordinates	1 & 1	
	11	14-11-2022	1	Discuss old question papers	1 & 1	
	12	15-11-2022	1	Solved old question papers	1 & 1	

Unit No.	Lesson No.	Date	No. of Periods	Topics / Sub-Topics	Objectives & Outcomes Nos.	References (Text Book, Journal…) Page Nos.:____to ____
2.	1.	16-11-2022	1	**Unit- II** Assembly of stiffness matrices	2 & 2	Structural Analysis by S.S.Bhavikati , Advanced Structural Analysis by Asohk.K.Jainn and Structural analysis by C.S.Reddy
	2.	17-11-2022	1	Local matrix and global matrix for load	2 & 2	
	3.	21-11-2022	1	Displacement vectors (Stiffness matrix in global coordinates)	2 & 2	
	4.	22-11-2022	1	Explain direct stiffness method	2 & 2	
	5.	23-11-2022	1	General procedure of assembly of stiffness matrices	2 & 2	
	6.	24-11-2022	1	Discuss on boundary conditions	2 & 2	
	7.	28-11-2022	1	Discuss old question papers	2 & 2	
	8.	29-11-2022	1	Solved old question papers	2 & 2	

Unit No.	Lesson No.	Date	No. of Periods	Topics / Sub-Topics	Objectives & Outcomes Nos.	References (Text Book, Journal…) Page Nos.: ____to ____
3.	1.	30-11-2022	1	**Unit-III** Introduction about Flexibility matrix method(Force Method)	3 & 3	Structural Analysis by S.S.Bhavikati , Advanced Structural Analysis by Asohk.K.Jainn and Structural analysis by C.S.Reddy
	2.	01-12-2022	1	Flexibility matrix approach to statically indeterminate beams	3 & 3	
	3.	05-12-2022	1	Methodology to calculate redundant forces of beam at joints using Flexibility matrix method	3 & 3	
	4.	06-12-2022	1	Methodology to calculate redundant forces of beam using flexibility matrix method	3 & 3	
	5.	07-12-2022	1	Analyze continuous beams by using flexibility matrix methods carrying with different loads	3 & 3	
	6.	08-12-2022	1	Analyze continuous beams by using flexibility matrix methods carrying with different loads and sinking supports	3 & 3	
	7.	12-12-2022	1	Analyze plane truss by using flexibility matrix methods carrying with different loads	3 & 3	
	8.	13-12-2022	1	Analyze plane frame by using stiffness matrix methods carrying with different loads	3 & 3	
	9.	14-12-2022	1	Discuss old question papers	3 & 3	
	10.	15-12-2022	1	Solved old question papers	3 & 3	
	11.	19-12-2022	1	Solved old question papers	3 & 3	

Unit No.	Lesson No.	Date	No. of Periods	Topics / Sub-Topics	Objectives & Outcomes Nos.	References (Text Book, Journal…) Page Nos.:____to ____
4.	1.	20-12-2022	1	**Unit-IV** Introduction about stiffness matrix method (Displacement Method)	4 & 4	Structural Analysis by S.S.Bhavikati , Advanced Structural Analysis by Asohk.K.Jainn and Structural analysis by C.S.Reddy
	2.	21-12-2022	1	Flexibility matrix approach to kinematically indeterminate beams	4 & 4	
	3.	22-12-2022	1	Methodology to calculate support moments of beam at joints using stiffness matrix method	4 & 4	
	4.	02-01-2023	1	Methodology to calculate redundant forces of beam using stiffness matrix method	4 & 4	
	5.	03-01-2023	1	Analyze continuous beams by using stiffness matrix methods carrying with different loads	4 & 4	
	6.	04-01-2023	1	Analyze continuous beams by using stiffness matrix methods carrying with different loads and sinking supports	4 & 4	
	7.	05-01-2023	1	Analyze plane truss by using stiffness matrix methods carrying with different loads	4 & 4	
	8.	09-01-2023	1	Analyze plane frame by using stiffness matrix methods carrying with different loads	4 & 4	
	9.	10-01-2023	1	Discuss old question papers	4 & 4	
	10.	11-01-2023	1	Solved old question papers	4 & 4	
	11.	12-01-2023	1	Solved old question papers	4 & 4	

Unit No.	Lesson No.	Date	No. of Periods	Topics / Sub-Topics	Objectives & Outcomes Nos.	References (Text Book, Journal…) Page Nos.:____to ____
5.	1.	17-01-2023	1	**Unit-V** Introduction about Special analysis procedures	5 & 5	Structural Analysis by S.S.Bhavikati , Advanced Structural Analysis by Asohk.K.Jainn and Structural analysis by C.S.Reddy
	2.	18-01-2023	1	What is static condensation?	5 & 5	
	3.	19-01-2023	1	Explain its importance with suitable example	5 & 5	
	4.	23-01-2023	1	What is sub-structuring?	5 & 5	
	5.	24-01-2023	1	Its importance in structural analysis	5 & 5	
	6	30-01-2023	1	What is effect due to initial and thermal stress in structures?	5 & 5	
	7	31-01-2023	1	**Special analysis procedures** Introduction about shear walls	5 & 5	
	8	01-02-2023	1	Necessity of shear walls in structures and their shapes	5 & 5	
	9	01-02-2023	1	Importance of shear walls in structures and their location in structures	5 & 5	
	10.	02-02-2023	1	Structural behaviour of large frames with shear wall	5 & 5	
	11.	06-02-2023	1	Structural behaviour of large frames without shear wall	5 & 5	
	12.	07-02-2023	1	Approximate methods of analysis of shear walls	5 & 5	
	13.	08-02-2023	1	Approximate methods of analysis of shear walls	5 & 5	
	14.	09-02-2023	1	Approximate methods of analysis of shear walls	5 & 5	
	15.	13-02-2023	1	Approximate methods of analysis of shear walls	5 & 5	

Signature of HOD

Signature of faculty

Date:

Date:

Note: 1. ENSURE THAT ALL TOPICS SPECIFIED IN THE COURSE ARE MENTIONED.
2. ADDITIONAL TOPICS COVERED, IF ANY, MAY ALSO BE SPECIFIED IN BOLD
3. MENTION THE CORRESPONDING COURSE OBJECTIVE AND OUT COME NUMBERS AGAINST EACH TOPIC.

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EVALUATION STRATEGY

Academic **Y**ear : 2022-23

Semester : I

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: **Matrix Methods in Structural analysis** Subject Code(**GR22D5001**

Name of the Faculty: GVV Satyanarayana Dept.: Civil Engineering

Designation : PROFESSOR

1. TARGET:

A) Percentage for pass: 98%

b) Percentage of class: 1st class with distinction - 60%
1st class - 40%

2. COURSE PLAN & CONTENT DELIVERY

(Please write how you intend to cover the contents: i.e., coverage of Units/Lessons by lectures, design, exercises, solving numerical problems, demonstration of models, model preparation, experiments in the Lab., or by assignments, etc.)

3. METHOD OF EVALUATION

3.1 ☐ Continuous Assessment Examinations (CAE-I, CAE-II)

3.2 ☐ Assignments/Seminars

3.3 ☐ Project Review/ Comprehensive viva-voce

3.4 ☐ Quiz

3.5 ☐ Semester/End Examination

3.6 ☐ Others

4. List out any new topic(s) or any innovation you would like to introduce in teaching the subjects in this Semester.

……………………………………………………………………………………………………..

Signature of HOD
Date:

Signature of faculty
Date:

GR22D5001 Matrix Methods in Structural Analysis	Course Outcomes				
Course Objectives	1	2	3	4	5
1	X				
2		X			
3			X		
4				X	
5					X

GR22D5001 Matrix Methods in Structural Analysis	Course Outcomes				
Assessment	1	2	3	4	5
1	X				
2		X			
3			X		
4				X	
5					X

GR22D5001 Matrix Methods in Structural Analysis	Course Objectives				
Assessment	1	2	3	4	5
1	X				
2		X			
3			X		
4				X	
5					X

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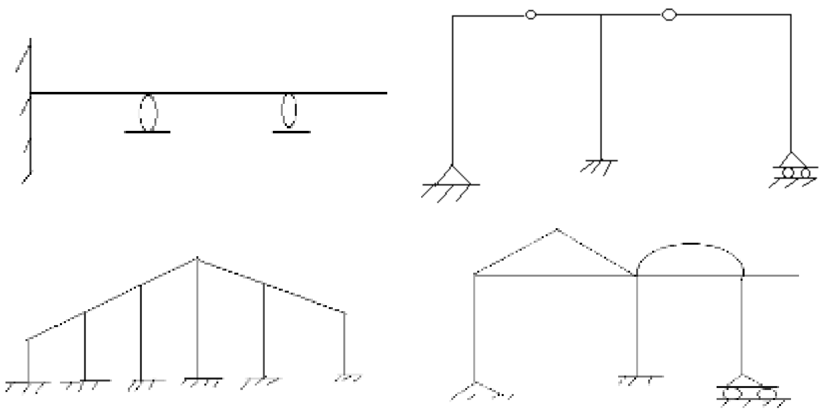
TUTORIAL SHEET - 1

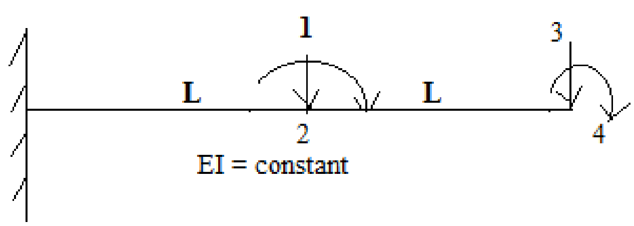
Academic Year : 2022-23 Date: 15-11-2022
Semester : I
Name of the Program: M.Tech (Structural Engineering) Year: I
Course/Subject: Matrix methods in Structural Analysis
Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

This Tutorial corresponds to Unit No. 1/ Lesson_**Introduction to Matrix methods of Analysis (GR22D5001)**

Q1. What is static and kinematic indeterminacies? Explain both indeterminacies with suitable examples.
Q2. Evaluate the static and kinematic indeterminacies of shown structures.



Q3. What is structural idealization and explain with neat figure.
Q4. Differentiate the flexibility matrix for the given co-ordinates.



Q4. Derive the relationship between stiffness and flexibility matrices.
Q5. Derive displacement equations for beam and truss elements.

Please write the Questions / Problems / Exercises which you would like to give to the students and also mention the Objectives/Outcomes to which these Questions / Problems / Exercises are related.

Objective Nos.: 1, 1

Outcome Nos.: 1, 1

Signature of HOD Signature of faculty

Date: Date:

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TUTORIAL SHEET - 2

Academic **Y**ear : 2022-23 Date: 29-11-2022
Semester : I
Name of the Program: M.Tech (Structural Engineering) Year: I
Course/Subject: **Matrix methods in Structural Analysis (GR22D5001)**
Name of the Faculty: Dr.GVV Satyanarayana Dept.: Civil Engineering
Designation : PROFESSOR

This Tutorial corresponds to Unit No. 2/ Lesson **Assembly of stiffness matrices**

Q1. Explain the procedure in assembling stiffness.
Q2. Write about transformation matrix and explain the terms local and global co-ordinates.
Q3. Explain direct stiffness method
Q4 Discuss on boundary conditions
Q5 Solutions of stiffness matrix equations
Q6. Write a computer algorithm to Analyse any structure with suitable example.

Please write the Questions / Problems / Exercises which you would like to give to the students and also mention the Objectives/Outcomes to which these Questions / Problems / Exercises are related.

Objective Nos.: 2
Outcome Nos.: 2,

Signature of HOD Signature of faculty

Date: Date:

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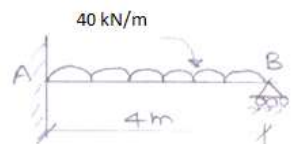
TUTORIAL SHEET - 3

Academic Year : 2022-23 Date: 19-12-2022
Semester : I
Name of the Program: M.Tech (Structural Engineering) Year: I
Course/Subject: **Matrix methods in Structural Analysis (GR22D5001)**
Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering
Designation : PROFESSOR

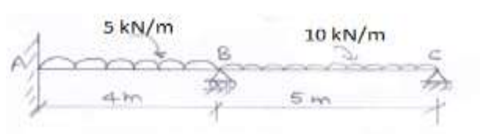
This Tutorial corresponds to Unit No. 3/ Lesson **Introduction about Flexibility matrix method(Force Method) And application to indeterminate beams**

Q1. Explain the stepwise procedure to analyze the statically indeterminate structures using Force (Flexibility) matrix and Displacement (Stiffness) Methods.
Q2. Analyse the propped cantilever beam given below using Force ethod.

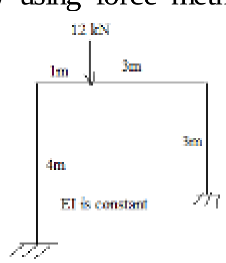


Q2. Determine the support moments and reactions of fixed beam using flexibility methods.

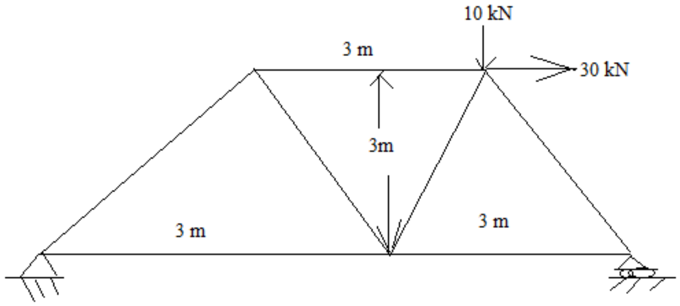
Q3. Analyze the continuous beam using flexibility matrix method as shown in figure.
Let $I_{ab} = 1.5\, I_{bc}$.



Q4. Analyse the portal frame as shown below using force method. Take EI as constant.



Q5. Analyse the truss as shown below using flexibility matrix method.



Please write the Questions / Problems / Exercises which you would like to give to the students and also mention the Objectives/Outcomes to which these Questions / Problems / Exercises are related.

Objective Nos.: 3

Outcome Nos.: 3

Signature of HOD

Signature of faculty

Date:

Date:

Gokaraju Rangaraju Institute of Engineering and Technology
(Autonomous)
Bachupally, Kukatpally, Hyderabad – 500 090. (040) 6686 4440

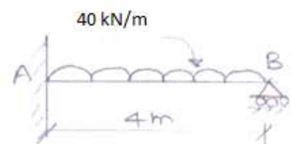
TUTORIAL SHEET - 4

Academic **Y**ear : 2022-23 Date: 12-01-2023
Semester : I
Name of the Program: M.Tech (Structural Engineering) Year: I
Course/Subject: **Matrix methods in Structural Analysis (GR22D5001)**
Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering
Designation : PROFESSOR

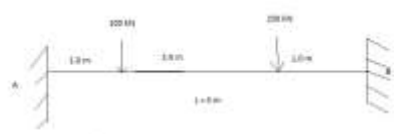
This Tutorial corresponds to Unit No. 4/ Lesson Introduction about stiffness matrix method(Displacement Method)

Q1. Explain the stepwise procedure to analyze the statically indeterminate structures using displacement or Stiffness matrix and Displacement (Stiffness) Methods.

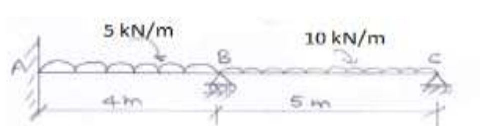
Q2. Analyse the propped cantilever beam given below using Displacement method.



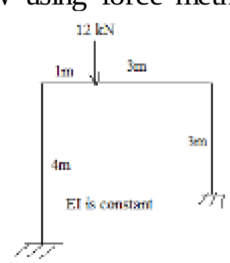
Q2. Determine the support moments and reactions of fixed beam using stiffness matrix methods.



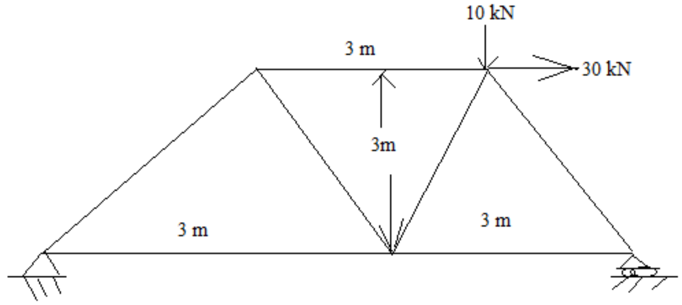
Q3. Analyze the continuous beam using flexibility stiffness method as shown in figure. Let I $_{ab}$ = 1.5 I $_{bc}$.



Q4. Analyse the portal frame as shown below using force method. Take EI as constant.



Q5. Analyse the truss as shown below using stiffness matrix method.



Please write the Questions / Problems / Exercises which you would like to give to the students and also mention the Objectives/Outcomes to which these Questions / Problems / Exercises are related.
Objective Nos.: 4
Outcome Nos.: 4

Signature of HOD

Signature of faculty

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TUTORIAL SHEET - 5

Academic **Y**ear : 2022-23 Date: 13-02-2023

Semester : I
Name of the Program: M.Tech (Structural Engineering) Year: I
Course/Subject: **Matrix methods in Structural Analysis (GR22D5001)**
Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation : PROFESSOR
This Tutorial corresponds to Unit No. 5/ Lesson **Special analysis procedures**
Q1. Describe the Importance about special analysis procedures using in structural analysis.
Q2. What is static condensation and explain its importance
Q3. Explain static condensation with suitable example
Q4. What is sub-structuring and write Importance of sub structuring in structural analysis
Q5. What is effect due to initial and thermal stress in structures?
Q6.What are the uses of shear walls and their location in large structures?
Q7. What are the varieties or shapes of shear walls?
Q8. Describe the behaviour of shear walls in large frames with and without shear walls.
Q9. Explain the different method in analysis of shear walls.

Please write the Questions / Problems / Exercises which you would like to give to the students and also mention the Objectives/Outcomes to which these Questions / Problems / Exercises are related.
Objective Nos.: 5
Outcome Nos.: 5

Signature of HOD Signature of faculty

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Bachupally, Kukatpally, Hyderabad – 500 090, (040) 6686 4440

ASSIGNMENT SHEET – 1

Academic **Y**ear : 2022-23 Date: 15-11-2022

Semester : I

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: **Matrix Methods in Structural Analysis (GR22D5001)**

Name of the Faculty: Dr.G.V.V. Satyanarayana Dept. Civil Engineering

Designation : PROFESSOR

This Assignment corresponds to Unit No.1

Q1. What is Static and kinematic indeterminacy of structures? Derive static and kinematic indeterminacy for given structures.

Q2. Differentiate between static determinate and indeterminate structures.
Q3. What is transformation matrix and its use?
Q4. Deduce the relationship between flexibility and stiffness matrices.
Q5. Derive displacement equations for truss and beam elements.
Q6. Define the terms dof and redundants at supports.
Q7. Differentiate local and global co-ordinates and how they are interconnected

Please write the Questions / Problems / Exercises which you would like to give to the students and also mention the Objectives/Outcomes to which these Questions / Problems / Exercises are related.

Objective Nos.: ……………………………………………………………………………………………….

Outcome Nos.: ……………………………………………………………………………………………….

Signature of HOD Signature of faculty

Date: Date:

Gokaraju Rangaraju Institute of Engineering and Technology
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Bachupally, Kukatpally, Hyderabad – 500 090, (040) 6686 4440

ASSIGNMENT SHEET – 2

Academic **Y**ear : 2022-232 Date: 29-11-2022

Semester : I

Name of the Program: M.Tech (Structural Engineering) Civil Year: I

Course/Subject: **Matrix Methods in Structural Analysis (GR22D5001)**

Name of the Faculty: Dr.G.V.V. Satyanarayana Dept. Civil Engineering

Designation : PROFESSOR

This Assignment corresponds to Unit No-2.

Q2. Explain the procedure to deduce a stiffness matrix using direct stiffness method.
Q3. Derive stiffness matrix for any structure with assigned co-ordinates.
Q4. What is Rank of matrix and evaluate the rank of matrix for the given matrix?
Q5. What is semi band width and explain its importance in structural analysis?
Q6. Write a computer alogarithm to deduce final forces in a truss member using stiffness matrix approach.
Q7. How to assemble the stiffness matrices?
Q8. Discuss on various boundary conditions used FEM.

Please write the Questions / Problems / Exercises which you would like to give to the students and also mention the Objectives/Outcomes to which these Questions / Problems / Exercises are related.

Objective Nos.: 2……………………………………………………………………………………….

Outcome Nos.: 2……………………………………………………………………………………….

Signature of HOD Signature of faculty

Date: Date:

Gokaraju Rangaraju Institute of Engineering and Technology
(Autonomous)
Bachupally, Kukatpally, Hyderabad – 500 090, (040) 6686 4440

ASSIGNMENT SHEET – 3

Academic Year : 2022-23 Date: 13-12-2022

Semester : I

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: **Matrix Methods in Structural Analysis (GR22D5001)**

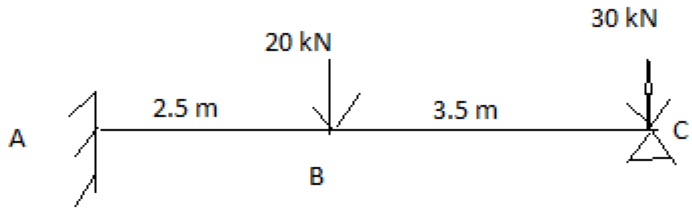
Name of the Faculty: Dr.G.V.V. Satyanarayana Dept. Civil Engineering

Designation : PROFESSOR

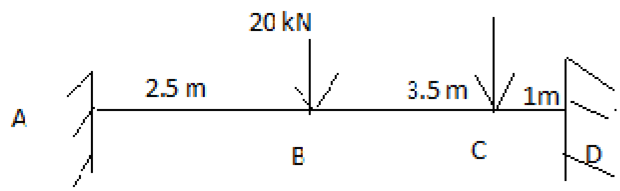
This Assignment corresponds to Unit No.3

Q1. Develop a flexibility matrix for the structure with assigned co-ordinates.

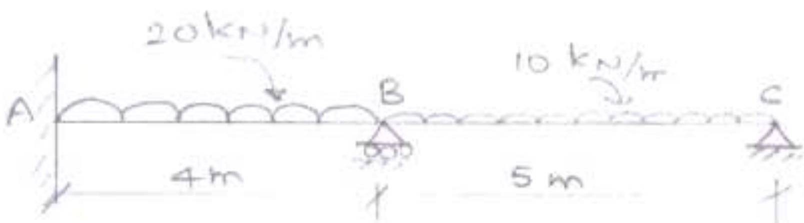
Q2. Analyse the propped cantilever beam using flexibility matrix method as shown below.



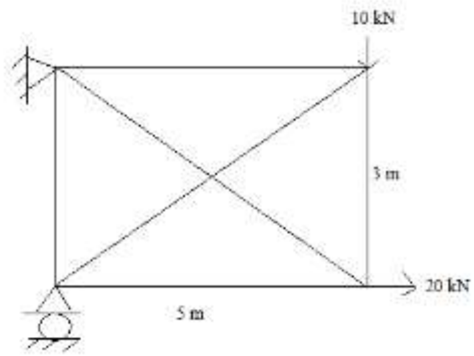
Q3. Determine the support moments and also draw SFD and BMD's of a fixed beam as shown in the figure below using force method.



Q3. Analyze the continuous beam as shown in figure below using flexibility method if the support C sinking 10 mm. Take EI = 18000 kn-m^2.



Q4. Explain the stepwise procedure to analyze a portal frame in flexibilty matrix method.
Q5. Analyse the truss as shown below using force method.



Please write the Questions / Problems / Exercises which you would like to give to the students and also mention the Objectives/Outcomes to which these Questions / Problems / Exercises are related.

Objective Nos.: 3……………………………………………………………………………………….

Outcome Nos.: 3………………………………………………………………………………………….

Signature of HOD

Date:

Signature of faculty

Date:

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(Autonomous)
Bachupally, Kukatpally, Hyderabad – 500 090, (040) 6686 4440

ASSIGNMENT SHEET – 4

Academic Year : 2022-23 Date: 12-01-2023

Semester : I

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis (GR22D5001)

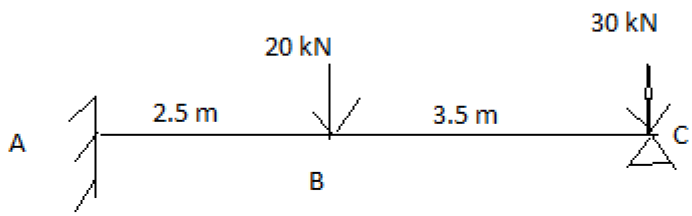
Name of the Faculty: Dr.G.V.V. Satyanarayana Dept. Civil Engineering

Designation : PROFESSOR

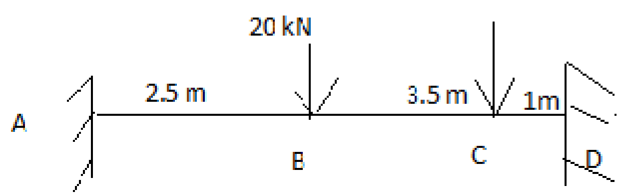
This Assignment corresponds to Unit No-4.

Q1. Develop a stiffness matrix for the structure with given dof's.

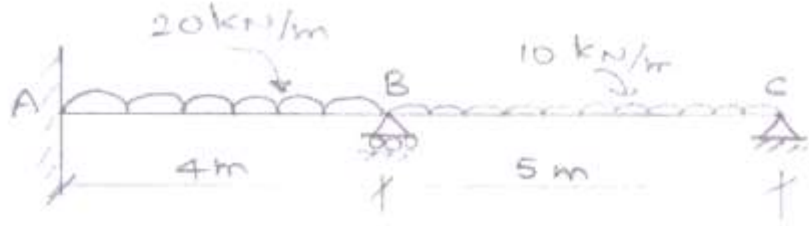
Q2. Analyse the propped cantilever beam using stiffness matrix method as shown below.



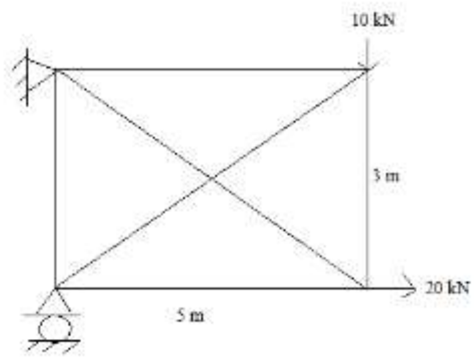
Q3. Determine the support moments and also draw SFD and BMD's of a fixed beam as shown in the figure below using displacement method.



Q3. Analyze the continuous beam as shown in figure below using stiffness matrix method if the support C sinking 10 mm. Take EI = 18000 kn-m^2.



Q4. Explain the stepwise procedure to analyze a portal frame in stiffness matrix method.
Q5. Analyse the truss as shown below using force method.



Please write the Questions / Problems / Exercises which you would like to give to the students and also mention the Objectives/Outcomes to which these Questions / Problems / Exercises are related.

Objective Nos.: 4……………………………………………………………………………………………

Outcome Nos.: 4……………………………………………………………………………………………

Signature of HOD

Date:

Signature of faculty

Date:

Gokaraju Rangaraju Institute of Engineering and Technology
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Bachupally, Kukatpally, Hyderabad – 500 090, (040) 6686 4440

ASSIGNMENT SHEET – 5

Academic **Y**ear : 2022-23 Date: 13-02-2023

Semester : I

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis (GR22D5001)

Name of the Faculty: Dr.G.V.V. Satyanarayana Dept. Civil Engineering

Designation : PROFESSOR

This Assignment corresponds to Unit No-5.

Q1. Explain the Importance about special analysis procedures.
Q2. What is static condensation and explain its importance?
Q3. Explain static condensation with suitable example.
Q4. What is sub-structuring and explain the Importance of sub structuring in structural analysis?
Q5. What is effect due to initial and thermal stress in structures?
Q6. Discuss in analysis of special structures.
Q7. Explain the term static condensation and describe with suitable example.
Q8. What is shear wall and list various types of shear walls.
Q9. Explain the role of shear walls in large structures and also explain with their locations.
Q10. Describe the behaviour of shear wall in large frames with and without shear walls.
Q11. Explain the different analysis methods of shear walls.

Please write the Questions / Problems / Exercises which you would like to give to the students and also mention the Objectives/Outcomes to which these Questions / Problems / Exercises are related.

Objective Nos.: 5 ……………………………………………………………………………………….

Outcome Nos.: 5 ……………………………………………………………………………………….

Signature of HOD Signature of faculty

Date: Date:

RUBRIC SHEET

Academic **Y**ear : 2022-23
Semester : I
Name of the Program: M.Tech Structural Engineering Year: I
Course/Subject: **Matrix Methods in Structural Analysis** Course Code: **GR22D5001**
Name of the Faculty: Dr.G V V Satyanarayana Dept.: Civil Engineering
Designation: Professor
Objective: To learn basics and concepts of Structural analysis.
Student Outcome: Behavioural studies or analyze the structural elements under loading and study different parameters such as induced forces, bending moments, shear forces, stresses, strains, deflection etc.,

			Beginning	**Developing**	**Reflecting Development**	**Accomplished**	**Exemplary**	**Score**
S. No	**Name of the Student**	**Performance Criteria**	**1**	**2**	**3**	**4**	**5**	
1	22241D 2004	Analysis of structural elements	Low level of knowledge on calculation of support reactions	Able to discuss the principles of energy theorems	Ability to explain the application of energy theorems	Full knowledge on application of energy theorems	Analyzing and implement in structures	5
		The level of knowledge on types structures such as arches, statically determinate and indeterminate beams	Low level of knowledge on types structures such as arches, statically determinate and indeterminate beams	Able to discuss types of structures and their importance in civil engineering constructions	Ability to explain types of structures and their importance in civil engineering constructions	Full knowledge on types of structures and their importance in civil engineering constructions	Analysing and application of knowledge on types of structures and their importance in civil engineering constructions	4
		The level of knowledge to analyse various engineering structures.	Low level of knowledge to analyse various engineering structures.	Ability to discuss and to study the various engineering structures	Ability to explain various engineering structures.	Full knowledge on various engineering structures.	Analysing and implementing the knowledge of various engineering structures.	3
							Average Score	4

MAPPING

GR22D5001 Matrix Methods in Structural Analysis	Course Outcomes				
Course Objectives	1	2	3	4	5
1	X				
2		X			
3			X		
4				X	
5					X

GR22D5001 Matrix Methods in Structural Analysis	Course Outcomes				
Assessment	1	2	3	4	5
1	X				
2		X			
3			X		
4				X	
5					X

GR22D5001 Matrix Methods in Structural Analysis	Course Objectives				
Assessments	1	2	3	4	5
1	X				
2		X			
3			X		
4				X	
5					X

Course	Program Outcomes					
	1	2	3	4	5	6
GR22D5001 Matrix Methods in Structural Analysis	X	X	X	X	X	X

GR22D5001 Matrix Methods in Structural Analysis	**Program Outcomes**					
Course Outcomes	**1**	**2**	**3**	**4**	**5**	**6**
Evaluate the static and kinematic indeterminacy and generate stiffness and flexibility matrices.	M		M	M	H	M
Analyse the skeleton structures using stiffness method under different coordinate system.	M		M	M	M	M
Use flexibility matrix method to analyse different structures.	M		H	M	M	M
Use stiffness matrix method to analyse different structures.	M	M	H	M	H	M
Analyse various types of structural members using special analysis procedures and shear walls in multi storied constructions	M	M	M	M	M	M

GR22D5001	GR22	Set - 1

M.Tech I Year I Semester Regular Examinations, March 2023

MATRIX METHODS IN STRUCTURAL ANALYSIS

(Civil Engineering)

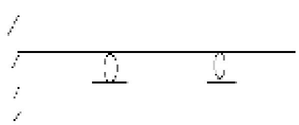
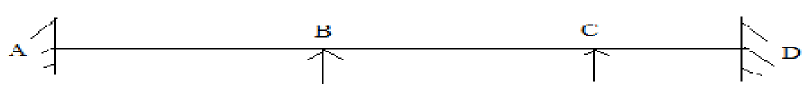
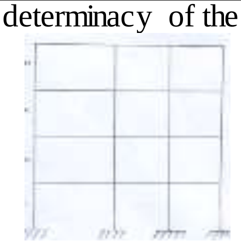
Time: 3 hours **Max Marks: 60**

Note:
1. Please verify the regulation of question paper and subject name
2. Question Paper Consists of Part - A and Part - B
3. Assume required data, if not given in the question

Bloom's (Taxonomy) Levels	Percentage of weight age	Marks allotted
BL1 (Knowledge: Remember)	30 to 40	18 to 24
BL2 (Comprehension: Understand)		
BL3 (Application: Apply)	60 to 70	36 to 42
BL4 (Analysis: Analyze)		
Total	100	60

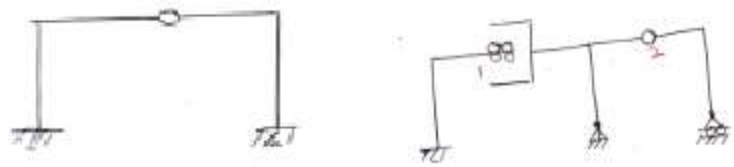
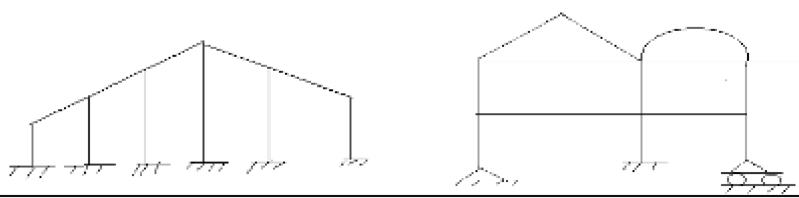
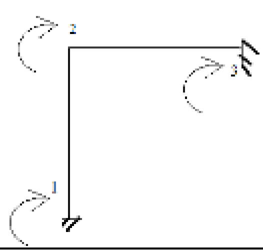
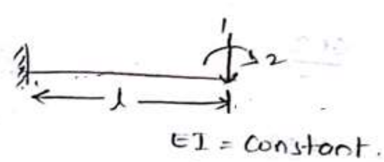
PART – A (BL1 to BL4)

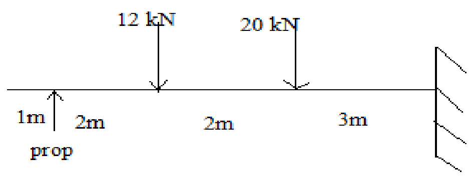
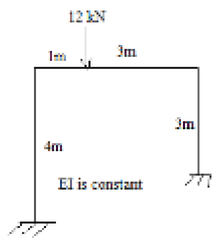
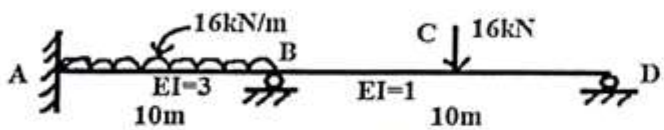
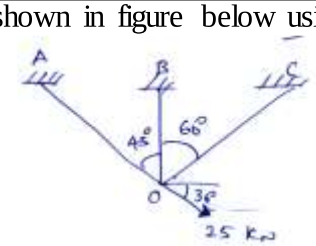
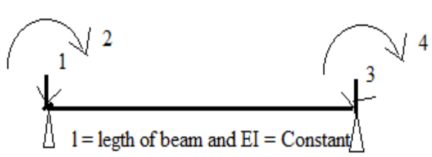
(Answer ALL Questions) **(10x1 = 10 Marks)**

1	What is static and kinematic indeterminacies?	BL- 1 CO1 1 M
2	Explain about transformation matrix in analysis of structures.	BL-2 CO1 1 M
3	How to differentiate between local and global coordinates.	BL-1 CO2 1 M
4	The stiffness matrix of a beam is given as $\begin{bmatrix} 4 & -1 \\ -1 & 4 \end{bmatrix}$, when the nodal displacements are $\begin{bmatrix} 1 \\ 2 \end{bmatrix}$ find the nodal forces	BL-1 CO2 1 M
5	Show the released structure for the beam given below: 	BL-1 CO3 1 M
6	What is the static in determinacy of given beam below, if only transverse vertical loads are considered: 	BL-1 CO3 1 M
7	How to find the kinematic in determinacy of a plane truss?	BL-1 CO4 1 M
8	Find out the kinematic in determinacy of the given structure: 	BL-1 CO4 1 M
9	What is sub structuring?	BL-1 CO5 1 M
10	List out the advantages shear walls.	BL-1 CO5 1 M

PART – B (BL1 to BL4)
(Answer ALL Questions) (5X10 = 50 Marks)

Each Question Carries 10 marks and may have a, b. as sub Questions

11	a)	i) Define the term of degree of freedom.	BL-1 CO1 Marks- 2
		ii) Show the relationship between stiffness and flexibility matrices.	BL-1 CO1 Marks- 3
	b)	Find out the static indeterminacy of the structures given below: 	BL-1 CO1 Marks- 5
[OR]			
12	a)	i) Explain the term redundancy in a structure.	BL-2 CO1 Marks- 2
		ii) Write about transformation co-ordinates with suitable example.	BL-1 CO1 Marks- 3
	b)	Find the kinematic indeterminacy of the structures given below 	BL-1 CO1 Marks- 5
13	a)	How to generate global stiffness matrix from local/element stiffness matriced	BL-1 CO2 Marks-5
	b)	Assemble $[k_1]$ and $[k_2]$ of the 2 element frame as shwn in figure below to generate [k] of the system. ake $[k_1\} = \begin{bmatrix} 2 & 1 \\ 1 & 4 \end{bmatrix}$ and $[k_2] = \begin{bmatrix} 2 & 1 \\ 1 & 4 \end{bmatrix}$ 	BL-3 CO2 Marks-5
[OR]			
14	a)	Develop stiffness matrix for the given structure using Direct Stiffness method or approach 	BL-3 CO2 Marks-5
	b)	Explain briefly about Solution of Stiffness Matrix Equations.	BL-2 CO2 Marks- 5

15	a)	Analyse the propped cantilever beam as shown in the figure below using flexibility matrix. Also draw the BMD and SFD's. 	BL- 4 CO3 Marks- 10
[OR]			
16	a)	Analyse the given plane frame as show below using force method. 	BL-4 CO3 Marks- 10
17	a)	Analyse the continuous beam shown in fig. by the stiffness matrix method and also draw the bending moment diagram: 	BL4 CO4 Marks- 10
[OR]			
18	a)	Analyse the plane truss as shown in figure below using displacement method. 	BL-4 CO4 Marks- 10
19	a)	Explain and Apply static condensation for a simply supported beam subjected to dof as shown below: 	BL-3 CO5 Marks- 10
[OR]			
20	a)	Compare the structural behavioue of large frames without shear wall	BL-4 CO5 Marks- 5
	b)	Distinguish between various methods for analysis of shear walls	BL-4 CO5 Marks- 5

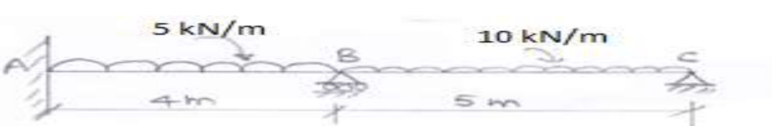
Gokaraju Rangaraju Institute of Engineering and Technology
(Autonomous)
I M.Tech. I Semester 2022-23 I Mid-Term Examinations – DEC 2022

2	2	2	4	1	D				

Name: ______________________________ **Branch/Section: Civil Engineering**
Subject: Matric Methods in Structural Analysis **Code: GR22D5001**

Branch: Civil Engineering **Max Marks: 30**
Date: 24 - 12-2022 (FN) **Duration: 120 min.**

Objective **(10 X 1 = 10 Marks)**
(Answer All Questions) **Time: 15 min.**

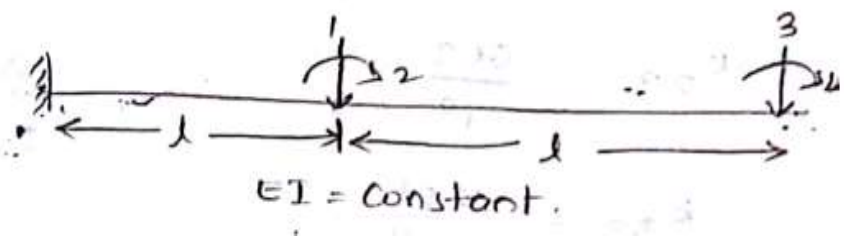
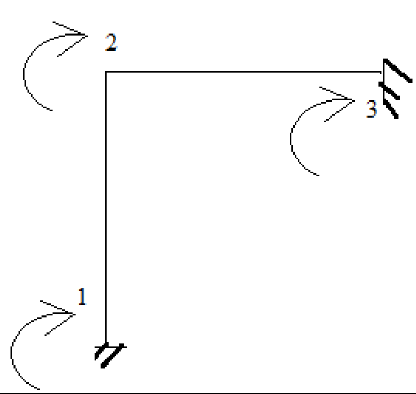
Q. No.	Unit	CO	BL*	PI
1	A simply supported beam having an internal hinge is a [ ] a) Structure b) Mechanism c) Elastic body d) None of the above	CO1	1	5.3.1
2	A statically indeterminate structure is the one which [ ] a) Cannot be analysed b) Can be analysed using equations of static's only c) Can be analysed using equations of static's and compatibility only d) Can be analysed using equations of compatibility only	CO1	1	5.2.2
3	Total dof at nay joint for pin joint of a space frame [ ] a) 2 b) 3 c) 6 d) 4	CO1	1	5.2.2
4	Flexibility [f] or [λ] means [ ] a) $\frac{\Delta}{F}$ b) $\frac{\theta}{M}$ c) Either a or b d) None of the above	CO1	2	5.2.2
5	Moment required to get unit slope when far end is hinged [ ] a) $\frac{4EI}{l}$ b) $\frac{3EI}{l}$ c) $\frac{EI}{l}$ d) Either b or c	CO2	1	5.2.2
6	Stiffness [k] means [ ] a) $\frac{F}{\Delta}$ b) $\frac{M}{\theta}$ c) Either a or b d) None of the above	CO2	1	5.2.2
7	What is static indeterminacy of the given continuous beam in case General and when only Vertical forces are considered (EI = Constant) [ ]  a) 3 & 2 b) 2 & 2 c) 3 & 3 d) 2 & 1	CO2	1	5.2.2
8	Rotation contribution for above continuous beam at joint B is equal to [ ] a) $\frac{55.41}{EI}$ b) $\frac{65.41}{EI}$ c) $\frac{20.625}{EI}$ d) $\frac{26.625}{EI}$	CO2	1	5.3.1
9	If $D_s <$ Dsthen which matrix method is preferable [ ] a) Flexibility b) Stiffness c) Either a or b d) None of the above	CO3	2	5.3.1
10	The size of flexibility matrix depends on [ ] a) D_S b) D_k c) dof d) External forces acting on beam	CO3	2	5.3.1

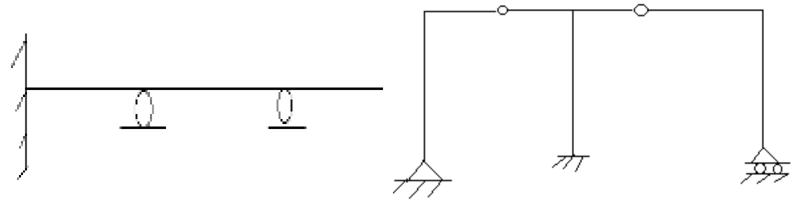
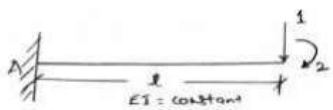
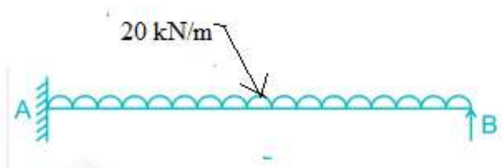
Gokaraju Rangaraju Institute of Engineering and Technology
(Autonomous)
I M.Tech. I Semester 2022-23 I Mid-Term Examinations – DEC 2022

Subject: Matric Methods in Structural Analysis **Code: GR22D5001**

Branch: Civil Engineering **Date:** 24-12-202#(FN)

Subjective **(4 X 5 = 20 Marks)**
(Answer Any FOUR Questions) **Time: 105 min.**

Q. No.	Unit	M	CO	BL*	PI
1	a) What is Static and kinematic indeterminacy of structures?	2	CO1	1	5.2.2
	b) Compare local and global co-ordinates and how they are interconnected	3	CO1	2	3.2.1
2	a) Explain briefly transformation of coordinates with suitable figure.	2.5	CO1	1	3.2.2
	b) Define the terms dof and redundants at supports.	2.5	CO1	1	5.2.2
3	Develop stiffness matrix for the given structure using Direct Stiffness method or approach 	5	CO2	3	5.3.1
4	a) How to assemble the stiffness matrices?	2	CO2	1	5.2.2
	b) Assemble $[k_1]$ and $[k_2]$ of the 2 element frame as shwn in figure below to generate [k] of the system. ake $[k_1\} = \begin{bmatrix}2 & 1\\1 & 4\end{bmatrix}$ and $[k_2] = \begin{bmatrix}2 & 1\\1 & 4\end{bmatrix}$ 	3	CO2	3	5.3.1

5	a) Find the static kinematic in determinacy indeterminacy of the structures given below: 	3	CO1	1	5.2.2
	b) Develop the flexibility matrices for the given co-ordinate system: 	2	CO3	3	5.3.1
6	a) The stiffness matrix of a beam is given as $\begin{bmatrix} 4 & 0.5 \\ 0.5 & 8 \end{bmatrix}$, when the nodal forces are $\begin{bmatrix} 5 \\ 2 \end{bmatrix}$ find the nodal displacements	2	CO2	1	5.1.1
	b) Analyse the propped cantilever beam as shown below using flexibility matrix method. Assume span length as l 	3	CO3	4	5.3.1

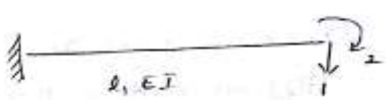
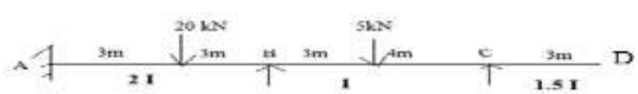
Gokaraju Rangaraju Institute of Engineering and Technology
(Autonomous)
I M.Tech. I Semester 2022-23 II Mid-Term Examinations – MARCH 2023

2	2	2	4	1	D				

Name: ______________________________ **Branch/Section: Civil Engineering**
Subject: Matric Methods in Structural Analysis **Code: GR22D5001**

Branch: Civil Engineering **Max Marks: 30**
Date: 02 - 03-2023 (FN) **Duration: 120 min.**

Objective **(10 X 1 = 10 Marks)**
(Answer All Questions) **Time: 15 min.**

Q. No.	Unit	CO	BL*	PI
1	Match the following from the following for coefficient of f_{22} = [ ] a) $\int_0^x \frac{m_1 m_1}{EI}$ b) $\int_0^x \frac{m_1 M}{EI}$ c) $\int_0^x \frac{m_2 m_2}{EI}$ d) $\int_0^x \frac{M}{EI}$	CO3	1	5.2.1
2	The number reactive force at hinged end support will be [ ] a) 0 b) 1 c) 2 d) 3	CO3	1	5.2.2
3	As per property of stiffness matrix the co-efficient of k_{ij} = [ ] a) k_{ij} b) k_{ji} c) f_{ij} d) f_{ji}	CO4	1	5.2.1
4	What is the co-efficient k_{22} for the given dof's ? [ ]  $\frac{4 EI}{l}$ b) $\frac{6\,EI}{l^3}$ c) - $\frac{12\,EI}{l^3}$ d) - $\frac{4\text{ EI}}{l^2}$	CO4	2	5.1.2
5	What is the co-efficient k_{11} for the beam shown in Q No.4 with dof's [ ] a) - $\frac{6\text{ EI}}{l^2}$ b) $\frac{12\,EI}{l^3}$ c) - $\frac{12\,EI}{l^3}$ d) $\frac{4\text{ EI}}{l}$	CO4	1	5.1.2
6	What is the dof for the given continuous beam [ ]  a) 3 b) 2 c) 1 d) 5	CO4	1	5.1.2
7	Estimate the relative stiffness for the member if far end is hinged [ ] a) $\frac{I}{L}$ b) 0.5 $\frac{I}{L}$ c) 0.75 $\frac{I}{L}$ d) 1.5 $\frac{I}{L}$	CO4	1	5.1.2
8	Estimate the relative stiffness for the member if far end is fixed [ ] a) $\frac{I}{L}$ b) 0.5 $\frac{I}{L}$ c) 0.75 $\frac{I}{L}$ d) 2 $\frac{I}{L}$	CO4	1	5.1.2

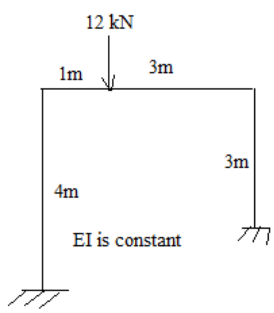
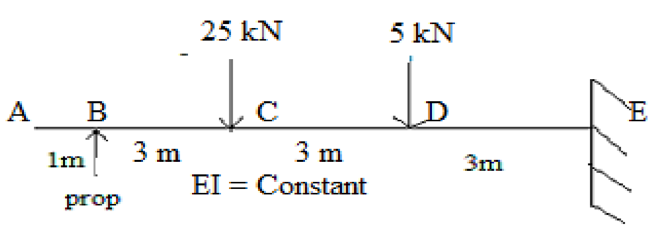
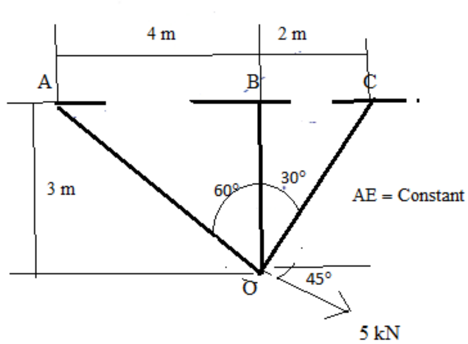
9	In static condensation the known displacements kept at __of displacement matrix [ ] a) Top b) Centre c) Bottom d) Any where	CO5	2	5.1.2
10	What happened the intensity thermal stresses in structural members when members are free to move? [ ] a) Increase c) decrease c) No change d) Either a or b	CO5	1	5.2.1

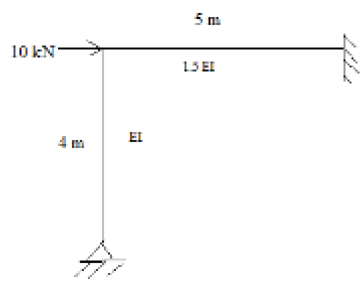
Gokaraju Rangaraju Institute of Engineering and Technology
(Autonomous)
I M.Tech. I Semester 2022-23 II Mid-Term Examinations – MARCH 2023

Subject: Matric Methods in Structural Analysis **Code: GR22D5001**

Branch: Civil Engineering **Date:** 02-03-2023 (FN)

Subjective **(4 X 5 = 20 Marks)**
(Answer Any FOUR Questions) **Time: 105 min.**

Q. No.	Unit	M	CO	BL*	PI
1	Analyze the given frame using force method as shown in figure below: 	5	CO3	4	5.2.1
2	Analyze the given frame using displacement method as shown in figure below: 	5	CO4	4	5.2.1
3	Analyse the plane truss using as shown below stiffness matrix approach. The supports a, b & c are hinged. 	5	CO4	4	5.2.1
4	a) What is static condensation?	2	CO5	1	5.1.3

	b) How initial and thermal stresses are influenced in the structures?	3	CO5	1	5.1.2
5	What are the different methods of analysis of shear walls and explain any two of them?	5	CO5	1	5.2.2
6	a) How to solve a plane truss using flexibility matrix method? (Only procedure steps)	2.5	CO3	4	5.2.2
	b) Generate stiffness matrix for the given below frame: . 	2.5	CO4	4	5.2.2

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M.Tech Structural Engg. I yr-I Sem- GR22 2022-23			
Matrix Methods in Structural Analysis GR22D5001 (MID-I)			
S.No	**Roll No**	**Name of Student**	**Maximum Marks (30 M)**
1	22241D2001	ADDAGATLA MAHESHKUMAR	20
2	22241D2002	AHMED ABDUL AZEEM	14
3	22241D2003	BAIRAPAKA BHARAT	8
4	22241D2004	BARLAPUDI ACHSAHKEERTHANA	26
5	22241D2005	CHAKALI SOWMYA	13
6	22241D2006	CHAPPIDI NARESH	14
7	22241D2007	DANTHALA HARIDEEPKUMAR	17
8	22241D2008	DEVIREDDY ANISH	15
9	22241D2009	DHARAVATHNAGENDAR	14
10	22241D2010	GANGAPURAM SUSHANTH REDDY	12
11	22241D2011	JEREPOTHULARAVALIKA	12
12	22241D2012	KADABOHINASAIPAVAN	9
13	22241D2013	KASUMURU BHARAT KUMAR	14
14	22241D2014	MACHARLA SRINIVAS	6
15	22241D2015	MALLI SREENIVASULU	20
16	22241D2016	SHAIK ABDUL MUQEED	17
17	22241D2017	SHAIK ZABI ULLAH	7
18	22241D2018	SONWANE SAHILSHIVAJIRAO	22
19	22241D2019	LINGAM LAKSHMI NARAYANA	4

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M.Tech Structural Engg. I yr-I Sem- GR22 2022-23			
Matrix Methods in Structural Analysis GR22D5001 (MID-II)			
S.No	**Roll No**	**Name of Student**	**Maximum Marks (30 M)**
1	22241D2001	ADDAGATLA MAHESHKUMAR	20
2	21241D2002	AHMED ABDUL AZEEM	15
3	21241D2003	BAIRAPAKA BHARAT	5
4	21241D2004	BARLAPUDI ACHSAHKEERTHANA	26
5	21241D2005	CHAKALI SOWMYA	14
6	21241D2006	CHAPPIDI NARESH	18
7	21241D2007	DANTHALA HARIDEEPKUMAR	14
8	21241D2008	DEVIREDDY ANISH	15
9	21241D2009	DHARAVATHNAGENDAR	12
10	21241D2010	GANGAPURAM SUSHANTH REDDY	15
11	21241D2011	JEREPOTHULARAVALIKA	12
12	21241D2012	KADABOHINASAIPAVAN	21
13	21241D2013	KASUMURU BHARAT KUMAR	17
14	21241D2014	MACHARLA SRINIVAS	6
15	21241D2015	MALLI SREENIVASULU	23
16	21241D2016	SHAIK ABDUL MUQEED	17
17	21241D2017	SHAIK ZABI ULLAH	17
18	21241D2018	SONWANE SAHILSHIVAJIRAO	26
19	21241D2019	LINGAM LAKSHMI NARAYANA	8

STRUCTURE:

A Structure refers to a System of Connected parts used to Support

In an when any elastic body, each one Subjected to a System of loads and deformation takes place and the resistance is setup against the deformation, then elastic body is known as structure.

Classification of structure:

1. Skeletal structures
2. Surface structures
3. Solid - structures.

1. Skeletal Structures: Structures can be idealized to a Series of straight or curved lines

Ex: Bearing frames.

2. Surface Structures: structures which can be idealised to plane or curved surfaces.

Ex: Slabs and Shells.

Angle of Inclination <30 flat roofs.

Angle of Inclination >30 pitched roofs.

3. Solid Structures: structures which can neither be idealised to a skeletal nor plane curved surfaces.

Ex: Massive Dimensions [All the dimensions are predominant]

→ Explain classification of skeletal structures.

Based on types of Joints:

i) Pin jointed frames:

In this joint members are connected by means of Pinjointed. This frame members can support only axial force and all external forces should act at member joints.

(ii) Rigid jointed frames:

These frames resist external forces by developing BM, SF, AF and twisting moments in the members of frames.

Based on dimensions:

(i) Plane frames:

All the members of the plane frame as well as external loads are assumed to be in one plane.

(a) Pin jointed plane frame: All the members can carry axial forces only

(b) Rigid jointed plane frame: These members can carry AF, SF, BM and twisting moment.

(ii) Space frames:

All the members of the plane donot lie in one plane it lies in another plane. very often it is also the combination of series of planes.

(a) Pin jointed space frame: Members will allow axial forces only

(b) Rigid jointed space frame: These members can carry AF, SF, BM and twisting moment

→ List out equation of static equilibrium:

Equations of static equilibrium

for plane frame: In case of plane fram subjected to in in-plane external forces.

Ex: XY plane.

$\Sigma F_x = 0 \quad \Sigma H = 0$

$\Sigma F_y = 0 \quad \Sigma V = 0$

$\Sigma F_z = 0 \quad \Sigma M = 0$

for space frame: $\Sigma F_x = \Sigma F_y = \Sigma F_z = 0$.

$\Sigma M_x = \Sigma M_y = \Sigma M_z = 0$.

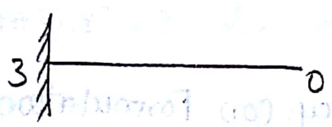
→ What is statically determinate structure.

These structures can be analysed with available equilibrium equations called as statically determinate structure.

These structures undergo finite deformation before the conditions of equilibrium are satisfied the deflection.

Ex: A cantilever beam, simply supported beam and a A suspension cable and 3-hinged Arch.

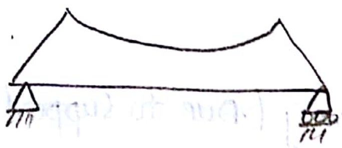
(i)



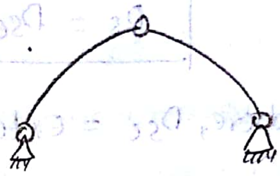
3+0.

(ii)

(iii)



(iv)



Statically Indeterminant:

Those structures cannot be analysed with available static equilibrium equations. In this structure the reaction components and internal stresses cannot be analysed with available static equilibrium condition. These structures can analyse with additional equation based on condition of compatibility consistency.

Consistency deformations (θ) rotations, horizontal con vertical displacement.

→ How to calculate static Indeterminate structures.

Degree of static indeterminacy is also known as redundancy.

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Equations in addition to static equilibrium equations necessary to complete analyse statically indeterminate structure. It is denoted by D_s

D_s = no. of unknowns − static equilibrium equations.

Note: Static equilibrium equations are two when only vertical forces are considered.

$\Sigma V = 0$, $\Sigma M = 0$.

→ Formulate the static Indeterminancy (or) Formulation of static Indeterminancy.

$$\boxed{D_s = D_{se} + D_{si}}$$

where, D_{se} = External Indeterminacy (Due to support reaction)

D_{si} = Internal Redundancy.

Ex: D_{se} is calculated as false

$D_{se} = r - 6$ for space frame

$D_{se} = r - 3$ for plane frame

r − unknown forces at supports

D_{si} = Static Internal redundancy

$D_{si} = m - (2j - 3)$ for pin jointed plane frame

$D_{si} = m - (3j - 6)$ for pinjointed space frame.

For rigid jointed plane frame − 3C

For rigid jointed space frame − 6C

NOTE: Simplified formulas including external as well as internal

1) Pinjointed plane frame

$$D_s = r - 3 + m - 2j + 3$$

$$D_s = (r+m) - 2j$$

2) Pin jointed Space frame

$$D_s = r - 6 + m - 3j + 6$$

$$D_s = (m+r) - 3j$$

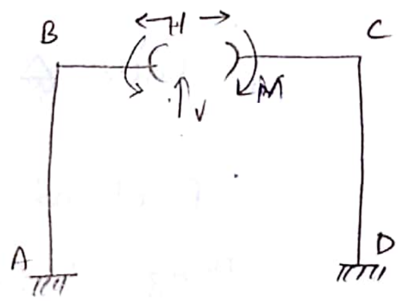
$(3m + r) - 3j$ for rigid jointed plane frame

$(6m + r) - 6j$ for rigid jointed space frame.

→ What is Cantilever tree Concept.

Cantilever tree Concept:

The total degree of indeterminacy of rigid frame can be obtained by using the statical indeterminacy criteria and alternative method is suggested here, the basis is that by cutting a Section, we are releasing the 3 resultants as shown in fig.



→ There are axial forces (H), shear force (V), BM (M)

→ Then total degree of Indeterminacy $= D_s$

D_s = no. of cuts × 3 = 3c for plane

= 6c for Space.

NOTE:

whenever is a Internal hinge the Static indeterminacy will reduce.

(i) Because the moment can't be transmitted from one end to another end.

(ii) Internal links (or) Bars: A link is a short bar with pin at each end. By this internal link the Static indeterminacy can be reduced by 2 ($\Sigma M = 0$, $\Sigma H = 0$)

→ Evaluate the static Indeterminacy of a given structure.

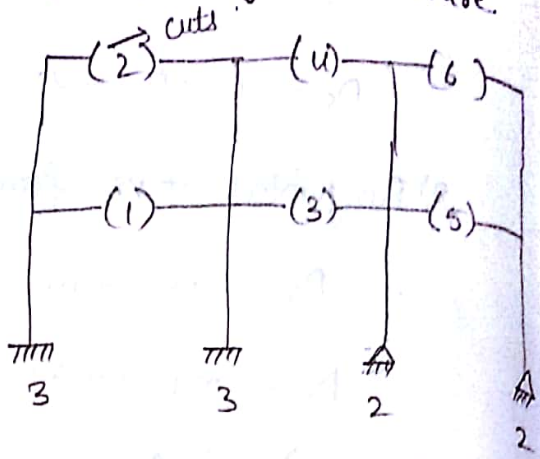
$D_s = 3C - 2$

$= 3(6) - 2 = 16$

(plane frame)

$D_s = (3m + r) - 3j$

(Rigid jointed plane frame)



$m = 14$, $r = 10$, $j = 12$

$(3(14) + 10) - 3(12) = (52 + 6) - 36 = 22$

when lateral forces are considered, no. of releases = 2

28/8/18

Type of Support	No. of reactions.
Fixed	M, H, V $= 3$
hinge	$H \rightarrow$ $\uparrow V$ $= 2$
Roller	$\uparrow V$ $= 1$
Fixed end —	0
Horizontal shear release	$H \rightarrow \downarrow$ VSF $= 2$
Vertical shear release	HSF $\rightarrow \uparrow V$ $= 2$.

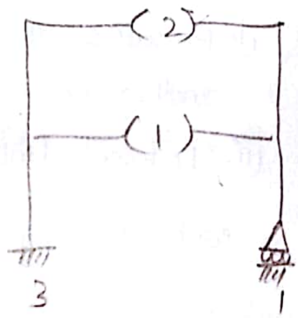
→ Calculate the static indeterminacy of a structure given below.

no. of releases = 2

$D_s = 3C - 2$

$= 3(2) - 2$

$= 4$

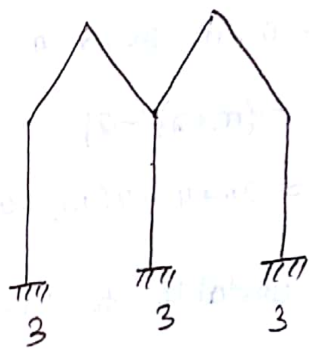


$m = 6$ $\quad D_s = (3m + r) - 3j$

$j = 6$ $\quad = (18+4) - 18$

$r = 4$ $\quad = 4$

→ Evaluate the static indeterminacy of a given structure.



no. of releases $= 0$

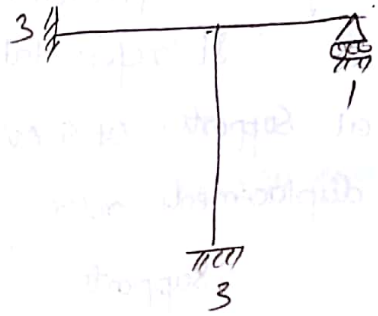
$m = 7, \; j = 8, \; r = 9$

$D_s = 3c - 0 = 3(2) = 6.$

$D_s = (3(7) + 9) - 3(8)$

$= 30 - 24 = 6.$

→ Evaluate the static indeterminacy of a given structures.



no. of releases $= 2$

$D_s = 3C - 2 = 3(2) - 2 = 4$

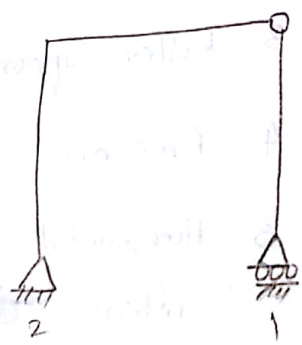
$m = 3; \; j = 4; \; r = 7$

$D_s = (3m + r) - 3j$

$= (3(3) + 7) - 3(4)$

$= 16 - 12 = 4$

→ The plane frame shown in the fig, Evaluate the stability and indeterminacy of the structure.



no. of releases $= 1$

$D_{sc} = 3C - 1 = 3(1) - 1 = 2$

$m = 3, \; j = 4, \; r = 3, \; R = 1$

$D_s = (3m + r) - 3j - R$

$(3(3) + 3) - 3(4) = 12 - 12 - 1 = -1$

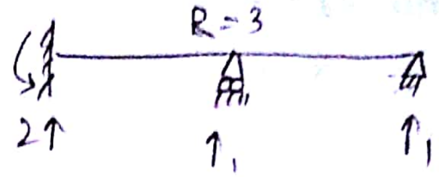
It is unstable

$3($ - - -

$33+180$ -

→ Calculate the static indeterminacy of the structure for lateral loads only

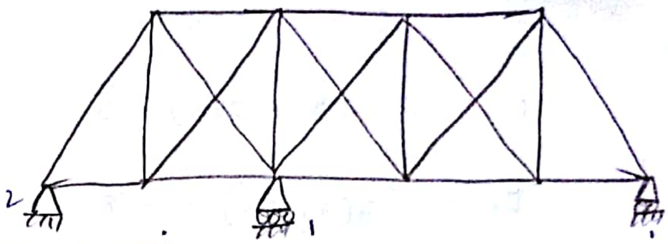
$m = 2,\ j = 3,\ r = 4$



$D_S = (3(2)+4) - 3(3) = 1$

→ Determine the static indeterminacy of a pin jointed structures.

$j = 10,\ m = 20,\ r = 4$



$D_S = (m+r) - 2j$

$= 20+4-2(10) = 4$

For unstable structure, $3m+r < 3j$

Stable structure, $3m+r = 3j$

Indeterminate structure, $3m+r > 3j$

Degrees of freedom:

It refers lateral displacements and rotational displacement at supports. ΔH & ΔV refers lateral displacements. Angular displacements refers kinematic indeterminacy.

Supports		degree of freedom		
1. Fixed	(3)	0	$\Delta H = \Delta V = \theta = 0$	
2. Pin support	(2)	1	$\Delta H = \Delta V = 0$	θ
3. Roller support	(1)	2	$\Delta V = 0$	$\Delta H,\ \theta$
4. Free end —	(0)	3	$\Delta H,\ \Delta V,\ \theta$.	
5. Horizontal shear release	2	1	$\Delta H,\ \Delta x$.	
6. Vertical shear release →	2	1	ΔV.	Δy.

Degrees of freedom for typical joints

Typical joint	D.O.F	Types of deflection
Free end	3	$\Delta H (\Delta x)$, $\Delta V (\Delta y)$, θ.
Hinge at one side	4	$2\Delta V$, ΔH, θ.
internal hinge	$3+2=5$	ΔH, ΔV, 3θ $(\theta_x, \theta_{y_1}, \theta_{y_2})$
Internal hinge	4	ΔH, ΔV, 2θ.
Closed damper	4	ΔH_1, ΔH_2, ΔV, θ.
open damper	4	$2\Delta V$, ΔH, θ

31/8/18

→ How to formulate a kinematic indeterminacy of the structures.

Formulation of kinematic Indeterminacy (D_K):

(i) for a rigid jointed plane frames,

$$D_K = NJ - C$$

where, N = no. of degree of freedom of each joints

J = no. of joints

C = no. of reaction components

NOTE: $C = r$, if the members are extensible

$C = m + r$, if the extension of the members 'm' are neglected.

(i) $D_K = 3j - r$ (for rigid jointed plane frame) and considering axial strains of members also.

(ii) $D_K = 3j - (m+r)$ (for rigid jointed plane frames and neglecting axial strains i.e., all are inextensible)

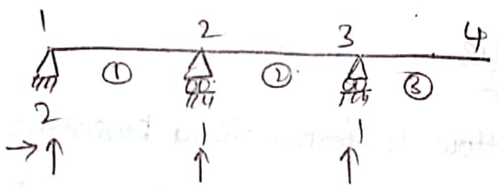
(iii) $D_K = 6j - r$ (for rigid jointed space frame and considering axial strains of members)

(iv) $D_K = 6j - (m+r)$ (for rigid jointed space frame and neglecting axial strains of the members.

NOTE: In calculation of degree of kinematic indeterminacy treat a supports also as joints.

[If D_K is increasing, size of stiffness matrix is also increases]

→ Evaluate the degree of kinematic indeterminacy for the given structure as shown in fig assuming the members are in axially stiff.



$j = 4,\ r = 4,\ m = 3.$

$D_K = 3j - r$

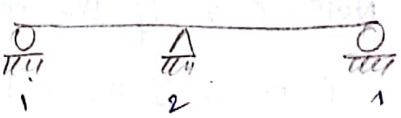
$= 3(4) - 4 = 12 - 4 = 8$

When, axial strains are neglected, $m = 3$

$D_K = 3j - (m+r)$

$= 3(4) - (3+4) = 12 - 7 = 5.$

→ Evaluate kinematic indeterminacy of beam as shown in fig



$j = 3,\ r = 4,\ m = 2$

extensible, $D_K = 3j - r$

$= 3(3) - 4 = 9 - 4 = 5$

Inextensible, $D_K = 3j - (m+r) = 3(3) - (2+4)$

$= 9 - 6 = 3$

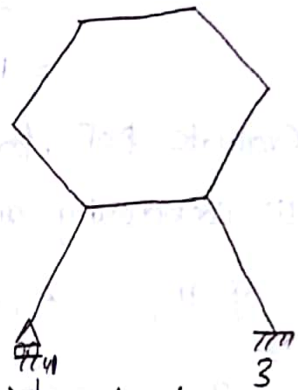
→ Evaluate the degrees of freedom for the frame as shown in fig and considering the members of axially stiff.

$D_K = 3j - r$

$= 3(8) - 4$

$= 24 - 4$

$= 20$



$D_K = 3j - (m + r) = 3(8) - (8 + 4)$

$= 24 - 12 = 12$

→ Neglecting axial deformations for the given structures determine DOF.

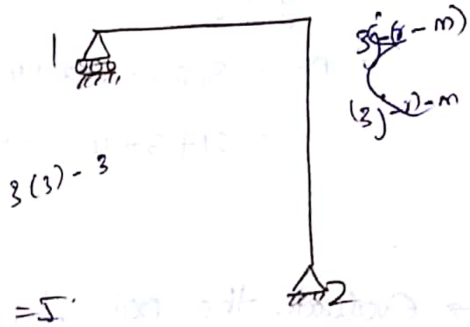
NOTE: If the column is only extensible.

$j = 3;\ m = 2,\ r = 3$

$D_K = 3j - (m + r)$

$= 3(3) - (2 + 3)$

$= 9 - 5 = 4$



Column is only inextensible, $D_K = 6 - 1 = 5$

→ Evaluate kinematic indeterminacy of structure when neglecting the axial deformations

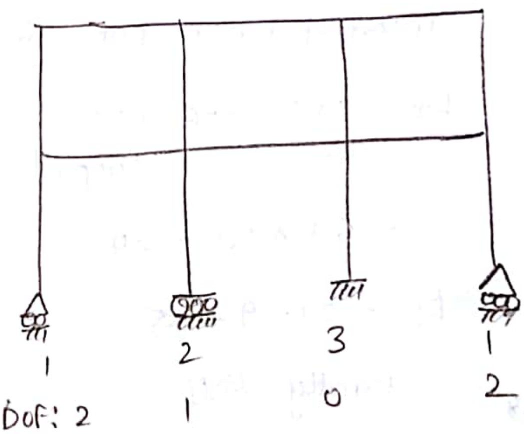
$j = 12,\ m = 14,\ r = 7$

$D_K = 3j - r$

$= 3(12) - 7 = 36 - 7$

$= 29$

$D_K = 29 - 14 = 15$



alternative:

DOF for fixed = 0

Roller = 2 + 2 = 4

H. Shear = 1

$r = 2 + 1 + 0 + 2 = 5$

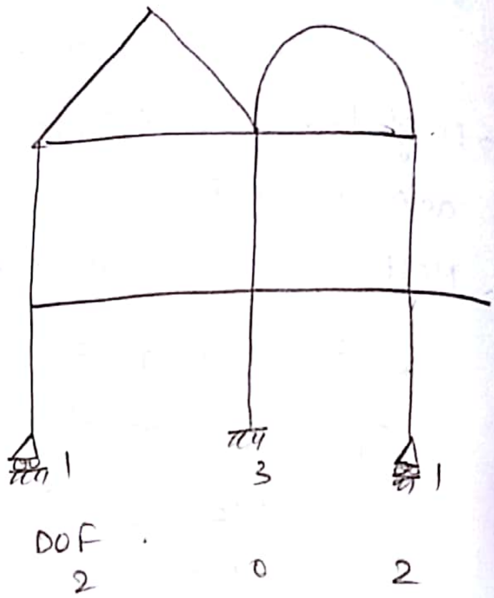
Rigid joints = 8

$D_K = 3j - r$

$= 24 - 5$

$= 19$

→ Evaluate DOF for members of structures as shown in fig.
(i) considering and by neglecting axial strains.



$j = 11, \; r = 5, \; m = 14$

$3j - r = 33 - 5 = 28$

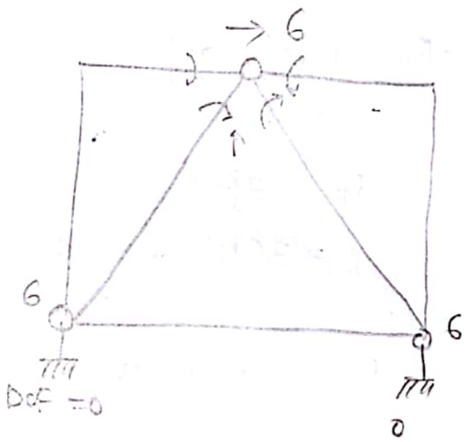
$D_K = 28 - 14 = 14$

→ Rigid joints = 7

$D_K = 3(7) + 1 \times 3 + 4$

$= 21 + 3 + 4 = 28$

→ Evaluate the DOF for the given member.



Rigid joints = 2

Internal hinge DOF = 6.

$D_K = 2 \times 3 + 3 \times 6 + (2 \times 0)$
support

$= 6 + 18 + 0 = 24$

$D_K = 24 - 9 = 15$

axially stiff.

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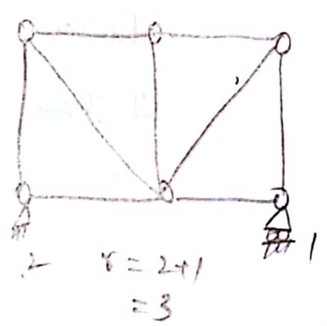
→ Evaluate kinematic indeterminacy of truss as shown in fig



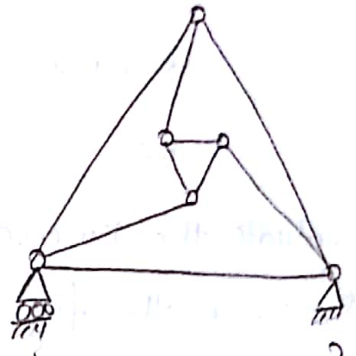
DOF = $D_K = 2j - r$

$= 2(6) - 3$

$= 12 - 3 = 9$

→ By observing the following frame shown below, Evaluate the static indeterminacy and kinematic indetermi

$m=9,\ r=1+2=3,\ j=6.$



$D_s = (m+r) = 2j$

$9+3 = \cancel{2(6)}\ 2(6)$

$D_s = (m+r)-2j = 12-12$

$= 0$ (Statically determinate)

{ D_s = (−) deficient

= (+) Redundant }

Very difficult to evaluate as it develops internal stresses

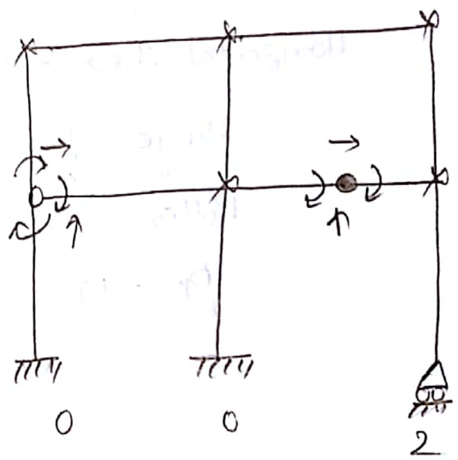
$D_K = 2j - r$

$= 2(6) - 3$

$= 12 - 3 = 9$

It is kinematically indeterminate with degree '9'

→ Evaluate kinematic indeterminacy of the frame as shown in the fig.



no. of rigid joints = 5

→ whenever, there is a pin joint it is not connected to one side but it is connected to another end.

no. of unknowns at hinge internal = 4

no. of unknowns at pin joint = 5.

DOF = 0, 0, 2

reactions = 0, 0, 2

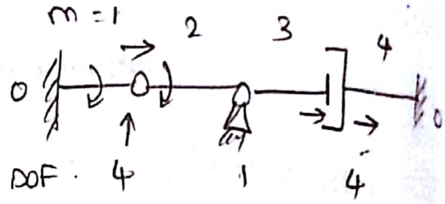
$D_k = 5\times3 + 5 + 4 + \underbrace{(0+0+2)}$

RJ PJ IH · Supports

$= 15 + 5 + 4 + 2$

$= 26.$

→ Evaluate the kinematic Indeterminacy of a structure as shown in the fig.



$D_k = 4 + 1 + 4 = 9$

$m = 4$

If members are inextensible

$D_k - m = 9 - 4 = 5.$

f ..0
A ..1
A ..2

→ Evaluate the degree of kinematic indeterminacy of the given structure as shown in the fig.

DOF at rigid joints

$= 3\times3 = 9$

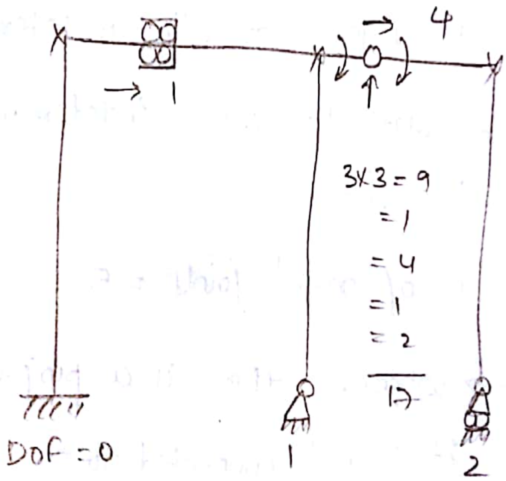
Internal hinge = 4

Horizontal shear = 1

Hinge = 1

Roller = 2

$D_k = 17$



$3j - r = e$

$3j' - (m+r) = Re.$

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Stiffness matrix method:

The statically indeterminate structures are analysed by flexibility matrix method.

If any structure is Kinematically indeterminate then the structure can be analysed by stiffness matrix method.

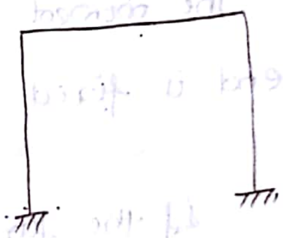
NOTE: If DKI > DSI, then flexibility matrix method is usefull.

Illy If DKI < DSI, then stiffness matrix method is useful.

→ Evaluate which method is suitable for analysis.

$D_S = 3C = 3(1) = 3.$

$m = 3$, $r = 6$, $j = 4$



$D_S = (3m+r) - 3j$

$= 9+6-12$

$= 3.$

$D_K = 3j - r$

$= 12 - 6$

$= 6.$ (Total)

$D_K = 3j - (r+m)$

$= 12 - (6+3)$

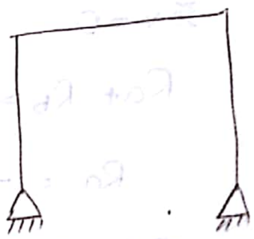
$= 3$ (inextensible).

Since $D_S = D_K$ any method is preferable.

$D_S = 3C - 2$

$= 3 - 2 = 1$

$r = 4$, $m = 3$, $J = 4$



$D_K = 3j - r = 12 - 4$

$= 8.$

$D_K = 5$ (if inextensible) $3j-(r+m)$ $12-(4+3)$

$D_K > D_S$, so that the flexibility matrix method is preferable.

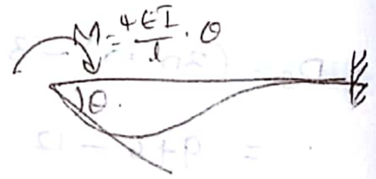
→ How to generate the stiffness matrix.

1. The size of stiffness matrix depends on degree of kinematic indeterminacy.

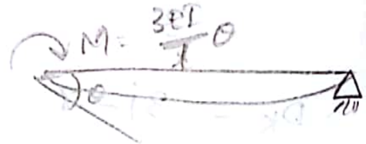
2. The element stiffness matrix is generated or determined by applying unit displacement at each node and determining the forces at each coordinate to sustain the displacement (As per stiffness, $K = \frac{P}{\Delta}$)

3. Similarly the element stiffness matrix is generated by applying unique rotation at each node and determining moment at each coordinate i.e., $K = \frac{M}{\theta}$

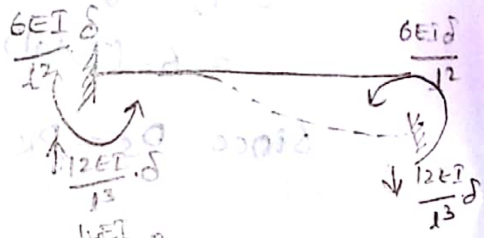
The moment required to get unique rotation. If far end is fixed $= \frac{4EI}{l} \cdot \theta$



If the far end is hinged the $M = \frac{3EI}{l} \cdot \theta$



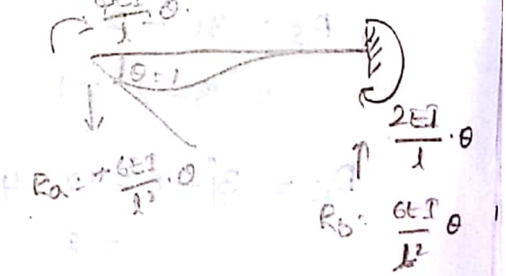
$M = \frac{6EI}{l^2} \cdot \delta$.



$\Sigma V = 0$.

$R_a + R_b = 0$

$R_a = -R_b \rightarrow (1)$



$\Sigma M_b = 0$

$R_a(l) + \frac{4EI}{l} \cdot \theta + \frac{2EI}{l} \cdot \theta + (R_b \times 0) = 0$

$R_a(l) = \frac{-6EI}{l}$

$R_a = -\frac{6EI}{l^2} \cdot \theta \; (\downarrow)$

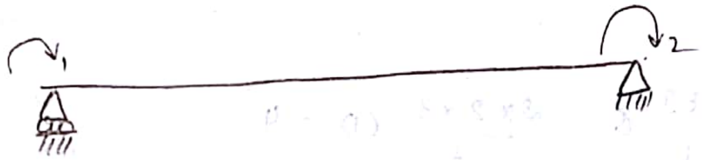
$$R_b = -\left(-\frac{6EI}{l^2}\theta\right)$$

$$R_b = \frac{6EI}{l^2}\cdot\theta \ (\uparrow)$$

Two equiunlike parallel forces are called Couple.

NOTE: In stiffness matrix method consider every joint as fixed.

→ Determine stiffness matrix for the beam as shown in fig with degrees of freedom as shown.



$l = 3$ Degree of freedom = 2.

$A = 1$ Size of stiffness matrix is 2×2

$E = 2$

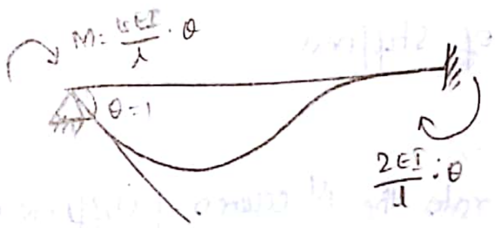
$I = 3.$

Step 1: Apply unit displacement (rotation) at 1 only and restrain 2 from rotation.

Now we will achieve the 1st column of stiffness matrix

$$[K] = \begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix}$$

K_{11} = Apply unit displacement at 1 and evaluate either moment or force at 1.

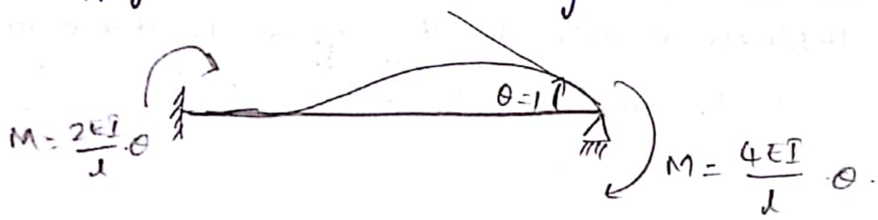


$$K_{11} = \frac{4EI}{l}.\theta = \frac{4\times2\times3}{3}.(1) = 8$$

$$K_{21} = \frac{2EI}{l}.\theta = \frac{2\times2\times3}{3}(1) = 4.$$

Step 2: Evaluate or generate the 2nd column of stiffness matrix.

Note: Apply unit rotation along coordinate 2



$$K_{12} = \frac{2EI}{l}.\theta = \frac{2\times2\times3}{3}.(1) = 4$$

$$K_{22} = \frac{4EI}{l}.\theta = \frac{4\times2\times3}{3}(1) = 8.$$

$$[K] = \begin{bmatrix} 8 & 4 \\ 4 & 8 \end{bmatrix}$$

Properties of stiffness matrix:

1. Stiffness matrix is a square matrix.
2. It is a symmetrical matrix, diagonal elements are positive, non-zero, non-negative.

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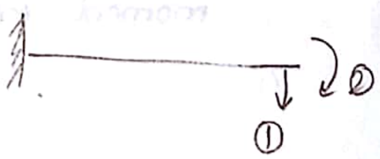
→ Develop or generate stiffness matrix for a beam of 2-coordinates.

For the given beam element

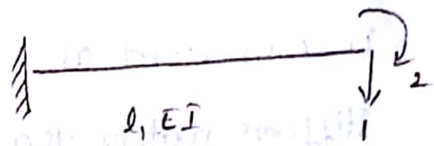


the DOF is 2 so size of stiffness matrix is 2x2

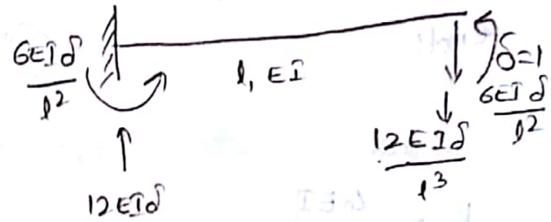
Step 1: To develop or generate the 1st column of stiffness matrix.

Apply unit displacement along Coordinate 1,

$$[K] = \begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix}$$



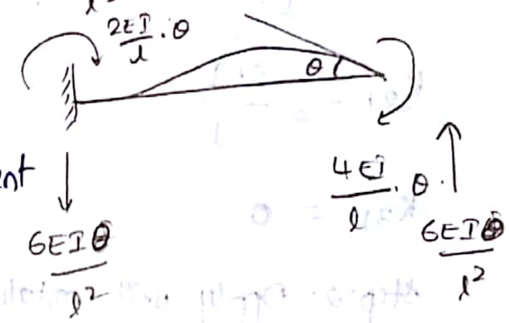
$$K_{11} = \frac{12EI\delta}{l^3}$$



$$K_{21} = -\frac{6EI\delta}{l^2}.$$

Step:2

To get develop of or generate the 2nd column of stiffness matrix. Apply unit displacement along coordinate 2.

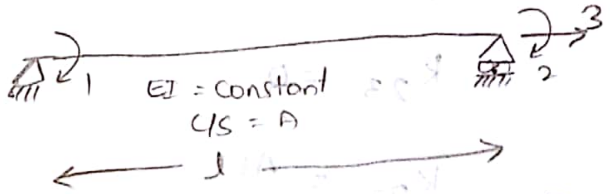


$$K_{12} = \frac{-6EI\theta}{l^2}$$

$$K_{22} = \frac{4EI\theta}{l}.$$

$$[K] = \begin{bmatrix} \frac{12EI}{l^3} & -\frac{6EI}{l^2} \\ \frac{-6EI}{l^2} & \frac{4EI}{l} \end{bmatrix}$$

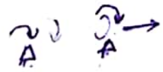
→ Develop or generate the stiffness matrix for the beam element as shown in the fig. (EI is constant w.r.t the DOF)



Here,

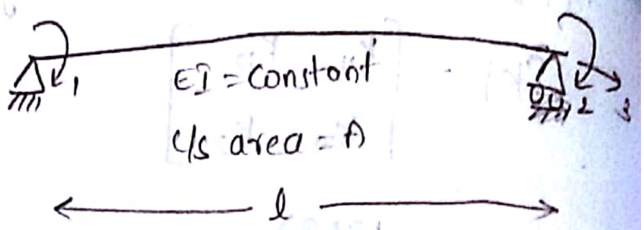
As the given DOF = 3

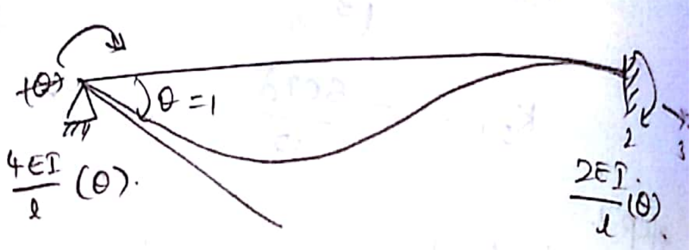
the ~~st~~ size of stiffness matrix = 3 × 3



Step1: To generate the 1st column of stiffness matrix apply unit displacement along the coordinate 1

But, whenever it is considered as stiffness matrix then there will be fixed ends.



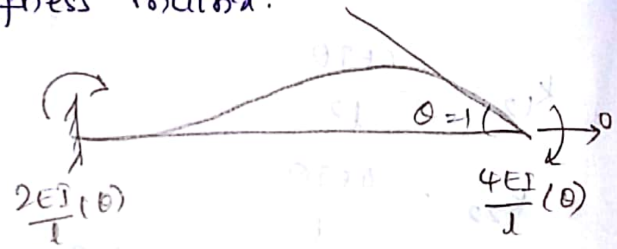


$k_{11} = \frac{4EI}{l}$.

$k_{21} = \frac{2EI}{l}$

$k_{31} = 0$

Step: 2! Apply unit rotation along coordinate 2 to generate 2nd column of stiffness matrix.



$k_{12} = \frac{2EI}{l}$

$k_{22} = \frac{4EI}{l}$

$k_{32} = 0$.

Step 3: To get the 3rd column of stiffness matrix, apply unit displacement along coordinate 3.

As horizontal displacement donot have any moment

$\therefore k_{13} = 0$.

As per hookes law

$k_{23} = 0$

$\delta = \frac{Pl}{AE}$

$k_{33} = \frac{AE}{l}$.

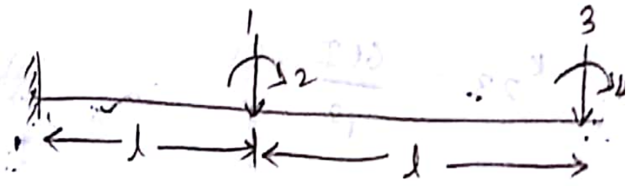
force, $P = \frac{\delta AE}{l}$.

$$[k] = \begin{bmatrix} \frac{4EI}{l} & \frac{2EI}{l} & 0 \\ \frac{2EI}{l} & \frac{4EI}{l} & 0 \\ 0 & 0 & \frac{AE}{l} \end{bmatrix}$$

→ Develop or generate stiffness matrix of the beam shown in the fig. w.r.t the 4 DOF.

As, DOF = 4

Size of stiffness matrix is 4x4.



Step 1: To get the first column of Stiffness matrix. Apply unit displacement along the coordinate 1.

$k_{11} = \frac{12EI}{l^3} + \frac{12EI}{l^3}$

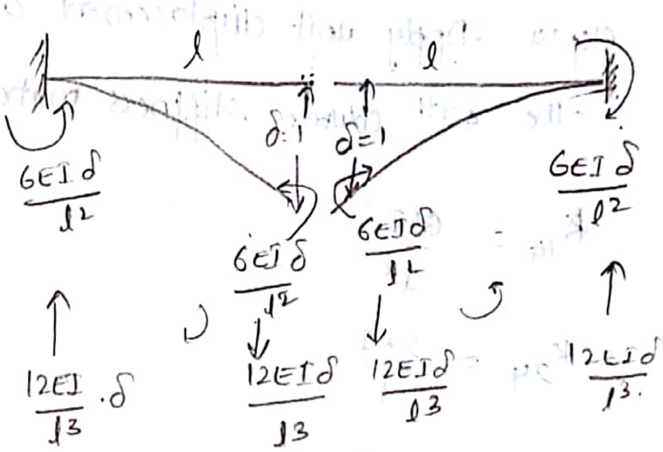
$k_{11} = \frac{24EI}{l^3}$

$k_{21} = \frac{-6EI}{l^2} + \frac{6EI}{l^2}$

$= 0.$

$k_{31} = \frac{-12EI}{l^3} + \cancel{\frac{6EI}{l^2}}$

$k_{41} = \frac{6EI}{l^2}$



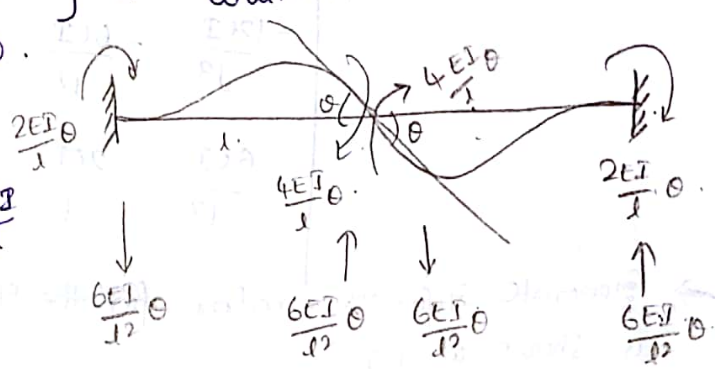
Step 2: Apply displacement along coordinate 2 to get the Stiffness along 2nd column.

$k_{12} = -\frac{6EI}{l^2} + \frac{6EI}{l^2} = 0.$

$k_{22} = \frac{4EI}{l} + \frac{4EI}{l} = \frac{8EI}{l}$

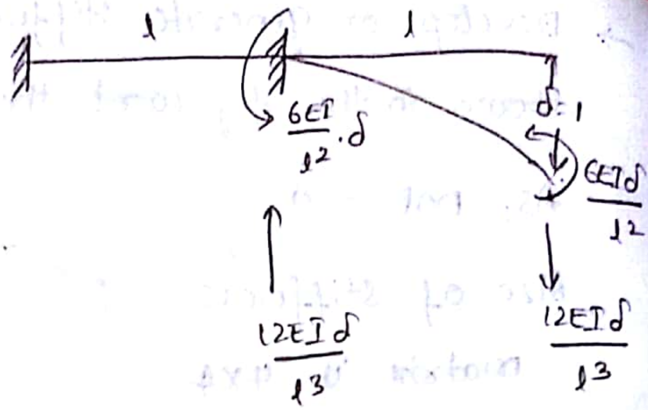
$k_{32} = -\frac{6EI}{l^2}$

$k_{42} = \frac{2EI}{l}.$



Step 3: To get the 3rd column of stiffness matrix Apply unit rotation along coordinate 3.

$K_{13} = -\frac{12EI\delta}{l^3}$

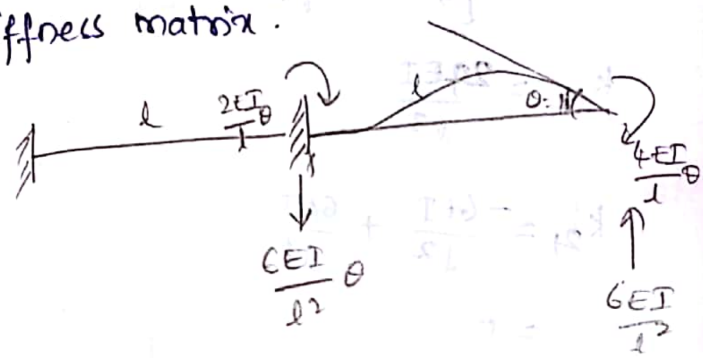


$K_{23} = -\frac{6EI}{l^2}$

$K_{33} = \frac{12EI}{l^3}$

$K_{43} = -\frac{6EI}{l^2}$

Step 4: Apply unit displacement along coordinate 4 to get the 4th column stiffness matrix.



$K_{14} = \frac{6EI}{l^2}$

$K_{24} = \frac{2EI}{l}$

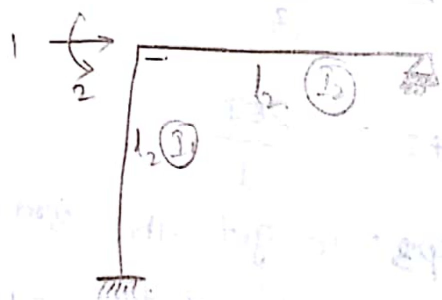
$K_{34} = -\frac{6EI}{l^2}$

$K_{44} = \frac{4EI}{l}$

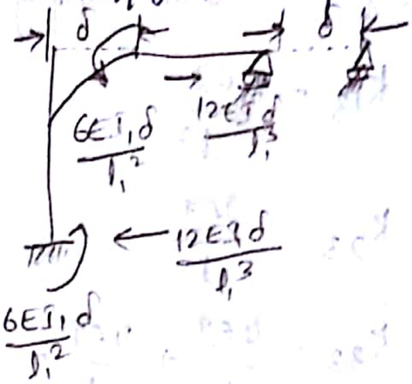
$$[K] = \begin{bmatrix} \frac{24EI}{l^3} & 0 & -\frac{12EI}{l^3} & \frac{6EI}{l^2} \\ 0 & \frac{8EI}{l} & -\frac{6EI}{l^2} & \frac{2EI}{l} \\ -\frac{12EI}{l^3} & -\frac{6EI}{l^2} & \frac{12EI}{l^3} & -\frac{6EI}{l^2} \\ \frac{6EI}{l^2} & \frac{2EI}{l} & -\frac{6EI}{l^2} & \frac{4EI}{l} \end{bmatrix}$$

→ Generate stiffness matrix for the structure with co-ordinate as shown in fig.

As the DOF is 2 the size of the stiffness matrix is 2x2.



To get 1st column of stiffness matrix, apply unit disp (Horiz) along Coordinate 1.

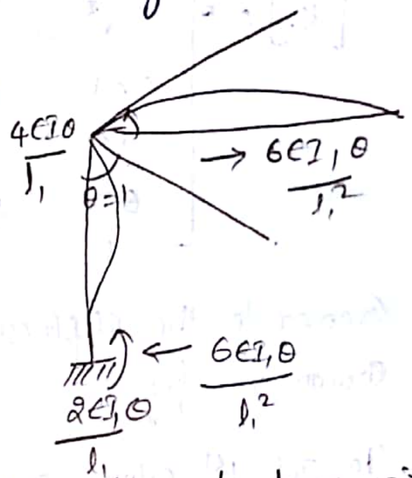


Left to right moment (−ve)

Right to left moment (+ve)

$K_{11} = \frac{12EI_1}{l_1^3}$ $\quad K_{21} = \frac{6EI_1}{l_1^2}$

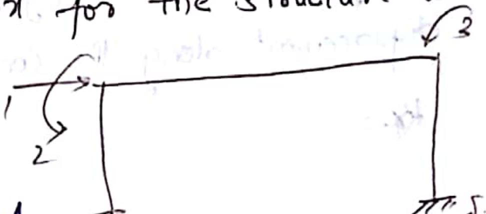
To get 2nd column, apply unit rotation along Coordinate-2.



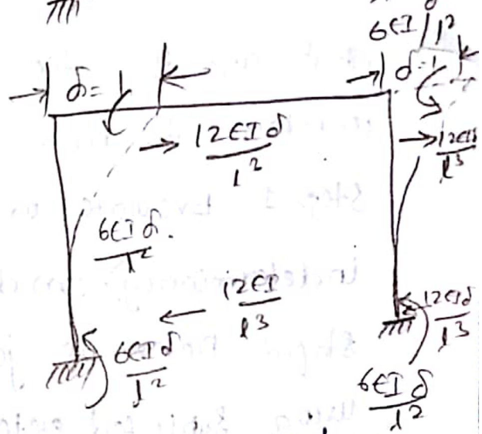
$K_{12} = \frac{6EI}{l_1^2}$ $\quad K_{22} = \frac{4EI_1}{l_1}$

$$[K] = \begin{bmatrix} \frac{12EI_1}{l_1^3} & \frac{6EI}{l_1^2} \\ \frac{6EI}{l_1^2} & \frac{4EI}{l_1} \end{bmatrix}$$

→ Generate the stiffness matrix for the structure with the given Coordinate system.



To get 1st column, apply unit displacement along the coordinate 1

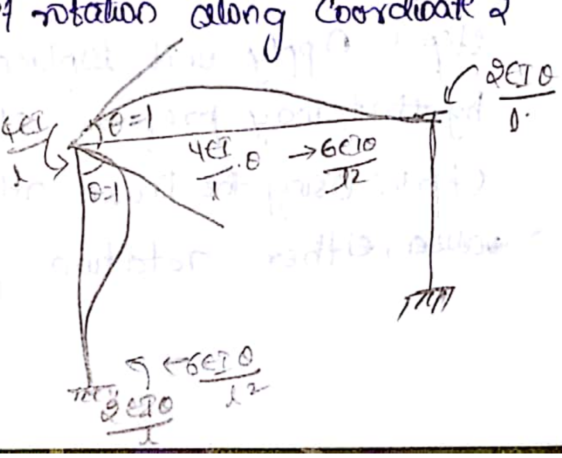


$K_{11} = \frac{12EI}{l^3} + \frac{12EI}{l^3} = \frac{24EI}{l^3}$

$K_{21} = \frac{6EI}{l^2}$

$K_{31} = \frac{6EI}{l^2}$

To get 2nd column, apply unit rotation along Coordinate 2



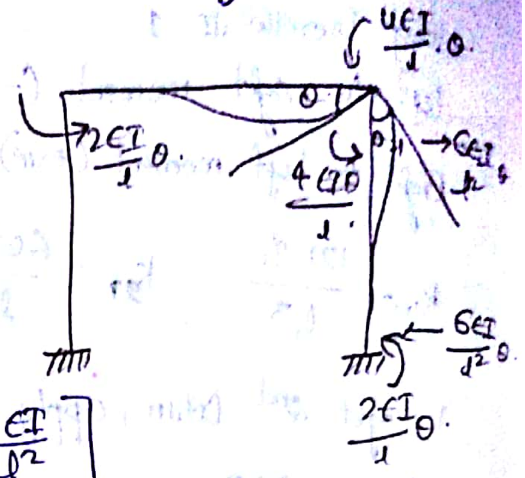
$K_{12} = \frac{6EI}{l^2}$

$K_{22} = \frac{4EI}{l} + \frac{4EI}{l} = \frac{8EI}{l}$

$K_{32} = \frac{2EI}{l}$.

To get 3rd column, apply unit rotation along Co-ordinate 3.

$$k_{13} = \frac{6EI}{l^2}$$

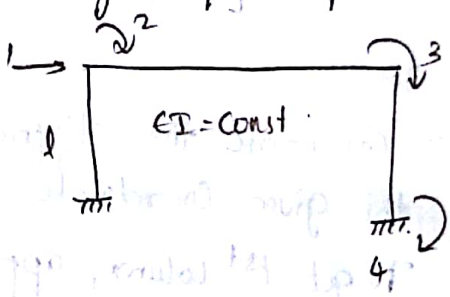


$$k_{23} = \frac{2EI}{l}$$

$$k_{33} = \frac{4EI}{l} + \frac{4EI}{l} = \frac{8EI}{l}$$

$$[K] = \begin{bmatrix} \frac{24EI}{l^3} & \frac{6EI}{l^2} & \frac{6EI}{l^2} \\ \frac{6EI}{l^2} & \frac{8EI}{l} & \frac{2EI}{l} \\ \frac{6EI}{l} & \frac{2EI}{l} & \frac{8EI}{l} \end{bmatrix}$$

→ Generate the stiffness matrix of the given portal frame as shown in fig.



To get 1st column, apply unit displacement along the Coordinate 1

k_{11} =

→ What are the steps that involve in analysing the kinematics indeterminate beams. (Stiffness matrix method).

Step 1: Evaluate or determine DKI (degree of kinematic indeterminacy) (or) degree of freedom.

Step 2: Determine joint loads using fixed end moments using subjected external loading particular beam.

Step 3: Apply unit displacement (or) along the coordinates by that way prepare stiffness matrix.

Step 4: Using the known relationship evaluate the unknown values, either rotation (or) displacement.

Step 5: Apply Unknown values and find out the unknown moment using slope deflection equation.

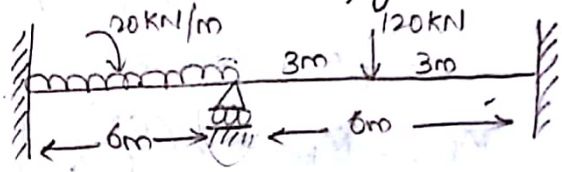
M_{ab} = external load.

δ = deflection levels / different levels.

Step 6: Evaluate the Support reactions to draw shear force and Bending moment diagram / using slope deflection equation.

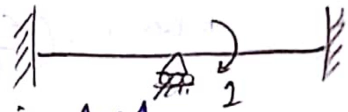
→ Analyse the given beam as shown in fig.

Step 1: Rotation is possible DOF = 1



$D_k = 0+1+0 = 1$.

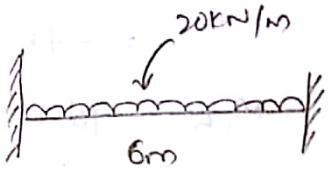
System of Coordinate is 1.



The size of the stiffness matrix is 1×1.

Step 2: Evaluate the joint loads.

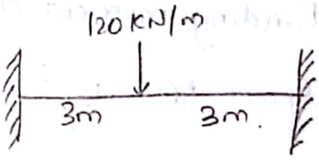
$$M_{ab} = \frac{-wl^2}{12} = -\frac{20(6)^2}{12} = -60\ kN/m$$



$$M_{ba} = \frac{wl^2}{12} = 60\ kN\text{-}m$$

$$M_{bc} = -\frac{wl}{8} = -90\ kN\text{-}m.$$

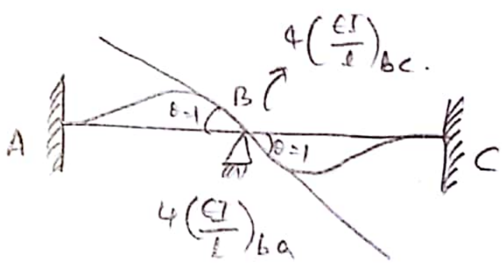
$$M_{cb} = \frac{wl}{8} = 90\ kN\text{-}m.$$



P_b = Joint load @ B = 60 − 90 = −30.

Step: 3:

$$k_{11} = \frac{4EI}{6} + \frac{4EI}{6} = \frac{8EI}{6} = \frac{4EI}{3}$$



Step 4: $K = \frac{P}{\delta}$

$$[K][\delta] = \{P\} - \{P_L\}$$

stiffness matrix, displacement factor, node, load vector

$$\left[\frac{4EI}{3}\right]\{\theta_b\} = \{30\}$$

$$\theta_b = 30 \times \frac{3EI}{4EI}$$

$$= \left(\frac{22.5}{EI}\right) \text{ Radians.}$$

Step 5:

$$M_{ab} = \bar{M}_{ab} + 2\left(\frac{EI}{l}\right)_{ab}\left[2\theta_a + \theta_b + \frac{3\delta}{\Delta ab}\right]$$

$$= -60 + 2\left(\frac{EI}{6}\right)\left(\frac{22.5}{EI}\right)$$ ($\because \delta = 0$ becoz they are at same level, $\theta_a = 0$, because of fixed ends)

$$= -60 + \frac{2EI}{6}\left[\frac{22.5}{EI}\right]$$

$$= -52.75 \text{ kN-m}$$

$$M_{ba} = \bar{M}_{ba} + 2\left(\frac{EI}{l}\right)_{ba}\left[(2\theta_b + \theta_a \pm 3\delta)\right]$$

$$= 60 + 2\left(\frac{EI}{6}\right) + \left[2\left(\frac{22.5}{EI}\right)\right] = 75$$

$$M_{bc} = -90 + 2\left(\frac{EI}{6}\right)\left(2 \times \frac{22.5}{EI}\right)$$

$$= -75$$

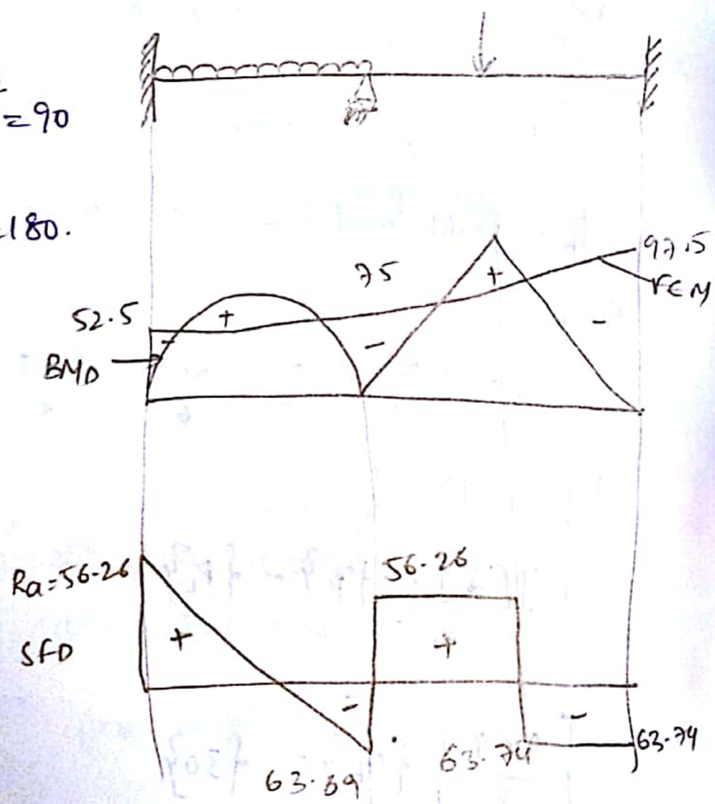
$$M_{cb} = 90 + 2\left(\frac{EI}{6}\right)\left(\frac{22.5}{EI}\right)$$

$$= 97.5$$

Bending moment diagram.

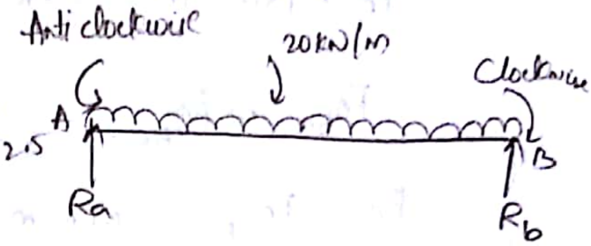
Span AB: $\frac{wl^2}{8} = \frac{20(6)^2}{8} = 90$

Span BC $= \frac{wl}{4} = \frac{120 \times 6}{4} = 180.$



Draw shear force diagram by evaluating the support reactions

$\Sigma M_b = 0$



$-52.5 + Ra(6) - 20(6)\left(\frac{6}{2}\right) + 75 = 0$

$Ra = \frac{52.5 - 75 + 360}{6}$

$= 56.26\ kN/m.$

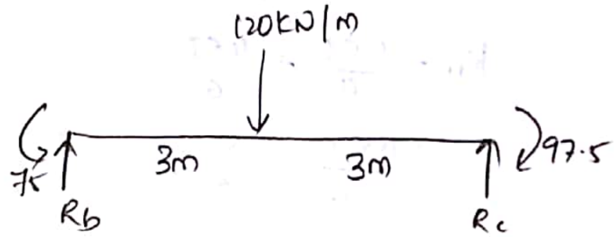
left to right – up ↑ +ve
down ↓ –ve

$-97.5 + Rc(6) + 75 - 120(3) = 0$

Right to left – clockwise is –ve
Anticlockwise is +ve.

$R_C = \frac{97.5 + 360 - 75}{6}$

$= 63.75$



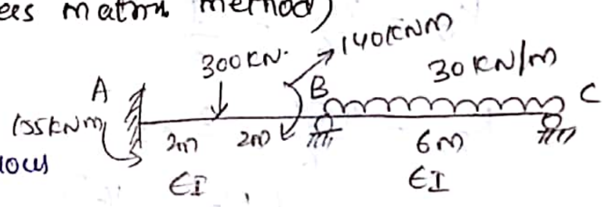
$Ra + Rb + Rc = 120 + 120$

$56.26 + Rb + 63.75 = 240$

$Rb = 120\ kN.$

→ Analyse the 2-span continuous beam as shown in the fig. Using displacement method (stiffness matrix method)

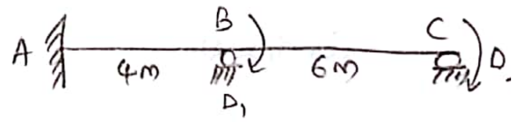
i) Evaluation of D_k (DOF)



By observation of above continuous beam the kinematic redundance $\theta_a, \theta_b, \theta_c$ as support A is fixed $\theta_A = 0$.

So that the kinematic redundance

$\theta_B = D_1$; $\theta_C = D_2$.



They are

ii) Evaluation of joints.

Span AB: $\overline{M}_{ab} = -\frac{300 \times 4}{8} = -150\ kN\text{-}m.$

$\overline{M}_{ba} = 150\ kN\text{-}m$

Span BC; $\overline{M}_{bc} = -\frac{30 \times (6)^2}{12} = -90\ kN\text{-}m$

$\overline{M}_{cb} = 90\ kN\text{-}m$

$P_B = 150 - 90 = 60 \, kN\text{-}m$

$\bar{M}_{ba} \sim \bar{M}_{bc}$.

$P_c = \bar{M}_{cb} = 90 \, kN\text{-}m$

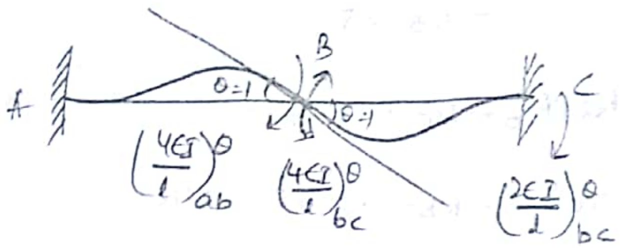
(iii) Evaluate stiffness co-efficient i.e., generation of stiffness matrix.

→ To get the 1st column of stiffness matrix apply unit rotation along coordinate 1.

$K_{11} = \frac{4EI}{4} + \frac{4EI}{6}$

$= \frac{10EI}{6} = \frac{5}{3}EI$

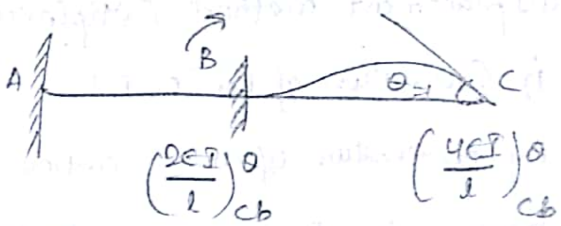
$K_{21} = \frac{2EI}{6} = \frac{1}{3}EI$



(ii) Apply unit rotation along coordinate 1 for 2nd column.

$K_{12} = \frac{2EI}{6} = \frac{EI}{3}$

$K_{22} = \frac{4EI}{6} = \frac{2}{3}EI$



$$[k] = EI \begin{bmatrix} 5/3 & 1/3 \\ 1/3 & 2/3 \end{bmatrix}$$

(iv) Evaluate the unknown values using the joint equilibrium condition

$K_{11} D_1 + K_{12} D_2 + P_1 = 0 \rightarrow (1)$

$K_{21} D_1 + K_{22} D_2 + P_2 = 0 \rightarrow (2)$

$\frac{5}{3} EI \, \theta_b + \frac{1}{3} EI \, \theta_c = -60 \rightarrow (1)$

$\frac{1}{3} EI \, \theta_b + \frac{2}{3} EI \, \theta_c = -90 \rightarrow (2)$

By solving (1) & (2)

$$EI\theta_b = -10 \Rightarrow \theta_b = \frac{-10}{EI}$$

$$EI\,\theta_c = -130 \Rightarrow \theta_c = \frac{-130}{EI}$$

(v) Evaluate the support/final moments at supports using slope deflection method.

$$M_{AB} = \bar{M}_{ab} + 2\left(\frac{EI}{l}\right)_{ab}\left[2\theta_a + \theta_b \pm \frac{3\delta}{l_{ab}}\right] \left[\because \delta = 0 \text{ a, b are at same level } \theta_a = 0\right].$$

$$= -150 + \frac{2EI}{4}\left[\frac{-10}{EI}\right]$$

$$= -155 \text{ kN-m.}$$

$$M_{BA} = 150 + \frac{2EI}{2}\left[2 \times \frac{-10}{EI}\right] = 140 \text{ kN-m.}$$

$$M_{BC} = -90 + \frac{2EI}{6}\left[\left(2 \times \frac{-10}{EI}\right) - \left(\frac{130}{EI}\right)\right]$$

$$= -90 + \frac{EI}{3}\left[\left(\frac{-20 - 130}{EI}\right)\right]$$

$$= -90 + \frac{EI}{3}\left[\frac{-150}{EI}\right]$$

$$= -140 \text{ kN-m.}$$

$$M_{CB} = \bar{M}_{cb} + \frac{2EI}{6}\left[2 \times \frac{-130}{EI} - \frac{10}{EI}\right]$$

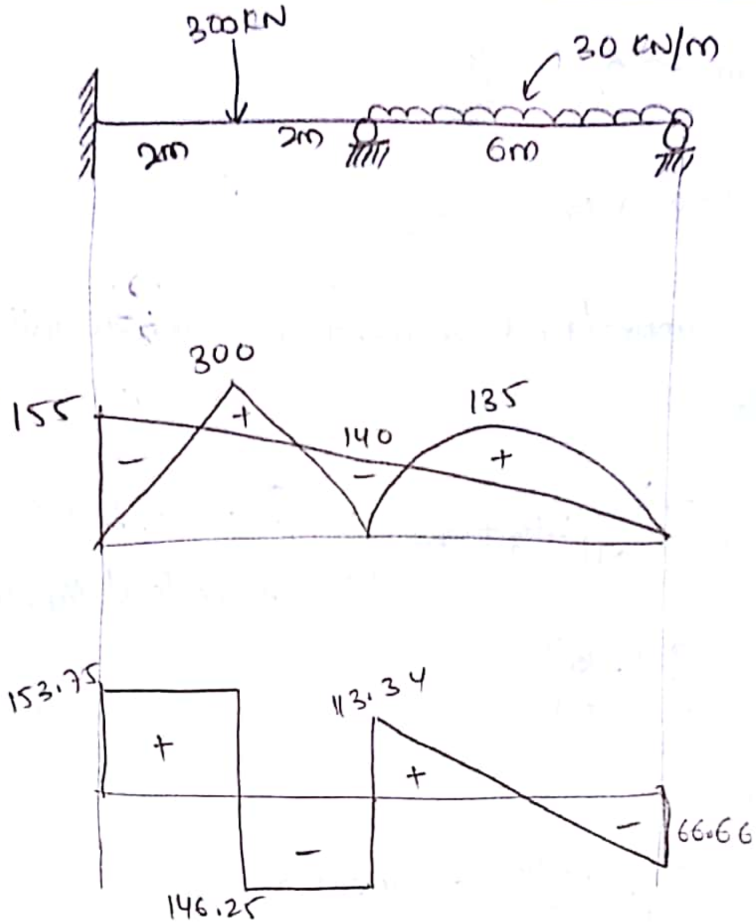
$$= -90 + \frac{EI}{3}\left[\frac{-260 - 10}{EI}\right]$$

$$= 90 + \left(\frac{-270}{30}\right) = 90 - 90 = 0.$$

(vi) Draw the bending moment diagram

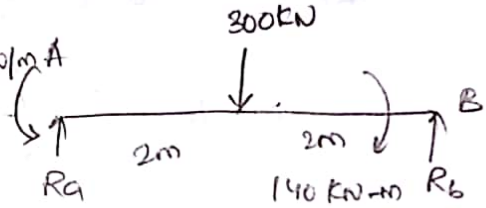
FBD: $\text{Span } AB = \frac{wl}{4} = \frac{300 \times 4}{4} = 300 \text{ kNm.}$

$$\text{Span } BC = \frac{wl^2}{8} = \frac{30(6)^2}{8} = 135 \text{ kN-m}$$



Evaluate the Support reactions to draw SFD.

$\Sigma M_b = 0$



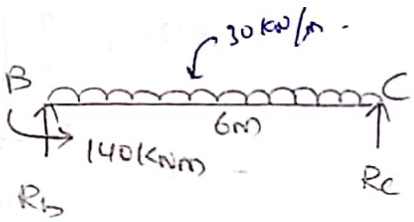
$-155 + R_a(4) - 300(2) + \cancel{140} = 0$

$$R_a = \frac{155 + 600 - 140}{4}$$

$= 153.75\,kN$

$\Sigma M_b = 0$ (Right)

$R_c(6) - 30 \times 6 \times \frac{6}{2} + 140 = 0$



$$R_c = \frac{540 - 140}{6} = \cancel{66.66\,KN} \; 67.5$$

$\Sigma V = 0$

$R_a + R_b + R_c = 300 + (300 \times 6)$

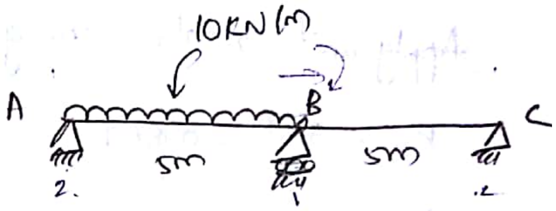
$153.75 + R_b + 66.66 = 300 + 180$

$R_b = 480 - 153.75 - 66.66$

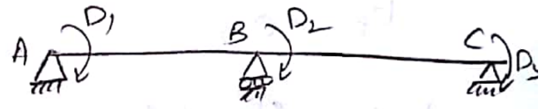
$R_b = 259.59\,KN$

→ Analyse the given Continuous beam using stiffness method (or) displacement method.

Step 1: In this beam Kinematic indeterminacy is 3.



D_1, D_2, D_3 are redundant rotation at A and B respectively



As Kinematic redundance is 3, the size of stiffness matrix is 3×3.

$3j - r$

Step 2: Evaluation of joint loads.

Span AB:

$$\bar{M}_{ab} = \frac{-10(5)^2}{12} = -20.83 \text{ KN-m.}$$

$$M_{ba} = 20.83 \text{ KN-m}$$

Span BC: $M_{bc} = 0$

$$M_{cb} = 0$$

because no external loads.

Joint loads

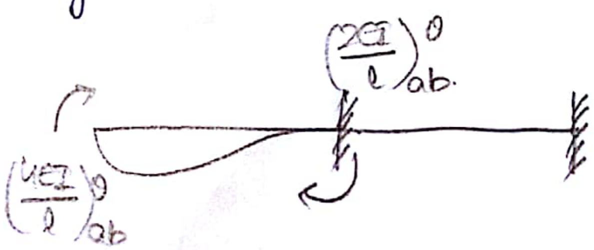
$P_1 = -20.83$, $P_2 = 20.83$ $(\bar{M}_{ba} \,\&\, \bar{M}_{bc} = 0)$

$P_3 = 0$

Step 3: Evaluate stiffness matrix.

→ Apply unit rotation along coordinate 1.

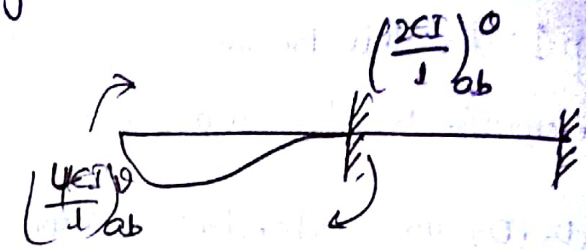
$$K_{11} = \frac{4EI}{5} = 0.8EI$$



$$K_{21} = \frac{2EI}{5} = 0.4EI$$

$K_{31} = 0.$

Apply unit rotation along coordinate 1

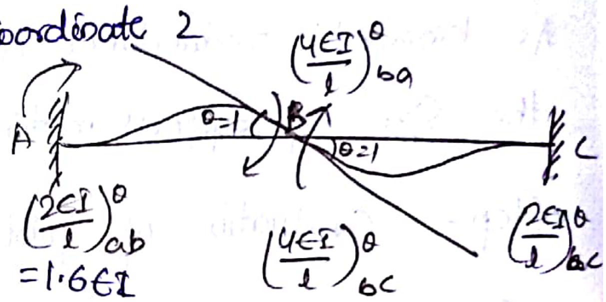


$K_{11} = \frac{4EI}{5} = 0.8EI$

$K_{21} = \frac{2EI}{5} = 0.4EI$

$K_{31} = 0$

Apply unit rotation along coordinate 2

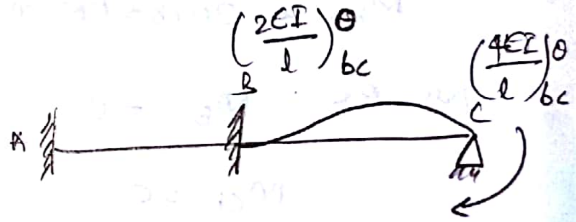


$K_{12} = \frac{2EI}{5} = 0.4EI$

$K_{22} = \frac{4EI}{5} + \frac{4EI}{5} = \frac{8EI}{5} = 1.6EI$

$K_{32} = \frac{2EI}{5} = 0.4EI$

Apply unit rotation along coordinate 3



$K_{13} = 0$

$K_{23} = \frac{2EI}{5} = 0.4EI$

$K_{33} = \frac{4EI}{5} = 0.8EI$

$$[K] = \begin{bmatrix} 0.8EI & 0.4EI & 0 \\ 0.4EI & 1.6EI & 0.4EI \\ 0 & 0.4EI & 0.8EI \end{bmatrix}$$

Step 4

→ Evaluate the unknown values i.e., rotations using known relationships or equilibrium conditions.

0.4
× 0.4

$$K_{11} D_1 + K_{12} D_2 + K_{13} D_3 + P_1 = 0$$

$$0.8EI \cdot D_1 + 0.4EI\, D_2 + 0 = 20.83 \rightarrow (1)$$

$$K_{21} D_1 + K_{22} D_2 + K_{23} D_3 + P_2 = 0$$

$$0.4EI D_1 + 1.6EI D_2 + 0.4EI D_3 = -20.83 \rightarrow (2)$$

$$K_{31} D_1 + K_{32} D_2 + K_{33} D_3 + P_3 = 0$$

$$0 + 0.4EI D_2 + 0.8 D_3 = 0 \rightarrow (3)$$

$\frac{6249}{1600}$

By solving 1, 2 and 3.

$+\frac{39.05}{EI}$

$$D_1 = \theta_1 = \frac{39.05}{EI}$$

-26.03

-13.018

$$D_2 = \theta_2 = \frac{-26.03}{EI}$$

$$D_3 = \theta_3 = +\frac{13.01}{EI}.$$

Step 5.

Evaluate the final moments (on) support moments.

$$M_{ab} = -20.83 + \frac{2EI}{5}\left[2 \times \frac{39.05}{EI} - \frac{26.03}{EI}\right]$$

78.10
-26.07
52.07

$$= -20.83 + \frac{2}{5}\left[78.1 - 26.03\right]$$

$$= -20.83 + \frac{2 \times 52.07}{5}$$

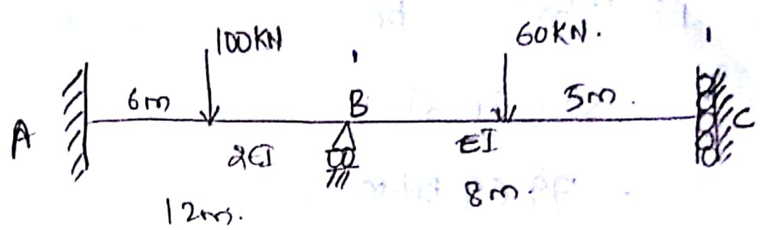
$$= 0.$$

$$M_{ba} = 20.83 + \frac{2EI}{5}\left[2 \times \frac{-26.03}{EI} + \frac{39.05}{EI}\right]$$

$$= 15.626 \text{ KN-m}$$

Scanned by CamScanner

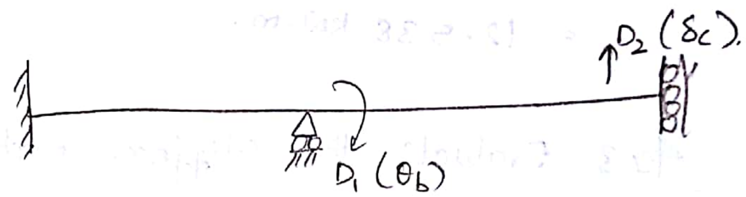
→ Analyse the continuous beam as shown in the fig using stiffness matrix method. support C is guided support.



Step 1:

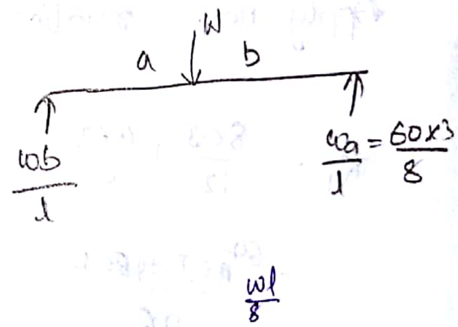
The continuous beam ABC having fixed at end A and roller support at end B as well as guiding support at C.

The kinematic redendents are rotation at B (θ_1) and vertical displacement at C (D_2)



Step:2:

Evaluate joint loads.



Span AB.

$$\bar{m}_{ab} = -\frac{100\times12}{8} = -150 \text{ KNm}$$

$$\bar{m}_{ba} = 150 \text{ KNm}.$$

Span BC.

$$m_{bc} = \frac{-wab^2}{l^2} = -\frac{60\times3\times5^2}{8^2}$$

$$= -70.31 \text{ KN-m}$$

$$m_{cb} = \frac{wa^2b}{l^2} = \frac{60\times3^2\times5}{8^2}$$

$$= 42.18 \text{ KN-m}$$

Joint loads :

$P_1 = \bar{m}_{ba} - \bar{m}_{bc}$

$= 150 - 70.31$

$= 79.69$ KN-m

$P_2 =$ total force acting at junction C $- \frac{1}{l}\{\bar{m}_{bc} + m_{ba}\}$.

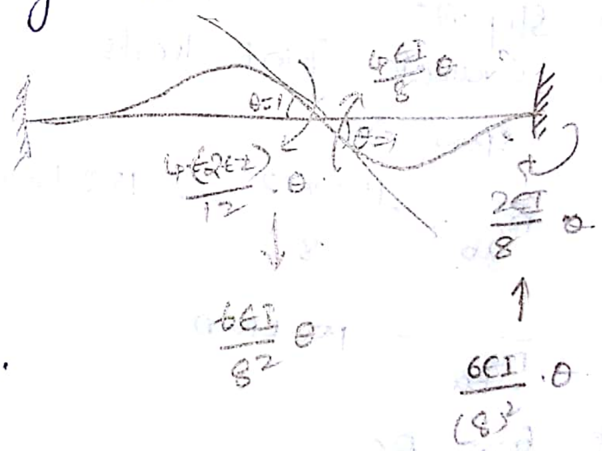
$= \boxed{\frac{60 \times 3}{8}} - \frac{1}{8}\{\underbrace{\bar{m}_{bc} + m_{ba}}_{-70.31+150}\} =$

$= 22.5 - 9.96$

$= 12.538$ KN-m.

Step 3: Evaluate the stiffness matrix

Apply uni. rotation along coordinate 1



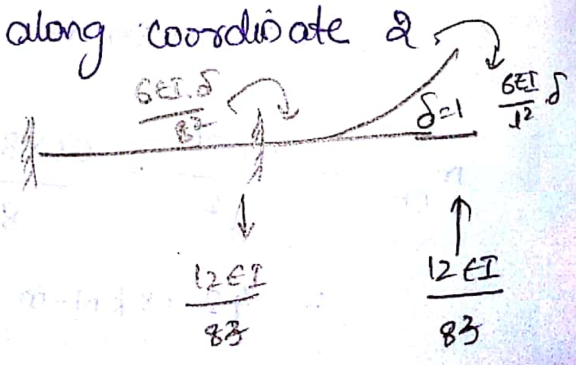
$K_{11} = \frac{8EI}{12} + \frac{4EI}{8}$

$= \frac{64EI + 48EI}{96}$

$= \frac{112EI}{96} = \frac{7}{6}EI.$

$K_{21} = \frac{6EI}{64}$

Apply unit displacement along coordinate 2



$K_{12} = \frac{6EI}{64}$

$K_{22} = \frac{12EI}{512}$

Apply the known relationships

$k_{11} D_1 + k_{12} D_2 + P_1 = 0$

$\frac{11\cancel{3}}{96} EI \cdot D_1 + \frac{6}{64} EI_{D_2} + 79.69 \rightarrow (1)$

$K_{21} D_1 + K_{22} D_2 + P_2 = 0.$

$\frac{6}{64} EI D_1 + \frac{12}{8^3} . EI D_2 + 12.528 \rightarrow (2)$

1.16

0.09

0.023

$D_1 = \theta_b = \frac{-30.3\cancel{6}}{EI}$

$D_2 = \delta_c = \frac{-489.84}{EI}.$

Evaluate final moments

$M_{AB} = \bar{m}_{ab} + \frac{2EI}{l}\left[2\theta_A + \theta_B + \frac{3\Delta}{l}\right]$

$M_{AB} = -150 + \frac{2EI}{12}\left[2 \times \left[\frac{-30.36}{EI}\right] + \left[-\frac{489.8}{EI}\right]\right]$

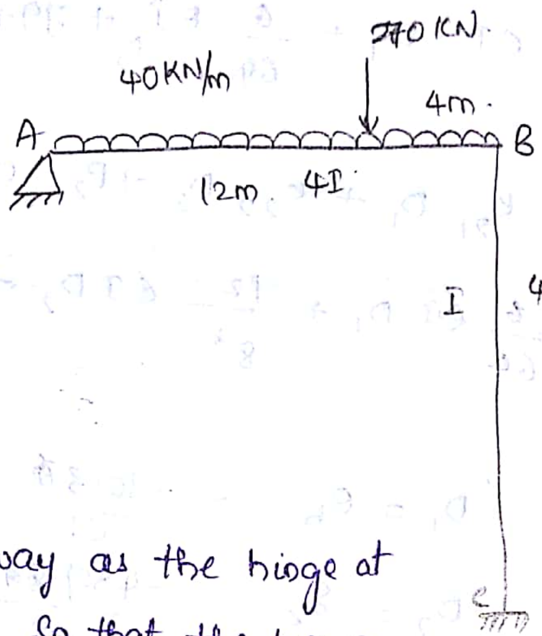
$M_{AB} = -241.75 \text{ kN-m}.$

$M_{BA} = \bar{m}_{ba} + \frac{2EI}{l}\left[2\theta_B + \theta_A + \frac{3\Delta}{l}\right]$

$= 150 + \frac{2EI}{12}\left[2 \times \left[\frac{-489.8}{EI}\right] + \left[-\frac{30.36}{EI}\right]\right]$

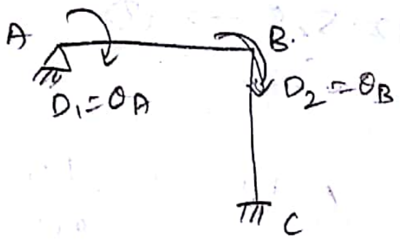
$M_{BA} = -18.32 \text{ kN-m}.$

→ Analyse the rigid frame as shown in the fig. using displacement method.



Step: 1:

Kinematic redendence.



The frame cannot sway as the hinge at 'A' prevents the swing so that the beam has 2 unknown redendants say θ_A and θ_B. but $\theta_C = 0$. (Because no chance of rotation as C is fixed)

Step 2: Evaluate the joint loads using the fixed end moments

$$\bar{m}_{ab} = -\frac{40(12)^2}{12} - \frac{270(8)(4)^2}{(12)^2} = -720 \text{ KN-m}$$

$$\bar{m}_{ba} = \frac{40(12)^2}{12} + \frac{270(8)^2(4)}{12^2} = 960 \text{ KN-m.}$$

$\bar{m}_{bc} = \bar{m}_{cb} = 0.$ (As there is no load on BC).

$P_1 = -720$ KN-m.

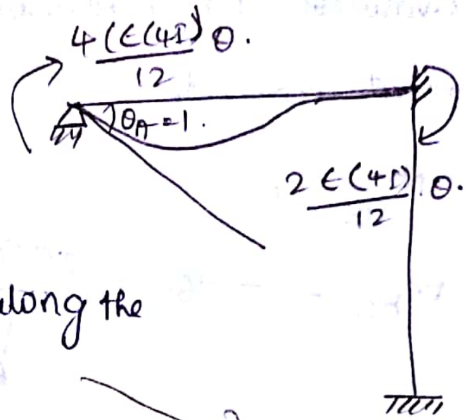
$P_2 = 960$ KN-m

Step: 3: ~~Generate~~ Generate stiffness matrix (or) stiffness matrix Coefficients -

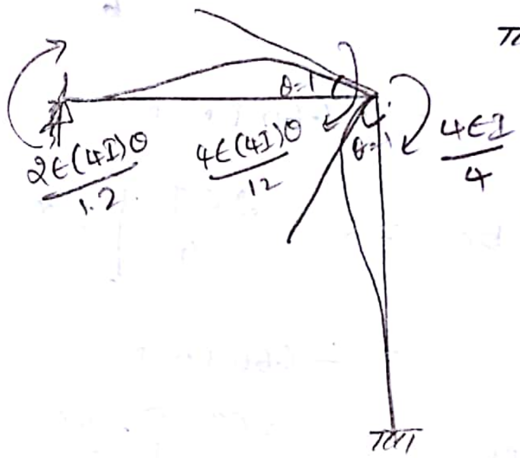
Apply the unit rotation along coordinate 2.

$K_{11} = \frac{4}{3} EI.$

$K_{21} = \frac{2}{3} EI$



Step 4: Apply unit rotation along the Coordinate 2.



$K_{12} = \frac{2}{3} EI$

$K_{22} = \frac{4}{3} EI + EI$

$= \frac{7}{3} EI$

Step 5: Evaluate the unknown values using the known relations (equilibrium conditions).

$K_{11} D_1 + K_{12} D_2 + P_1 = 0.$

$\frac{4}{3} EI . D_1 + \frac{2}{3} EI = 720 . \rightarrow \cancel{①}$

$4EI\, D_1 + 2EI D_2 = 2160 \rightarrow ①.$

$K_{21} D_1 + K_{22} D_2 = -P_2$

$\frac{2}{3} EI\, D_1 + \frac{7}{3} EI\, D_2 = -960.$

$\frac{2}{3} EI\, D_1 + 7 EI\, D_2 = -2880 \rightarrow ②.$

By solving ① & ②

$D_1 = \theta_A = \frac{870}{EI}$

$D_2 = \theta_B = -\frac{660}{EI}.$

Evaluate or determine, the final moments or support moments.

$$\begin{array}{r} +1320 \\ +870 \\ \hline 1350 \end{array}$$

$M_{ab} = 0$

$$M_{ba} = -960 + \frac{\cancel{2}E(4I)}{\cancel{12}\ 6}\left[\cancel{2}\times\frac{-660}{EI} + \frac{870}{EI}\right]$$

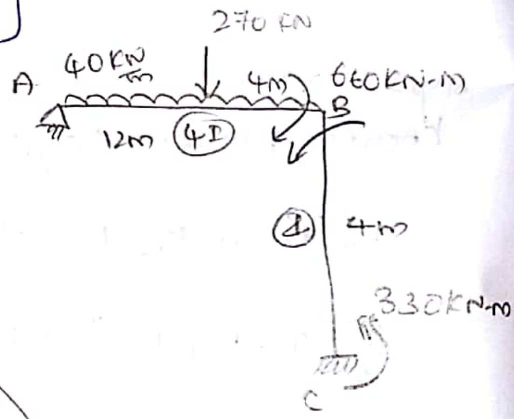
$= 660$ kN-m.

$$M_{bc} = 0 + \frac{2EI}{4}\left[2\times\frac{-660}{EI}\right]$$

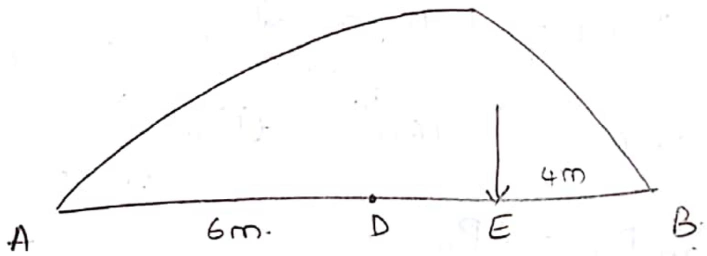
$= -660$ kN-m.

$$M_{cb} = 0 + \frac{2EI}{4}\left[\frac{-660}{EI}\right]$$

$= -330$ kN-m.



Draw BM diagram.



$$R_a = \overset{UDL}{\frac{40\times 12}{2}} + \overset{PL}{\frac{270\times 4}{12}}$$

$= 240 + 90 = 330$

~~$R_b = 240 + 180 =$~~

$$R_b = \frac{40\times 12}{2} + \frac{270\times(8)}{12}$$

$= 240 + 180 = 420$.

$$M_d = (330\times 6) - 40\times 6\times\frac{6}{2}$$

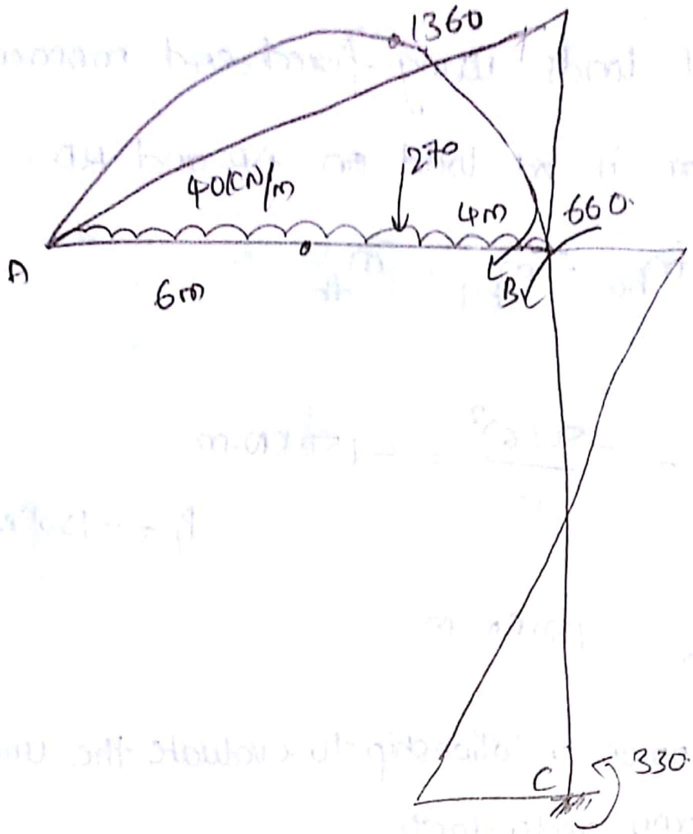
$= 1980 - 720$

$= 1260$

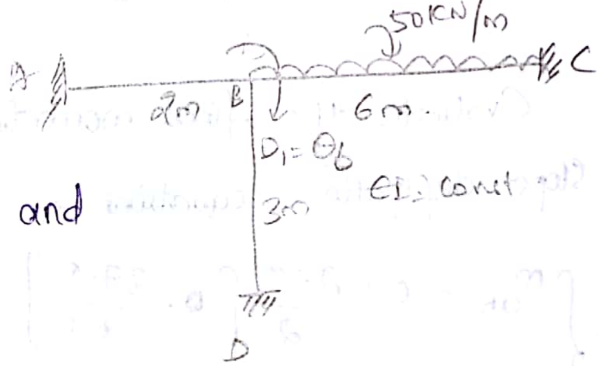
$$M_e = (420\times 4) - 40\times 4\times\frac{4}{2}$$

$= 1680 - 320$

$= 1360$



→ Draw the BM dia as shown in the fig. use system stiffness approach. The frame is built in A, B, C and it has a stiff joint at B. It covers a uniformly distributed load of intensity 50 kN/m on BC and each of uniform C/S.



Step 1:

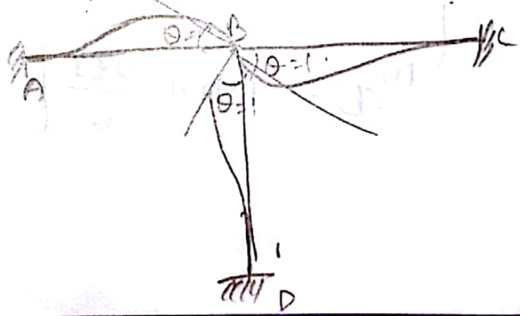
Kinematic redendency for the structure is 1 and it is at joint B.

$\theta_a = \theta_c = \theta_d = 0$

(As they are built in fixed)

Step 2:

Evaluate stiffness matrix coefficient. Apply unit rotation along joint B i.e., coordinate 1



$$K_{11} = \underset{(AB)}{\frac{4EI}{2}}(1) + \underset{(BC)}{\frac{4EI}{6}} + \underset{(BD)}{\frac{4EI}{3}}$$

$$= \frac{6EI + 2EI + 4EI}{3} = \frac{12EI}{3}$$

$$= 4EI$$

Evalue joint loads using fixed end moments.

As there is no load on AB and BD

$$\therefore \overline{m}_{ab} = \overline{m}_{ba} = \overline{m}_{bd} = \overline{m}_{db} = 0$$

$$\overline{m}_{bc} = \frac{-50(6)^2}{12} = -150\ \text{KN-m}.$$

$P_1 = -150\ \text{KN-m}$

$$\overline{m}_{cb} = 150\ \text{KN-m}.$$

Use the known relationship to evaluate the unknown values or unknown redendants.

$$K_{11} D_1 + P_1 = 0$$

$$\frac{4EI}{} D_1 = 150.$$

$$\theta_b = D_1 = \frac{37.5}{EI} \text{ radians.}$$

Evaluate the final moments on Support moments using Slope deflection equations.

Span AB

$$m_{ab} = 0 + \frac{2EI}{2}\left[0 \cdot \frac{37.5}{EI}\right] = 37.5\ \text{KN-m}.$$

$$m_{ba} = 0 + \frac{2EI}{2}\left[2 \times \frac{37.5}{EI} + 0\right] = 75\ \text{KN-m}.$$

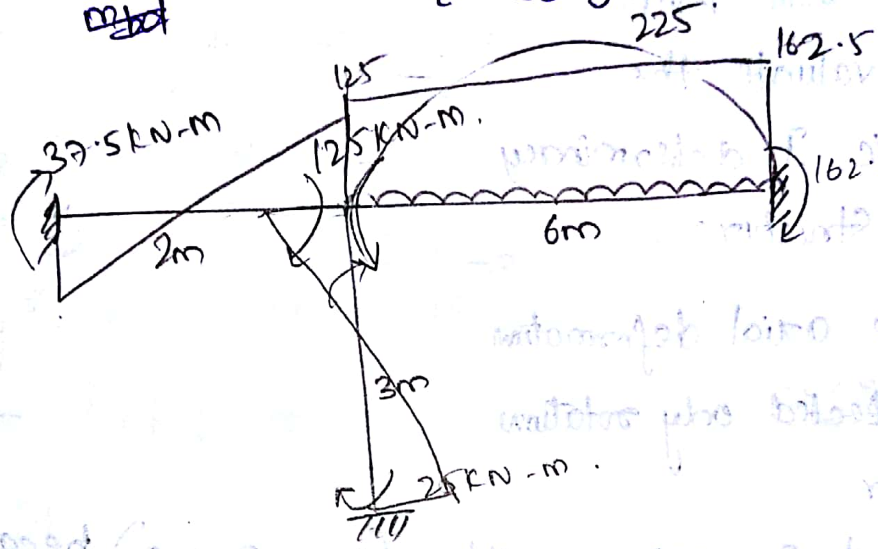
Span BC

$$m_{bc} = -150 + \frac{2EI}{6}\left[2 \times \frac{37.5}{EI} + 0\right] = -125\ \text{KN-m}$$

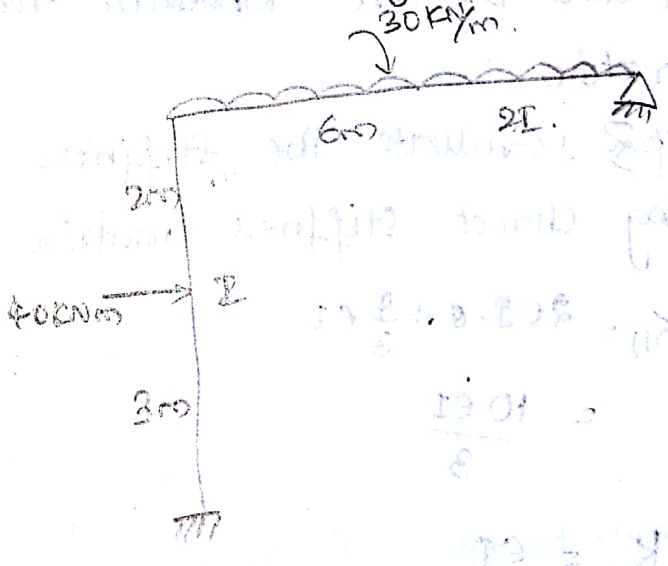
$$m_{cb} = 150 + \frac{2EI}{6}\left[\frac{37.5}{EI}\right] = 162.5\ \text{KN-m}$$

Span BD
$$m_{bd} = 0 + \frac{2EI}{3}\left[2 \times \frac{37.5}{EI}\right] = 50\ kN\text{-}m!$$

$$m_{db} = 0 + \frac{2EI}{3}\left[\frac{37.5}{EI}\right] = 25\ kN\text{-}m.$$

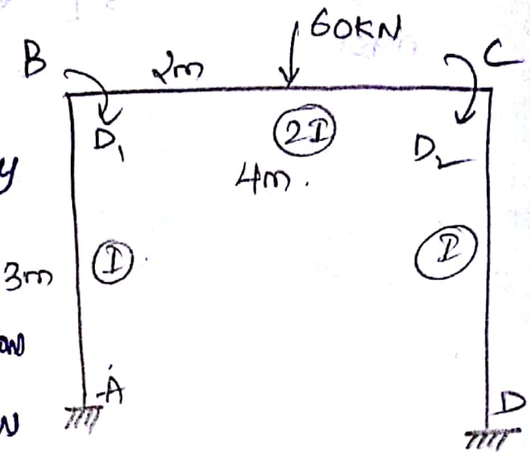


→ Compute the end moments for the frame as shown in the fig and draw the BM diagram.



Analysis of Symmetrical frames:

Analyse the Symmetrical frame by stiffness matrix method or using system approach also draw BMD.



Step 1: Evaluate the Kinematic Indeterminacy of the Structure.

As the axial deformation are neglected, only rotation can occur

θ_B and θ_C are possible $(\theta_A = \theta_D = 0)$ because A and D are fixed ends.

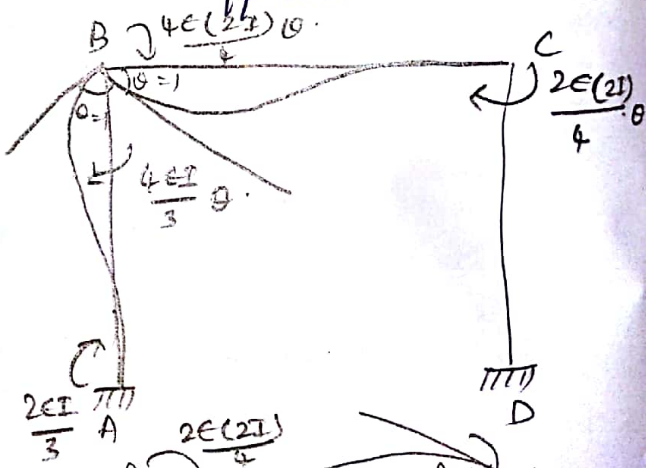
D_1 and D_2 are kinematic redendants in clockwise direction.

Step 2: Evaluate the stiffness matrix coefficients using direct stiffness matrix approach.

$$K_{11} = 2EI \cdot \theta + \frac{4}{3}EI$$

$$= \frac{10EI}{3}$$

$$K_{21} = EI$$

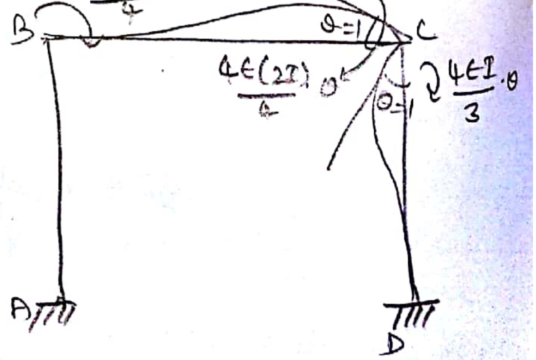


Apply unit rotation along the coordinate 2.

$$K_{12} = EI$$

$$K_{22} = 2EI + \frac{4}{3}EI$$

$$= \frac{10EI}{3}$$



Scanned by CamScanner

Step 2: Evaluate joint loads.

$\bar{m}_{ab} = \bar{m}_{ba} = 0.$

$\bar{m}_{bc} = -\frac{wl}{8} = -\frac{60\times4}{8} = -30\,kN\text{-}m$

$\bar{m}_{cb} = +30\,kN\text{-}m$

$\bar{m}_{cd} = \bar{m}_{dc} = 0.$

$P_1 = -30\,kN\text{-}m, \quad P_2 = 30\,kN\text{-}m.$

Step 4: Apply equilibrium conditions at joints.

$K_{11} \cdot D_1 + K_{12} \cdot D_2 + P_1 = 0$

$\frac{10}{3} EI D_1 + EI \cdot D_2 = 30 \rightarrow ①.$

(3.33)

$K_{21}\, D_1 + K_{22}\, D_2 + P_2 = 0.$

$EI.\, D_1 + 3.33.\, EI\, .D_2 = -30 \rightarrow ②.$

By solving ①, & ②

$D_1 = \theta_B = \frac{12.87}{EI}$

$D_2 = \theta_C = \frac{-12.87}{EI}.$

Step 5: Evaluate or determine the support moments or joint moments using slope deflection formula.

$\bar{m}_{ab} = 0 + \frac{2EI}{3}\left[\frac{12.87}{EI}\right] = 8.58\,kN\text{-}m$

$m_{ba} = 0 + \frac{2EI}{3}\left[2\times\frac{12.87}{EI}\right] = 17.16\,kN\text{-}m.$

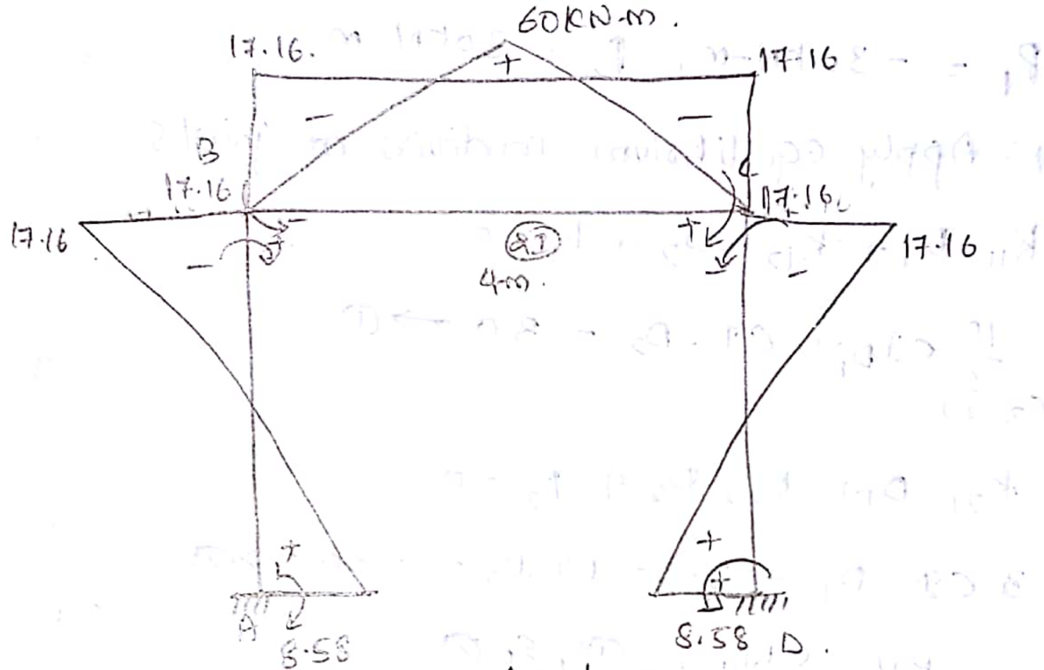
$m_{bc} = -30 + \frac{2E(2I)}{4}\left[2\times\frac{12.87}{EI} - \frac{12.87}{EI}\right] = -17.16\,kN\text{-}m$

$$m_{cb} = 30 + \frac{2E(2I)}{4}\left[2\times\frac{-12.87}{EI} + \frac{12.87}{EI}\right]$$

$$= 17.16\ KN\text{-}m.$$

$$m_{cd} = 0 + \frac{2EI}{3}\left[-2\times\frac{12.87}{EI}\right] = -17.16\ KN\text{-}m$$

$$m_{dc} = 0 + \frac{2EI}{3}\left[-\frac{12.87}{EI}\right] = -8.58\ KN\text{-}m.$$

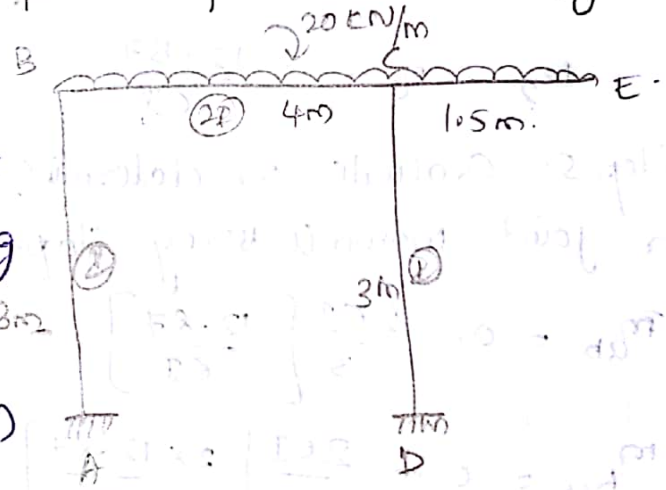


→ Analysis of unsymmetrical frames.

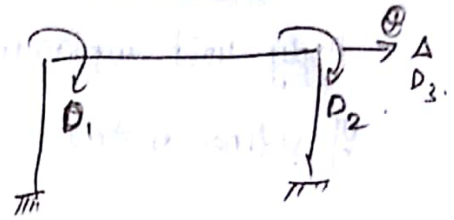
Draw the BMD for the frame shown in fig

step 1

This frame is assymmetrical w.r.t geometry and loading Hence the frame will get ~~by~~ sway (Δ)



The kinematic ~~of~~ redendants are θ_B and θ_C ($\theta_A = \theta_D = 0$) as ends A and D are fixed. So that the kinematic redands θ_B & θ_C are rotation in clockwise and is +ve.



Step 2: Evaluate joint load.

$\bar{m}_{ab} = \bar{m}_{ba} = 0$

$\bar{m}_{bc} = -\frac{wl^2}{12} = -\frac{20(4)^2}{12} = -26.67$ kN-m

$\bar{m}_{cb} = \frac{wl^2}{12} = \frac{20(4)^2}{12} = 26.67$ kN-m.

$\bar{m}_{ce} = -w \times l \times \frac{l}{2} = -20 \times 1.5 \times \frac{1.5}{2} = -22.5$ kN-m.

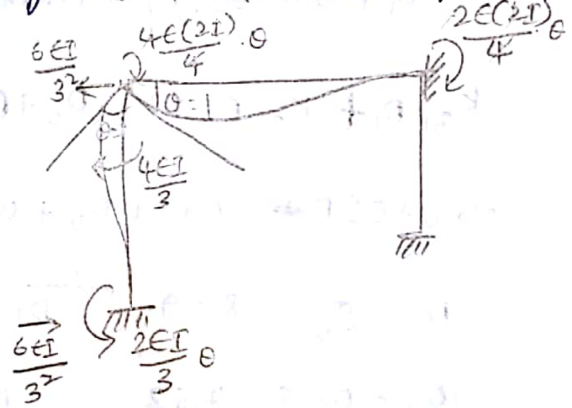
$P_1 = -26.67$ kN. $P_2 = 26.67 - 22.5$ kN-m
$= 4.17$ kN-m

$P_3 = 0$.

Step 3: Evaluate the stiffness matrix coefficients using

To generate the 1st column of stiffness matrix apply unit rotation along the coordinate 1.

$K_{11} = 2EI + \frac{4}{3}EI = \frac{10EI}{3}$
$= 3.33EI$



$K_{21} = EI$.

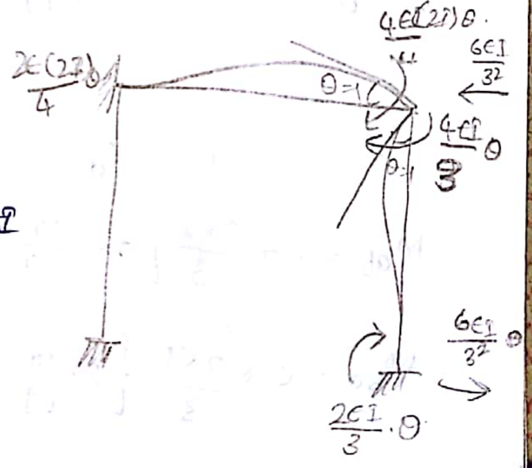
$K_{31} = -\frac{2}{3}EI = -0.67EI$.

To get the 2nd column of stiffness matrix apply unit rotation along coordinate 2

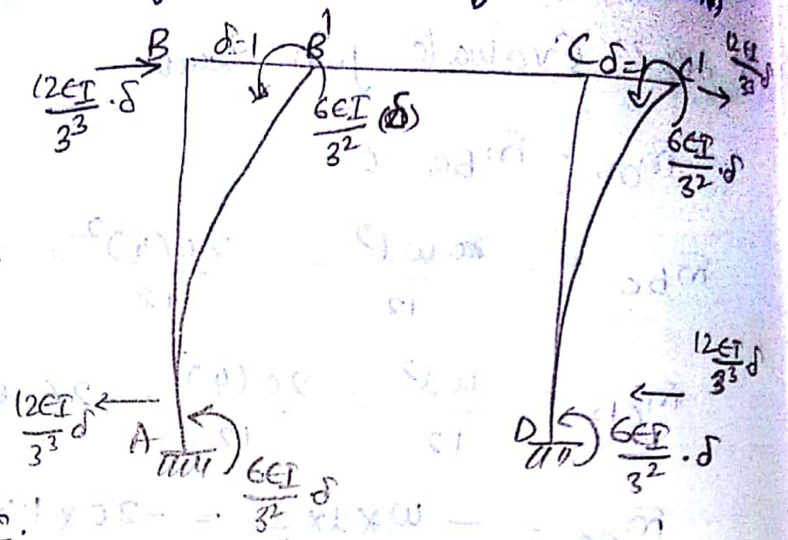
$K_{12} = EI$.

$K_{22} = 2EI + \frac{4}{3}EI = \frac{10EI}{3} = 3.33EI$

$K_{32} = -\frac{2}{3}EI = -0.67EI$



Apply unit displacement along coordinate 3 to get 3rd column of stiffness matrix



$K_{13} = -0.67EI$

$K_{23} = -0.67EI$

$K_{33} = \frac{12EI}{27} + \frac{12EI}{27}$

$= \frac{24}{27} EI = 0.88EI.$

Evaluate the unknown values using equilibrium condition

$K_{11} D_1 + K_{12} D_2 + K_{13} D_3 + P_1 = 0$

$3.33EI\ D_1 + EI\ D_2 - 0.67EI\ D_3 = 26.67 \rightarrow (1)$

$K_{21} \cdot D_1 + K_{22} D_2 + K_{23} D_3 + P_2 = 0.$

$EI \cdot D_1 + 3.33EI \cdot D_2 + 0.67EI\ D_3 = -4.17 \rightarrow (2)$

$K_{31} D_1 + K_{32} D_2 + K_{33} D_3 + P_3 = 0$

$-0.67EI D_1 + 0.67EI D_2 + 0.88EI \cdot D_3 = 0 \rightarrow (3)$

$D_1 = \theta_b = 8.59$ $\qquad D_1 = \theta_b = \frac{10.01}{EI}$

$D_2 = \theta_c = -4.62$ $\qquad D_2 = \theta_c = \frac{-3.21}{EI}$

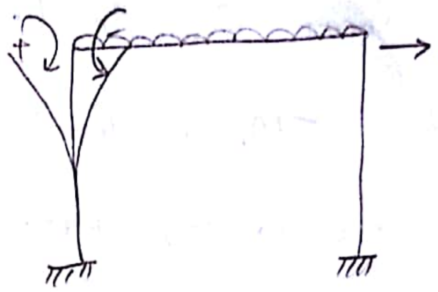
$D_3 = \delta = -3.97$ $\qquad D_3 = \delta = \frac{5.17}{EI}.$

$\theta_a = \theta_d = 0.$

$M_{ab} = 0 + \frac{2EI}{3}\left[0 + \frac{10}{EI} - \frac{3 \times 5.11}{EI(3)}\right] = +3.53\text{kN-m}.$

$M_{ba} = 0 + \frac{2EI}{3}\left[2 \times \frac{10}{EI} - \frac{3 \times 5.11}{3(EI)}\right] = 9.92\text{kN-m}$

$M_{bc} = -26.67 + \frac{2E(2I)}{4}\left[2\times\frac{10}{EI} - \frac{3.22}{EI}\right]$



$= -9.89$ kN·m $\left[\delta = 0 \text{, as B \& C are at same level}\right]$.

$M_{cb} = 26.67 + \frac{2E(2I)}{4}\left[2\times\frac{-3.22}{EI} + \frac{10}{EI}\right]$.

$= 30.23$ kN-m.

$M_{cd} = 0 + \frac{2EI}{3}\left[2\left(-\frac{3.22}{EI}\right) + 0 - \frac{3\times5.11}{EI(3)}\right]$

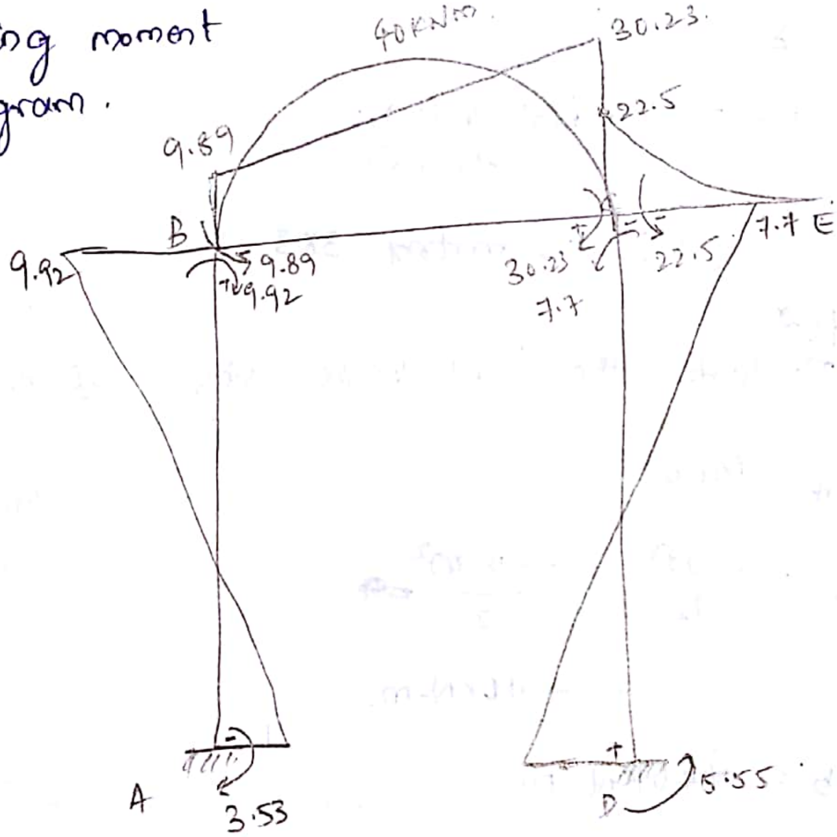
$= -7.7$ kN-m

$M_{dc} = 0 + \frac{2EI}{3}\left[0 - \frac{3.22}{EI} - \frac{3\times5.11}{3EI}\right]$

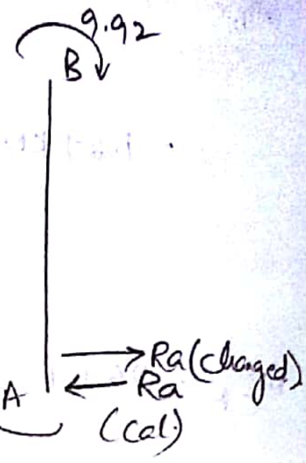
$= -5.55$ kN-m.

$M_{ce} = -22.5$.

Bending moment diagram.



~~Shear~~ Evaluate horizontal reactions at A.



$\Sigma M_b = 0$ (down)

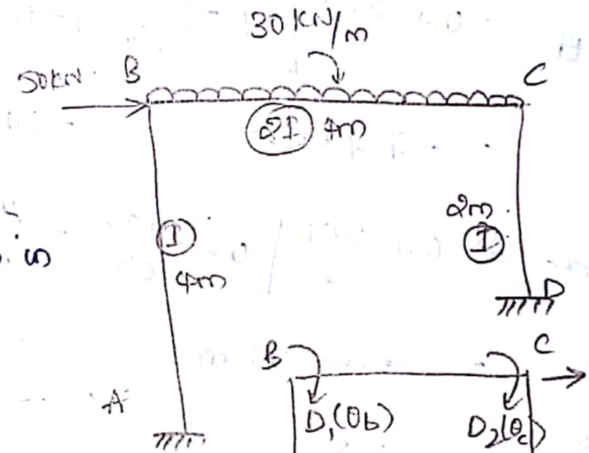
$3.53 + Ra(3) + 9.92 = 0.$

$$Ra = \frac{-9.92 - 3.53}{3}$$

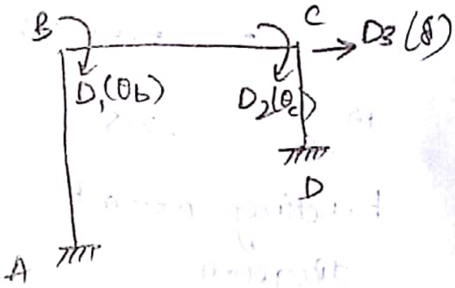
$Ra = -4.48\,kN.$

→ Draw the BMD and the elastic curve for the frame

Step 1: Evaluate the kinematic redundancy of the given frame.



D_1, D_2, D_3 as shown in the fig.



$D_1 = \theta_b$

$D_2 = \theta_c$

$D_3 = \delta$

$\theta_a = \theta_d = 0$ (as both ends are fixed).

Size of stiffness matrix 3x3.

Step 2:

Evaluate the joint loads using fixed end moments

$\bar{M}_{ab} = \bar{M}_{ba} = 0$

$$\bar{M}_{bc} = -\frac{wl^2}{12} = \frac{-30(4)^2}{12}$$

$= -40\,kN\text{-}m.$

$\bar{M}_{cb} = +40\,kN\text{-}m.$

$\bar{M}_{cd} = \bar{M}_{dc} = 0$ (as no load is acting).

joint loads from fixed end moments.

$D_1 = \bar{m}_{ba} \sim \bar{m}_{bc}$.

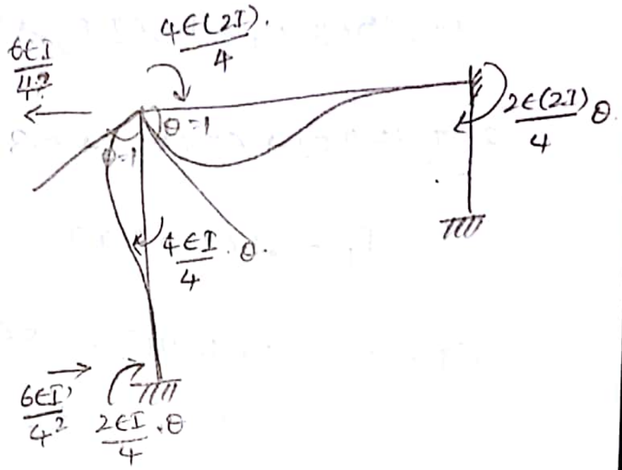
$= 0 - 40$ KN-m $= -40$ KN-m

$D_2 = 40$ KN-m.

$D_3 = 50$ KN.

→ Evaluate the stiffness matrix (SM).

To get the 1st column of SM apply unit rotation along coordinate 1



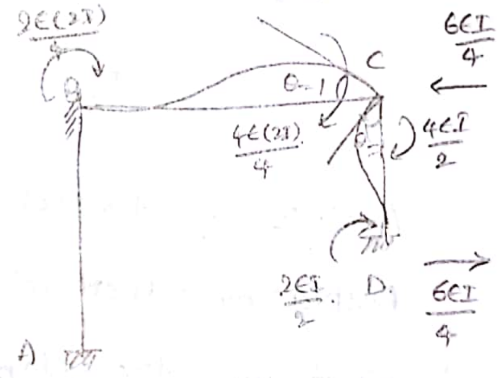
$K_{11} = 2EI\theta + EI$

$= 3EI$.

$K_{21} = EI$

$K_{31} = -0.375EI$.

To get the 2nd column of stiffness matrix apply unit rotation along coordinate 2.

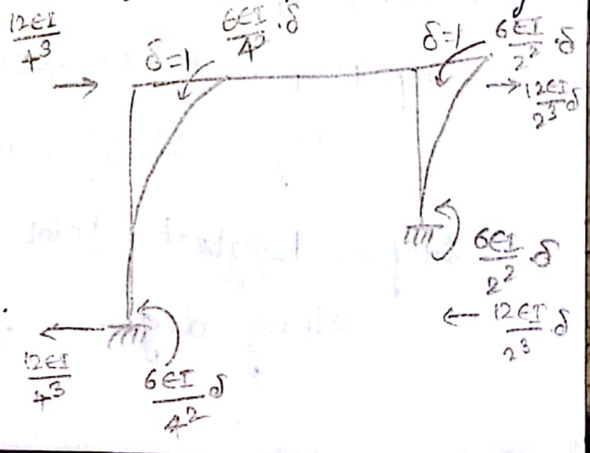


$K_{12} = EI$

$K_{22} = 2EI + 2EI = 4EI$.

$K_{32} = -1.5EI$.

To get the 3rd column of SM apply unit displacement along coordinate 3.



$K_{13} = \frac{-6EI}{4^2} = 0.375EI$

$K_{23} = -1.5EI$.

$K_{33} = \frac{12EI}{4^3} + \frac{12EI}{2^3} = 1.687EI$.

Evaluate the unknown values using equilibrium eqns

$K_{11}D_1 + K_{12}D_2 + K_{13}D_3 + P_1 = 0 \rightarrow ①$

~~$3EI\,D_1 + EI\,D_2 + 0.375EI\,D_3 + =$~~ $\rightarrow ①$

$K_{21}D_1 + K_{22}D_2 + K_{23}D_3 + P_2 = 0 \rightarrow ②$

~~$EI\,D_1 + 4EI\,D_2 + 1.5EI \cdot D_3 =$~~ $\rightarrow ②$

$K_{31}D_1 + K_{32}D_2 + K_{33}D_3 + P_3 = 0 \rightarrow ③$

~~$-0.375EI\,D_1 - 1.5EI\,D_2 + 1.687EI\,D_3 =$~~ $\rightarrow ③$

$3EI(-40) + EI(40) + 0.375(50) + P_1 = 0$

$P_1 = +61.25\,EI$

$EI(-40) + 4EI(40) - 1.5EI(50) + P_2 = 0$

$P_2 = -45\,EI$

$-0.375EI(-40) - 1.5EI(40) + 1.687EI(50) + P_3 = 0$

$P_3 = -39.35\,EI$

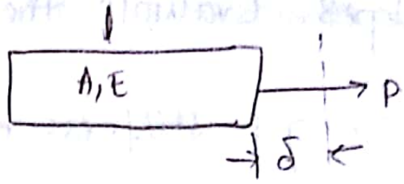
Analysis of trusses using stiffness matrix / Displacement method.

→ What are the steps involved to analyse stiffness matrix method:

Step 1: Evaluate Kinematic redundancy ~~indeterminacy~~ or provide degrees of freedom where possible.

Step 2: Evaluat Joint loads using unit displacements along degrees of freedom

$$\delta = \frac{Pl}{AE}$$



$$1 = \frac{Pl}{AE} \quad \frac{m^2}{m} \cdot \frac{N}{m^2}.$$

$$P = \frac{AE}{l}. \quad (AE = \text{rigidity modulus}) = \text{Axial rigidity}. \quad \frac{AE}{l} = \text{axial stiffness.}$$

Step 3: Evaluate unknown values i.e., degree of freedom using the equilibrium equation.

Step 4: Evaluate the unknown forces in the members due to loading.

~~Note~~: ~~Analyse~~ the given truss as shown in fig using stiffness matrix method.

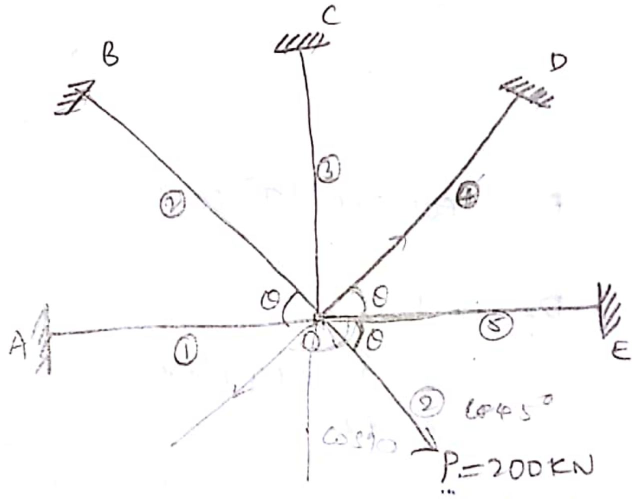
The axial load,

$P = 200$ KN.

and $\theta = 45°$

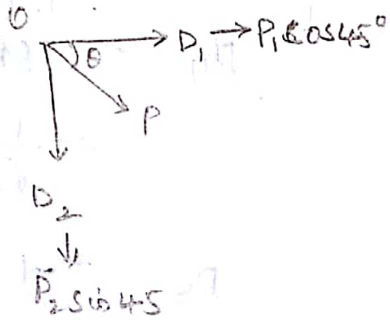
The axial stiffness

$\frac{AE}{l}$



The above system has 2 independent displacement say D_1 and D_2 at joint 'O' as shown in the fig.

Evaluate the joint loads.



$$P_1 = 200 \cos 45° = \frac{200}{\sqrt{2}}$$

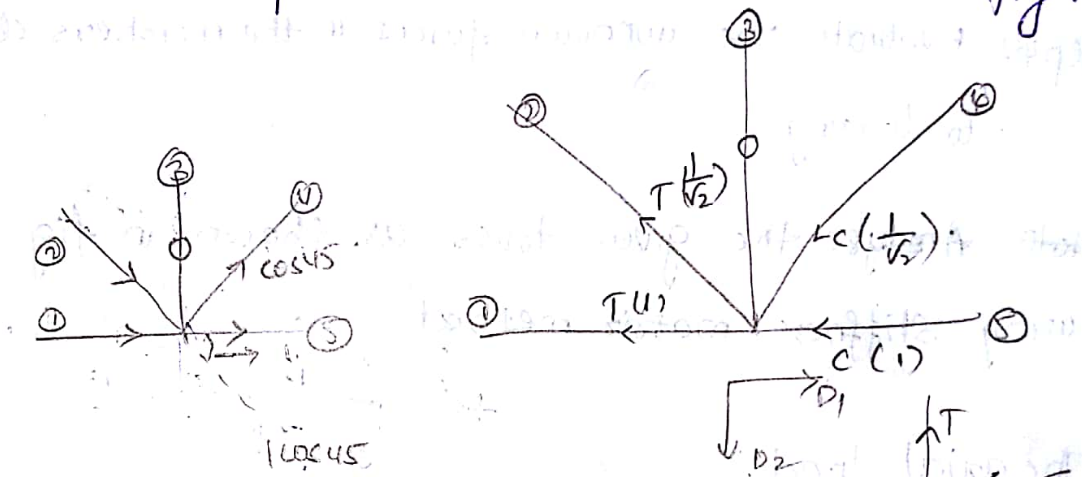
$$P_2 = 200 \sin 45° = \frac{200}{\sqrt{2}}$$

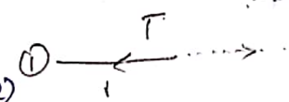
Step 3: Evaluate the stiffness matrix coefficients.

To get stiffness matrix, Apply unit displacement along D_1 and D_2 successively at 'O'.

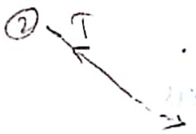
Apply unit displacement along D_1 (i.e., along coordinate 1) ("if the displacement induces tension in the member then it is positive and if it is compression then it is negative.

The displacements are as shown in the fig.



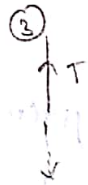


D_1 = ~~cos~~ 1.0 (T) (+ve)



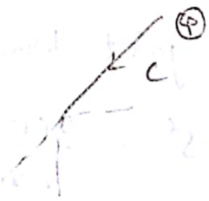
$D_2 = 1 \cos 45^\circ$

$= \frac{1}{\sqrt{2}}$ (T) (+ve)



$D_3 = \cos 90^\circ$

$= 0$



$D_4 = 1 \cdot \cos 45^\circ$ ~~1 sin 45°~~

$= -\frac{1}{\sqrt{2}}$ (C) (−ve)

$D_5 = -1$ (C) (−ve)

The Coefficients of matrix in 1st column

$$K_{11} = \frac{AE}{l}\left[+1+\frac{1}{\sqrt{2}}\cos 45+\frac{1}{\sqrt{2}}\cdot\cos 45^\circ+1\right]$$

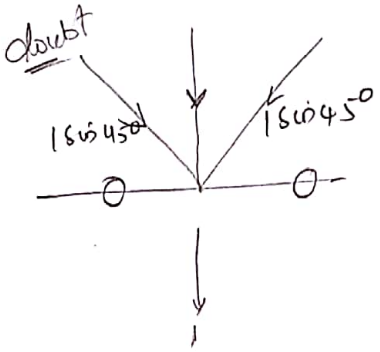
$$= \frac{AE}{l}\left[1+\frac{1}{\sqrt{2}}\times\frac{1}{\sqrt{2}}+\frac{1}{\sqrt{2}}\frac{1}{\sqrt{2}}+1\right] = \frac{3AE}{l}.$$

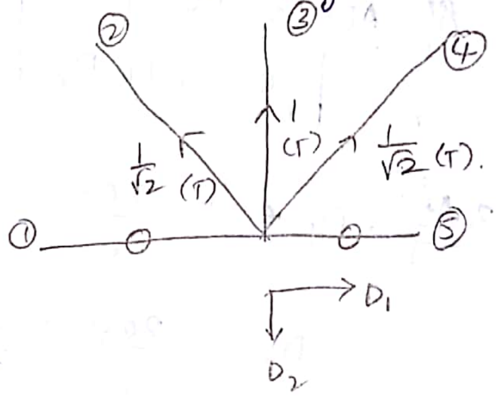
$$K_{21} = \frac{AE}{l}\left[0+\frac{1}{\sqrt{2}}\cdot\sin 45+0+\frac{1}{\sqrt{2}}\sin 45^\circ\right]$$

$$= \cancel{\frac{AE}{l}}\ 0.$$

Apply unit displacement Vertically along coordinate 2

$K_{21} =$





$D_1 = 0.$, $D_2 = \frac{1}{\sqrt{2}}$ (T) $D_3 = 1$ (T)

$D_4 = \frac{1}{\sqrt{2}}$ (T) $D_5 = 0.$

$$K_{12} = \frac{AE}{l}\left[0+\frac{1}{\sqrt{2}}\cos 45^\circ+0-\frac{1}{\sqrt{2}}\cos 45^\circ+0\right]$$

$$= 0.$$

$$K_{22} = \frac{AE}{l}\left[0+\frac{1}{\sqrt{2}}\sin 45^\circ+1+\frac{1}{\sqrt{2}}\sin 45^\circ+0\right]$$

$$= \frac{2AE}{l}.$$

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$$[K] = \frac{AE}{l}\begin{bmatrix} 3 & 0 \\ 0 & 2 \end{bmatrix}$$

Note: In pin jointed frames, the loads acts at joints (panel joints) and hence P is -ve. So that the relationship between the stiffness

$$\begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix}\begin{bmatrix} D_1 \\ D_2 \end{bmatrix} = \begin{bmatrix} P_1 \\ P_2 \end{bmatrix}$$

$$\cancel{K_{11} D_1 + K_{12} D_2 = P_1}$$

$$\cancel{\frac{AE}{l}} \frac{AE}{l}\begin{bmatrix} 3 & 0 \\ 0 & 2 \end{bmatrix}\begin{bmatrix} D_1 \\ D_2 \end{bmatrix} = \begin{bmatrix} 200/\sqrt{2} \\ 200/\sqrt{2} \end{bmatrix}$$

$$\frac{3AE}{l} \cdot D_1 \cancel{+} = \frac{200}{\sqrt{2}}$$

$$D_1 = \frac{200}{\sqrt{2}} \times \frac{l}{3AE}$$

$$= \frac{47.14\, l}{AE}$$

$$D_2 = \frac{200}{\sqrt{2}} \times \frac{l}{2AE}$$

$$= \frac{70.71\, l}{AE}.$$

→ list out memberal forces due to unit displacements along the redundant directions (K_{md})

$$K_{md} = \frac{AE}{l}\begin{bmatrix} 0 & 0 \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 0 & 1 \\ -\frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ -1 & 0 \end{bmatrix}$$

The final forces are calculated using the load relationship

$$\{K_{md}\}\begin{Bmatrix} D_1 \\ D_2 \end{Bmatrix} = \{P_m\}.$$

$$\frac{AE}{l}\begin{bmatrix} 0 & 0 \\ 1/\sqrt{2} & 1/\sqrt{2} \\ 0 & 1 \\ -1/\sqrt{2} & 1/\sqrt{2} \\ -1 & 0 \end{bmatrix} \frac{l}{AE}\begin{bmatrix} 47.14 \\ 70.71 \end{bmatrix} = \begin{bmatrix} P_1 \\ P_2 \\ P_3 \\ P_4 \\ P_5 \end{bmatrix}.$$

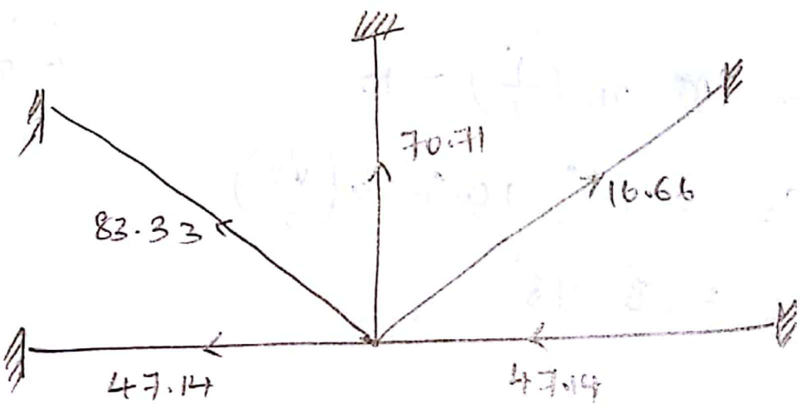
$P_1 = 47.14\,KN\,(T)$

$P_2 = 83.33\,KN\,(T)$

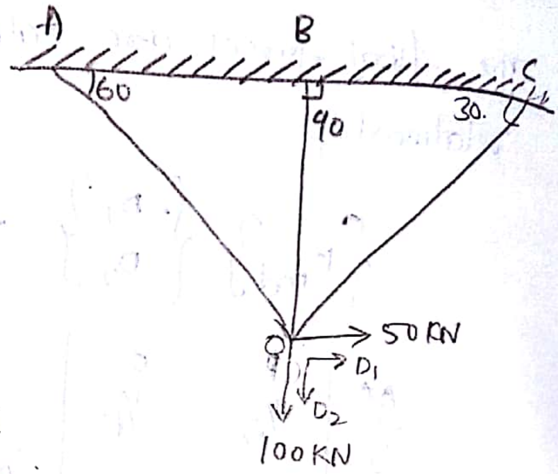
$P_3 = 70.71\,KN\,(T)$

$P_4 = 16.66\,KN\,(T)$

$P_5 = -47.14\,KN\,(C).$



→ Analyse the pinjointed truss as shown in fig by Stiffness method when axial stiffness of the members like $\left(\frac{AE}{l}\right)_{OA} = 20\,KN/mm$, $\left(\frac{AE}{l}\right)_{OB} = 60\,KN/mm$ and $\left(\frac{AE}{l}\right)_{OC} = 30\,KN/mm$.



Step 1: Assume the redundancy at 'O'

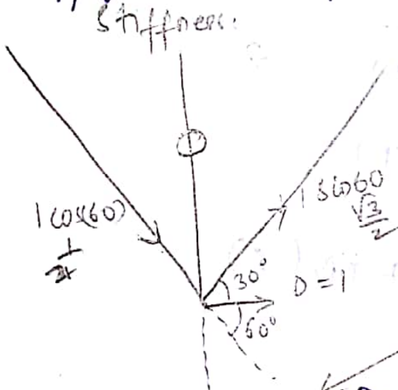
joint loads

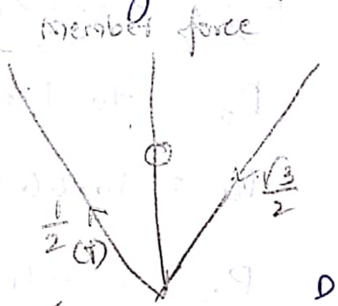
$P_1 = 50\,KN$.

$P_2 = 100\,KN$.

Evaluate memberal forces and stiffness matrix coefficients with uniform displacement along Coordinate 1 as well as 2.

Apply unit displacement along coordinate 1.





$D_1 = \left(\frac{AE}{l}\right) \cos 60$

$= 20 \cos 60$

$10\ \frac{1}{2}$

~~$D_1 = \frac{AE}{l}\ 20\left(\frac{1}{2}\right) = 10$~~

$D_1 = 20\left(\frac{1}{2}\right) + 0 + 30\left(\frac{\sqrt{3}}{2}\right)$

$= 35.98$

1

$D_1 = 20 \cdot \left(\frac{1}{2}\right) = 10$

$D_2 = 0$

$D_3 = 30 \frac{\sqrt{3}}{2} = 25.98$

$K_{11} = \left(\frac{1}{2} \cdot \frac{1}{2}\right) 20 + 0 + \left(\frac{\sqrt{3}}{2} \times \cos 30^\circ\right) 30$

$= 5 + \frac{3}{4} \times 30$

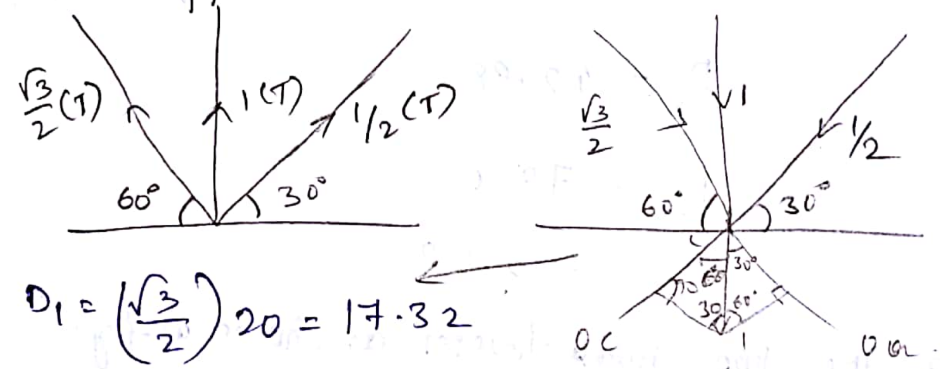
$= 27.5 \text{ kN}.$

$K_{21} = \left(\frac{1}{2} \sin 60^\circ\right) 20 - \left(\frac{\sqrt{3}}{2} \sin 30^\circ\right) 30.$

$= -4.33 \text{ KN}.$

||ly apply unit displacements along the coordinate 2.

Stiffner. Memberal forces.



$D_1 = \left(\frac{\sqrt{3}}{2}\right) 20 = 17.32$

$D_2 = 1(60) = 60$

$D_3 = \frac{1}{2}(30) = 15$

$K_{12} = \left(\frac{\sqrt{3}}{2} \cos 60^\circ\right) 20 + 0 - \left(\frac{1}{2} \cos 30^\circ\right) 30$

$= 8.66 - 12.99$

$= -4.33$

$K_{22} = 20\left(\frac{\sqrt{3}}{2} \sin 60\right) + 1(60) + \left(\frac{1}{2} \sin 30^\circ\right) 30$

$= 82.5$

$$\begin{bmatrix} 27.5 & -4.33 \\ -4.33 & 82.5 \end{bmatrix}\begin{bmatrix} D_1 \\ D_2 \end{bmatrix} = \begin{bmatrix} 50 \\ 100 \end{bmatrix}$$

Rep $\Rightarrow$ $27.5D_1 - 4.33D_2 = 50 \rightarrow (1)$

$-4.33D_1 + 82.5D_2 = 100 \rightarrow (2)$

$D_1 = 2.02$

$D_2 = 1.31$

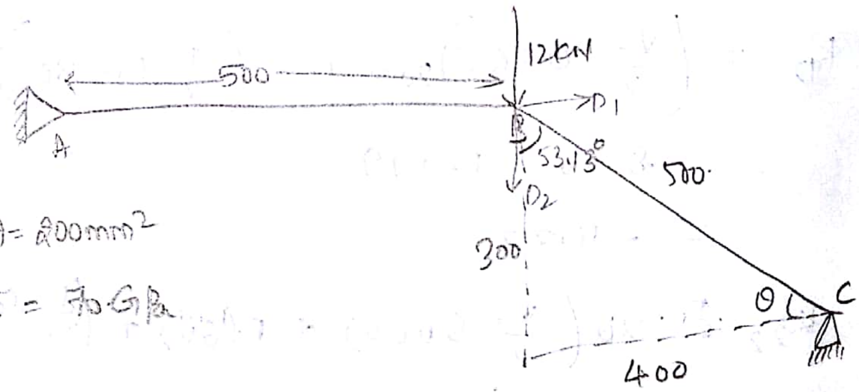
$$K_{red} = \begin{bmatrix} 10 & 17.32 \\ 0 & 60 \\ -25.98 & 15 \end{bmatrix}\begin{bmatrix} 2.02 \\ 1.31 \end{bmatrix} = \begin{bmatrix} P_1 \\ P_2 \\ P_3 \end{bmatrix}$$

$P_1 = 42.88$

$P_2 = 78.6$

$P_3 = -32.82$.

→ For the two bars trusses as shown in fig. determine the forces in the members. Take young's modulus $E = 70\,GPa$, c/s area of members $= 200\,mm^2$



$A = 200\,mm^2$

$E = 70\,GPa$

$\tan\theta = \frac{300}{400} = \frac{3}{4}$

$\theta = \tan^{-1}(3/4)$
$= 36.87$

Step-1 Axial stiffness of the member.

$1 GPa = 10^9 MPa$

$1 kN = 10^3 N$

$1 Pa = 10^6 N$.

$$P = \left(\frac{AE}{L}\right)_{ab\,(or)\,bc} = \frac{\frac{200 \times 70 \times 10^9}{10^3 \times 10^6}}{500} = 28 kN/mm$$

Hence the size of stiffness matrix is 2x2

Step 2: Calculate the joints

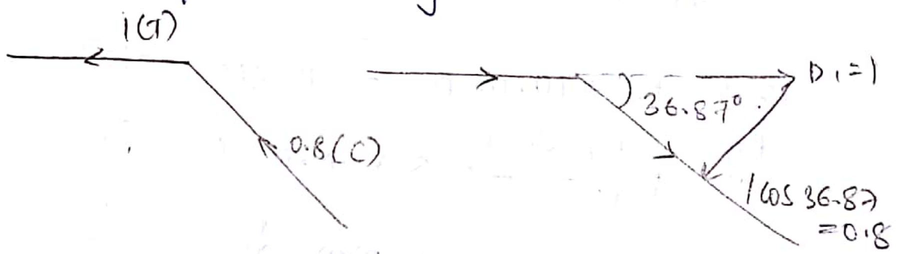
$P_1 = 0 kN$.

$P_2 = 12 kN$

$$P = \begin{bmatrix} 0 \\ 12 \end{bmatrix}$$

Step 3: Evaluate the stiffness matrix coefficients and memberal forces.

Apply unit displacement along the coordinate 1.



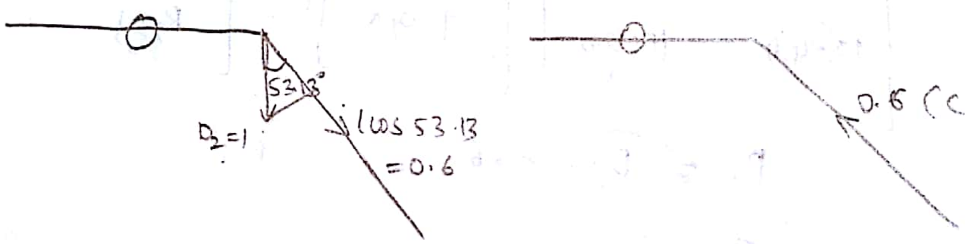
$K_{11} = (1)(28) + (0.8 \cos(36.87)) \times 28$

$= 45.902 kN$

$K_{21} = 0 + (0.8 \times \sin 36.87) \times 28$

$= 13.44 kN$.

Similarly apply unit displacement along coordinate 2.



$$K_{12} = 0 + (0.6 \times \sin 53.13)\,28$$
$$= 13.44$$

$$K_{22} = 0 + (0.6 \cos 53.13)\,28$$
$$= 10.08$$

$$[K] = \begin{bmatrix} 45.92 & 13.44 \\ 13.44 & 10.08 \end{bmatrix}$$

Step: 4: Calculate the redundant forces using joint equilibrium conditions.

$$K_{11} D_1 + K_{12} D_2 = P_1$$

$$45.92 \times D_1 + 13.44 D_2 = 0 \rightarrow (1)$$

$$K_{21} D_1 + K_{22} D_2 = P_2$$

$$13.44 D_1 + 10.08 D_2 = 12\text{ KN} \rightarrow (2)$$

By solving (1) & (2)

$$D_1 = -0.57 \text{ mm. } (\leftarrow)$$

$$D_2 = 1.95 \text{ mm } \downarrow$$

Evaluate the forces in the members using the known relationships.

$$[K_{md}] \begin{Bmatrix} D_1 \\ D_2 \end{Bmatrix} = \begin{Bmatrix} P_1 \\ P_2 \end{Bmatrix}$$

$$\begin{bmatrix} 45.92 & 13.44 \\ 13.44 & 10.08 \end{bmatrix} \begin{bmatrix} -0.57 \\ 1.95 \end{bmatrix} = \begin{bmatrix} P_1 \\ P_2 \end{bmatrix}$$

$$P_1 = 0.0336$$

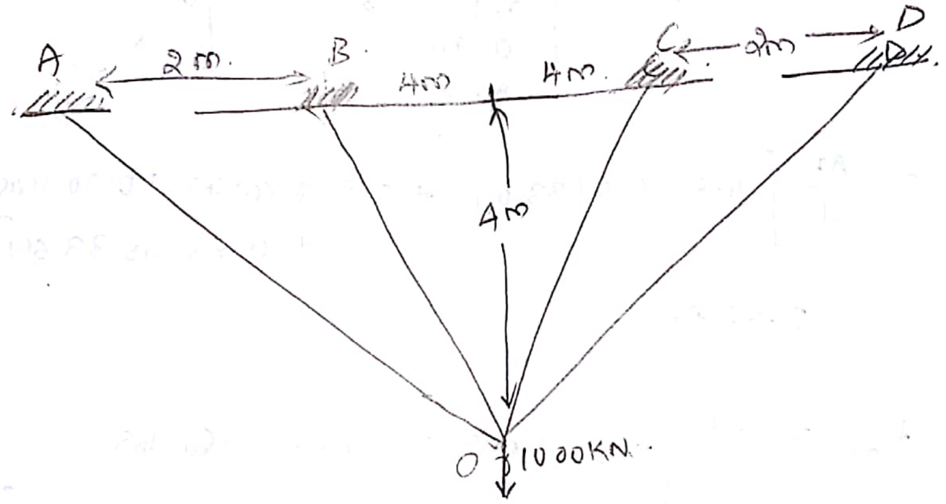
$$P_2 =$$

$$\begin{bmatrix} 1 & 0 \\ -0.8 & -0.6 \end{bmatrix} \begin{bmatrix} -0.571 \\ 1.95 \end{bmatrix} = \begin{bmatrix} f_1 \\ f_2 \end{bmatrix}$$

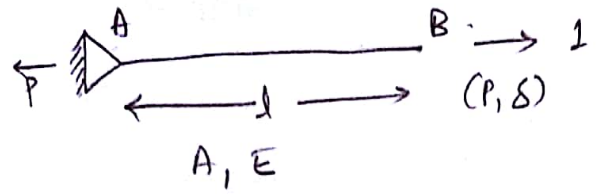
$f_1 = -0.571$ KN (C).

$f_2 = -0.714$ KN (C)

Evaluate the forces in the members OA, OB, OC, OD using stiffness matrix method. The C/S area of all members are constant and youngs modulus also.



→ Explain the Coordinate System.



(one-dimensional)

Consider a bar 'AB' of length 'L'. end ~~hated~~ in position at A and free to move at B. If a force acts at B as shown in the fig. above.

Hinge A will ~~move~~ develop a force 'P' towards left of 'A'. i.e., bar AB will stretch by value of δ.

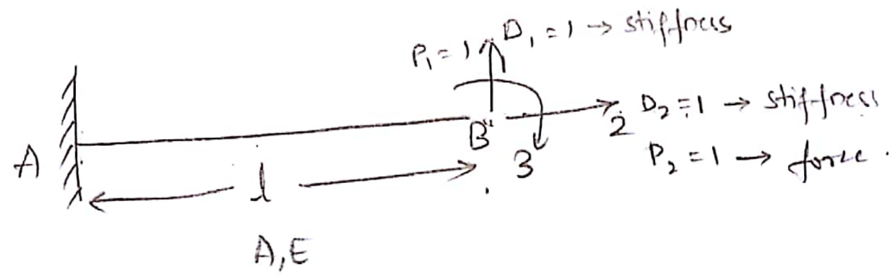
$$\delta = \frac{Pl}{AE}$$

'B' will move towards right by $\frac{Pl}{AE}$

In shortcut the stiffness of the member is assumed from δ. i.e.,

$$K = \frac{P}{\delta} = \frac{AE}{l}. \rightarrow \text{stiffness matrix}$$

$$f = \frac{l}{AE} = \frac{1}{k} = \frac{\delta}{P} \rightarrow \text{flexibility.}$$



The arrow at B defines the coordinates and it indicates the point and the direction either the force 'P' or the displacement 'δ' based on which flexibility or stiffness are defined.

→ What is transformation matrix (or) rotation matrix

→ different types of Coordinate systems

① Global Coordinate System / Cartesian Coordinate System.

② Local coordinate system; may have (x, y) and also (x, y, z)

→ taking any end on a line as origin.

③ Natural Coordinate System.

→ taking an origin inside the specified line.

ξ – Jhi → horizontal axis

η → eta → vertical axis

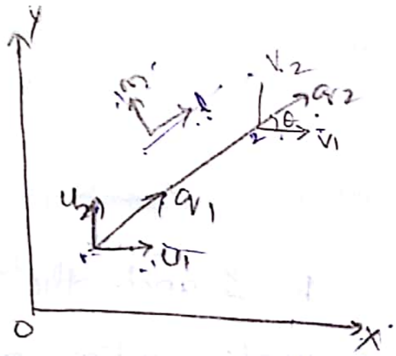
ζ → Gita → for inclined / z axis.

Transformation matrix.

Let us consider a truss element as shown in fig. q_1 and q_2 are the displacements of the node 1 and node 2 (or) end 1 and end 2.

X, Y = Global coordinates

l, m = local coordinates.



In the initial coordinate system the displacements are (u_1, v_1) and (u_2, v_2) at node 1 & 2 resp.

$$\cos\theta = x_1 / u_1$$

$$x_1 = u_1 \cos\theta.$$

$$\sin\theta = \frac{x_2}{v_1}$$

$x_2 = v_1 \sin\theta$

$q_1 = x_1 + x_2$

$= u_1 \cos\theta + v_1 \sin\theta$.

lly, $q_2 = u_2 \cos\theta + v_2 \sin\theta$.

$$\begin{Bmatrix} q_1 \\ q_2 \end{Bmatrix} = \begin{Bmatrix} \cos\theta & \sin\theta & 0 & 0 \\ 0 & 0 & \cos\theta & \sin\theta \end{Bmatrix} \begin{Bmatrix} u_1 \\ v_1 \\ u_2 \\ v_2 \end{Bmatrix}$$

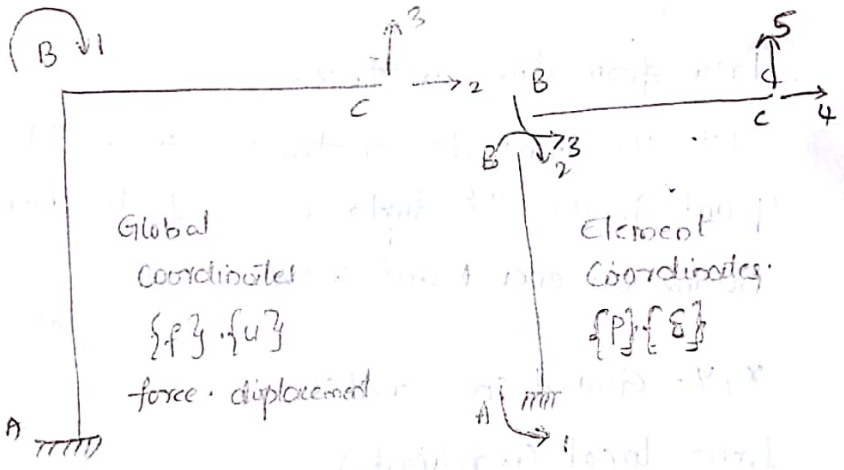
The post transformation matrix is used to convert the local co-ordinate system into global coordinate system.

Note:

This transformation matrix is also used for displacements.

→ ~~Irrespective~~ of

→ Explain the transformation ~~of~~ coordinates.



For 1 and the same structure we can choose the coordinate system most suited to aim solution in problem solving, it is useful to define a coordinate system dealing with the entire structure, coordinates are assigned to locations i.e., especially at nodes or joints. where, the loads are likely to be act. This kind of coordinates are called system of coordinates or Global Coordinates.

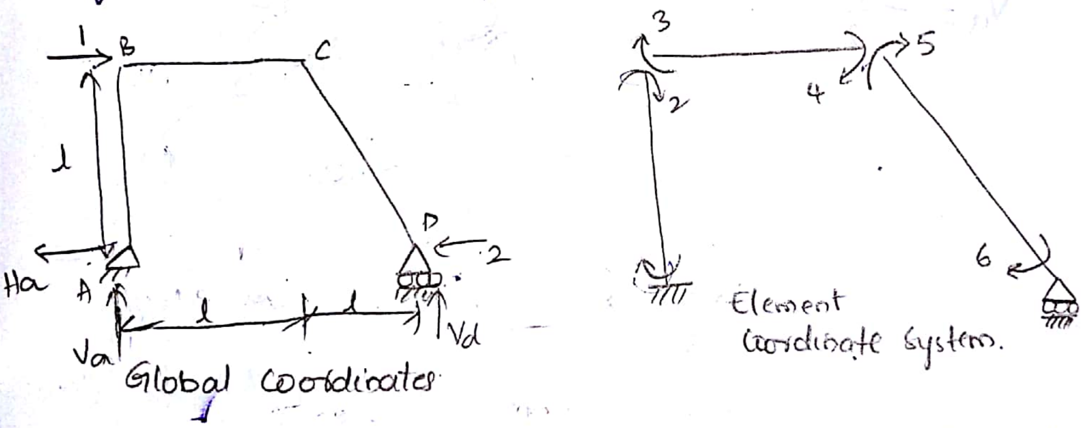
In Global coordinates force and displacement are denoted as f and u. where as in element Coordinates they are P and δ. this { } are taken because it indicates column matrix. $\begin{bmatrix} P_1 \\ P_2 \end{bmatrix}_{1\times 2}$

The two Coordinate System differed only Orientation. In present case, the two Sets of coordinates appear to be unrelated but all these say relate to the structure.

let us derive a transformation matrix such as

$\{P\} = [b]\{F\}$

Generate the transformation matrix 'b' for the given coordinate system.



By the observations of the both coordinate system the size of transformation matrix is 6×2.

To get the 1st column of transformation matrix apply unit force along coordinate 1.

when $f_1 = 1$ then $f_2 = 0$.

$\Sigma V = 0$

$V_a + V_d = 0$

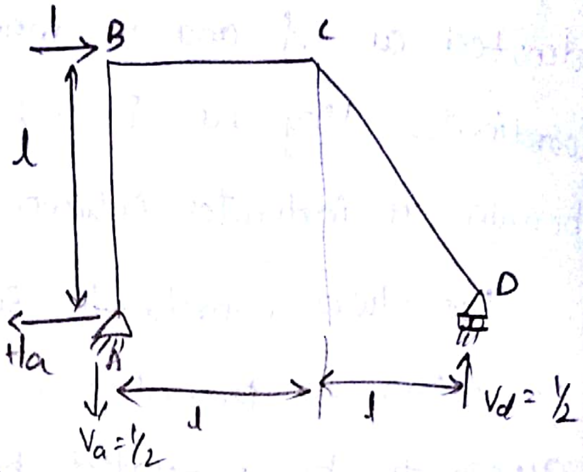
$V_a = -V_d \rightarrow ①$

$\Sigma H = 0$

$-H_a + 1 = 0$

$-H_a = -1$

$H_a = 1$



$\Sigma M_d = 0$

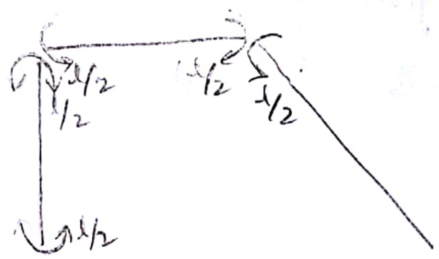
$V_a(2l) + 1(l) = 0$

$V_a = \frac{-l}{2l} = -\frac{1}{2} (\downarrow)$

$-V_d = -\frac{1}{2}$

$V_d = \frac{1}{2} (\uparrow)$

$V_a = -\frac{1}{2}$



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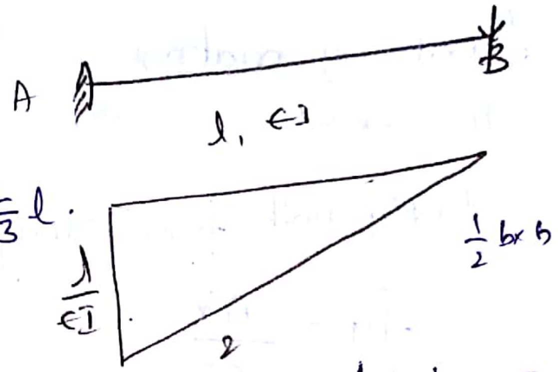
Generate a flexibility matrix for the given co-ordinates

To calculate or determine the first column of flexibility matrix.

Apply unit force along co-ordinate ①

$$f_{11} = \frac{A\bar{x}}{EI}$$



$$f_{11} = \left\{ \frac{\frac{1}{2} \times l \times l}{EI} \right\} \times \frac{2}{3} l.$$

$$f_{11} = \frac{l^2}{2EI} \times \frac{2}{3} l.$$

$\frac{1}{2} l \times b$ $\quad$ $\frac{2}{3} l$ $\quad$ $\frac{l}{EI}$

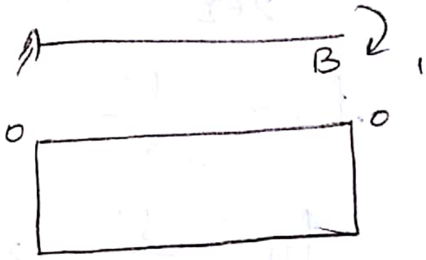
$$f_{11} = \frac{l^3}{3EI}.$$

$$f_{21} = \frac{1}{2} \times l \times \frac{l}{EI}$$

$$f_{21} = \frac{l^2}{2EI}.$$

Apply unit moment along coordinate ②

$$f_{12} = 1 \times \frac{1}{EI} \times \frac{l^2}{2}$$



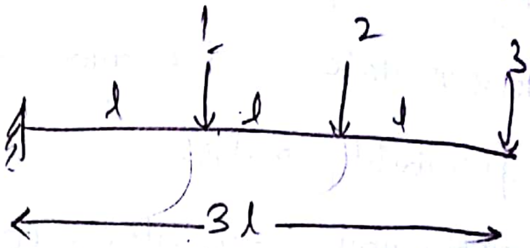
$$f_{12} = \frac{l^2}{2EI}$$

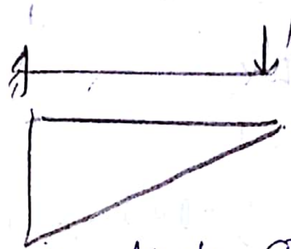
$$f_{22} = \frac{l}{EI}$$

$$[f] = \frac{1}{EI} \begin{bmatrix} l^3/3 & l^2/2 \\ l^2/2 & l \end{bmatrix}$$

Evaluate the flexibility matrix for the given Coordinates System.

As the given Coordinates are '3' the size of flexibility matrix is 3x3.



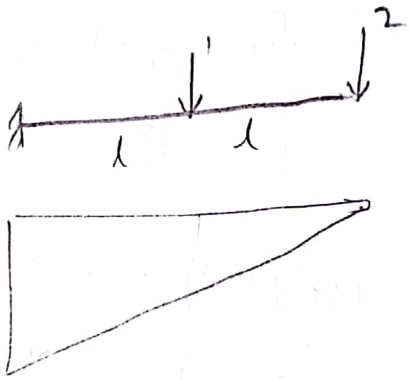


→ Apply unit force along coordinate 1

$$f_{11} = \frac{A\bar{x}}{EI}$$

$$= \frac{\left\{\frac{1}{2} \times l \times l\right\}}{EI} \times \frac{2}{3} l.$$

$$f_{11} = \frac{l^3}{3EI}.$$



$$f_{21} = \frac{l^2}{2EI} \times \left(l + \frac{2}{3} \times l\right)$$

$$= \frac{l^2}{2EI} \times \left(\frac{5l}{3}\right)$$

$\frac{l^2}{2EI}\left(l+\frac{5}{3}l\right)$ Ans

$$f_{21} = \frac{5l^3}{6EI}$$

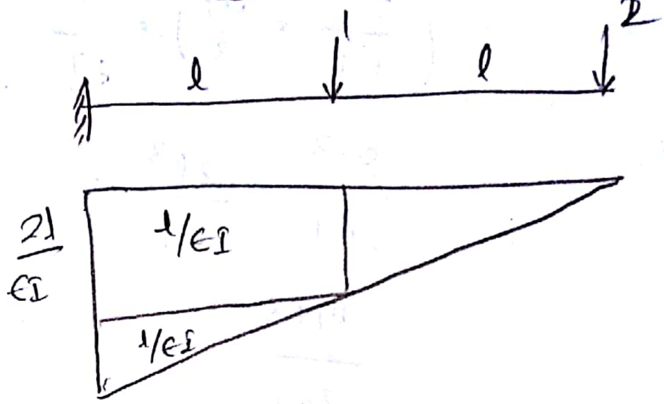
$$f_{31} = \frac{l^2}{2EI} \times \left(2l + \frac{2}{3} \times l\right)$$

$$= \frac{8l^3}{6EI} \Rightarrow \frac{4l^3}{3EI}$$

→ Apply unit force along coordinate ②.

$$f_{12} = \left(\frac{1}{2} \times l \times \frac{l}{EI}\right)\left(\frac{2}{3} \times l\right) + \left(\frac{l}{EI} \times l\right) \times \frac{l}{2}$$

$$f_{12} = \frac{l^3}{3EI} + \frac{l^3}{2EI}$$

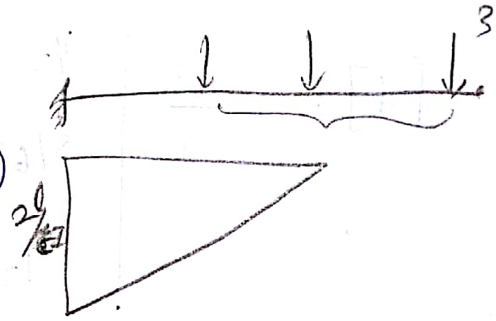


$$f_{12} = \frac{5l^3}{6EI}.$$

$$f_{22} = \left(\frac{1}{2} \times 2l \times \frac{2l}{EI}\right) \times \left(\frac{2}{3} \times 2l\right)$$

$$= \frac{2l^2}{EI} \times \frac{4l}{3}$$

$$f_{22} = \frac{8l^3}{3EI}.$$



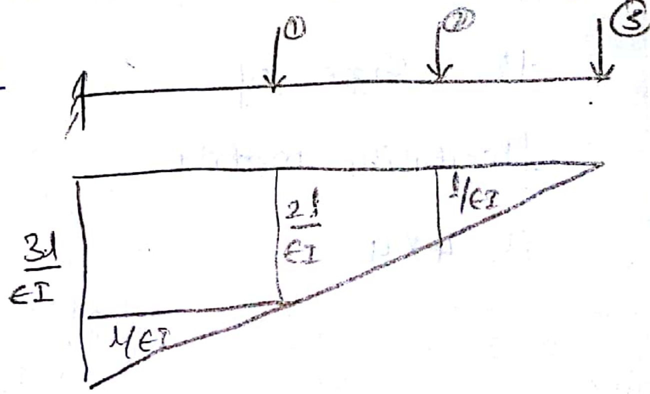
$$f_{32} = \frac{2l^2}{EI}\left(l + \frac{2}{3}(2l)\right)$$

$$f_{32} = \frac{14l^3}{3EI}$$

Apply unit force along coordinate ③

$$f_{13} = \left(\frac{1}{2} \times l \times \frac{l}{EI}\right)\left(\frac{2}{3} \times l\right) + \left(l \times \frac{2l}{EI} \times \frac{l}{2}\right)$$

$$= \frac{l^3}{3EI} + \frac{l^3}{EI}$$



$$f_{13} = \frac{4l^3}{3EI}.$$

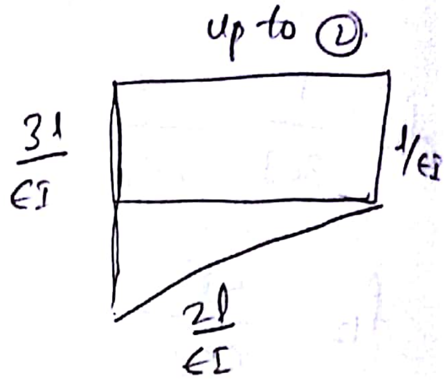
Scanned by CamScanner

$$f_{23} = \left(\frac{1}{2} \times 2l \times \frac{2l}{EI}\right)\left(\frac{2}{3} \times 2l\right) + \left(2l \times \frac{l}{EI}\right) \times \frac{2l}{2}$$

$$= \left(\frac{2l^2}{EI} \times \frac{4l}{3}\right) + \frac{2l^3}{EI}$$

$$= \frac{8l^3}{3EI} + \frac{2l^3}{EI}$$

$$= \frac{14l^3}{3EI}$$

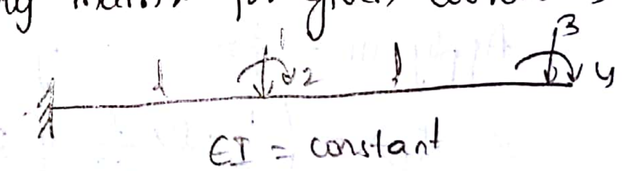


$$f_{33} = \left(\frac{1}{2} \times 3l \times \frac{3l}{EI}\right) \times \frac{2}{3} \times (3l)$$

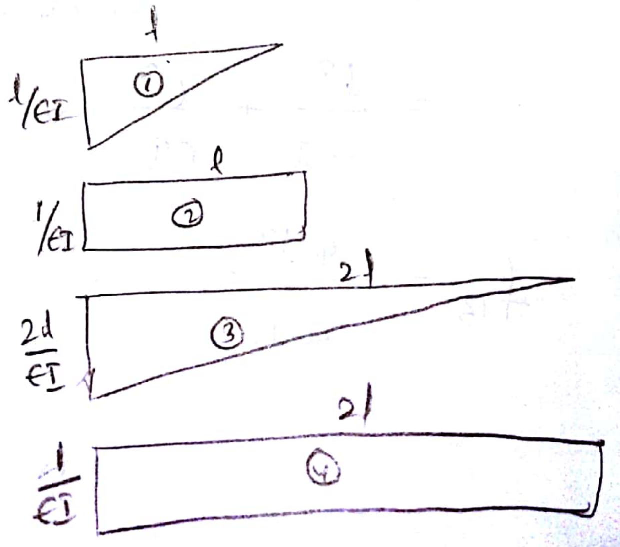
$$= \frac{9l^3}{EI}.$$

$$[f] = \frac{l^3}{EI}\begin{bmatrix} 1/3 & 5/6 & 4/3 \\ 5/6 & 8/3 & 14/3 \\ 4/3 & 14/3 & 9 \end{bmatrix}$$

→ Evaluate flexibility matrix for given coordinates

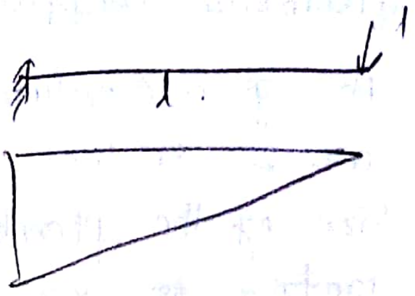


As the given coordinates are 4 the size of flexibility matrix is 4×4.



→ Apply unit force along coordinate ①

$$f_{11} = \left(\frac{1}{2} \times l \times \frac{l}{EI}\right) \times \left(\frac{2}{3} \times l\right)$$



$$f_{11} = \frac{l^3}{3EI}$$

$$f_{21} = \left(\frac{1}{2} \times l \times \frac{l}{EI}\right) = \frac{l^2}{2EI}$$

$$f_{31} = \left(\frac{1}{2} \times l \times \frac{l}{EI}\right)\left(l + \frac{2}{3} \times l\right) = \frac{5l^3}{6EI}$$

$$f_{41} = \frac{1}{2} \times l \times \frac{l}{EI} = \frac{l^2}{2EI}$$

Apply unit force along coordinate ②

$$f_{12} = \left(\frac{1}{EI} \times l\right) \times \frac{l}{2} = \frac{l^2}{2EI}, \quad f_{22} = \frac{1}{EI} \times l = \frac{l}{EI}$$

$$f_{32} = \left(\frac{1}{EI} \times l\right)\left(\frac{l}{2} + l\right) = \frac{3l^2}{2EI}, \quad f_{42} = \left(\frac{1}{EI} \times l\right) = \frac{l}{EI}$$

Apply unit force along coordinate ③

$$f_{13} = \left(\frac{1}{2} \times \frac{l}{EI} \times l\right)\left(\frac{2}{3} \times l\right) + \left(\frac{l}{EI} \times l\right)\frac{l}{2} = \frac{5l^3}{6EI}$$

$$f_{23} = \left(\frac{1}{2} \times \frac{l}{EI} \times l\right) + \left(\frac{l}{EI} \times l\right) = \frac{l^2}{2EI} + \frac{l^2}{EI} = \frac{3l^2}{2EI}$$

$$f_{33} = \left(\frac{1}{2} \times \frac{2l}{EI} \times 2l\right)\left(\frac{2}{3} \times 2l\right) = \frac{8l^3}{3EI}, \quad f_{43} = \left(\frac{1}{2} \times 2l \times \frac{2l}{EI}\right) = \frac{2l^2}{EI}$$

Apply unit moment along coordinate ④

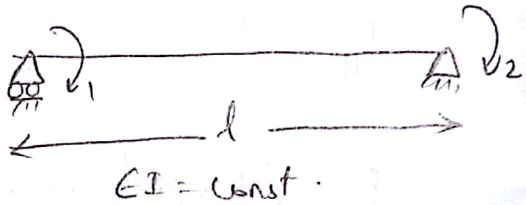
$$f_{14} = \left(\frac{1}{EI} \times l \times \frac{l}{2}\right) = \frac{l^2}{2EI}, \quad f_{24} = \left(\frac{1}{EI} \times l\right) = \frac{l}{EI}, \quad f_{34} = \left(\frac{1}{EI} \times 2l \times l\right) = \frac{2l^2}{EI}$$

$$f_{44} = \frac{1}{EI} \times 2l = \frac{2l}{EI}$$

$$[f] = \frac{1}{EI}\begin{bmatrix} l^3/3 & l^2/2 & 5l^3/6 & l^2/2 \\ l^2/2 & l & 3l^2/2 & l \\ 5l^3/6 & 3l^2/2 & 8l^3/3 & 2l^2 \\ l^2/2 & l & 2l^2 & 2l \end{bmatrix}$$

→ Generate or develop the flexibility matrix (or) flexibility Coefficient for the given coordinate system

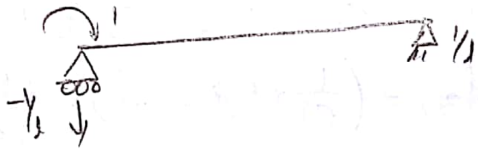
The given coordinates are 2. So that the size of the flexibility matrix is 2x2. the



flexibility matrix will be obtained by applying unit force along each coordinate, one at time and obtaining the displacement.

→ To get 1^{st} column of flexibility matrix apply unit moment along coordinate ①.

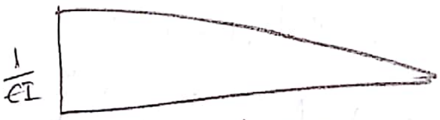
$\Sigma V = 0$



$R_a + R_b = 0$

$R_a = -R_b$.

$\Sigma M_b = 0$



$R_a \times l + 1 = 0$

$-\frac{1}{l} \times l + 1 = 0.$

$R_a = -1/l$

$R_b = 1/l$.

To get flexibility matrix Coefficient evaluate Conjugate shear along the Coordinate.

$\Sigma V = 0$

$V_a + V_b = \frac{1}{2} \times l \times \frac{1}{EI}$

$= \frac{l^2}{2EI}.$

$\Sigma M_b = 0$

$$V_a \times l - \frac{l}{2EI} \times \frac{2}{3}(l) = 0.$$

$$V_a \times l - \frac{l^2}{3EI} = 0$$

$$V_a = \frac{l}{3EI} \Rightarrow f_{11}$$

$$V_b = \frac{l}{2EI} - \frac{l}{3EI}$$

$$V_b = \frac{3l - 2l}{6EI}$$

$$V_b = \frac{l}{6EI} \Rightarrow f_{21}.$$

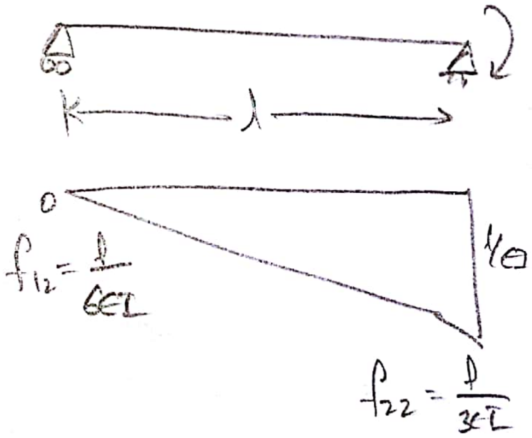
Note:

In any case a unit moment is applied at any support or any joint the flexibility coefficient at near end is $l/3EI$ and for opposite end is $l/6EI$.

→ Similarly apply unit moment along coordinate ②

$$f_{12} = \frac{l}{6EI}$$

$$f_{22} = \frac{l}{3EI}$$

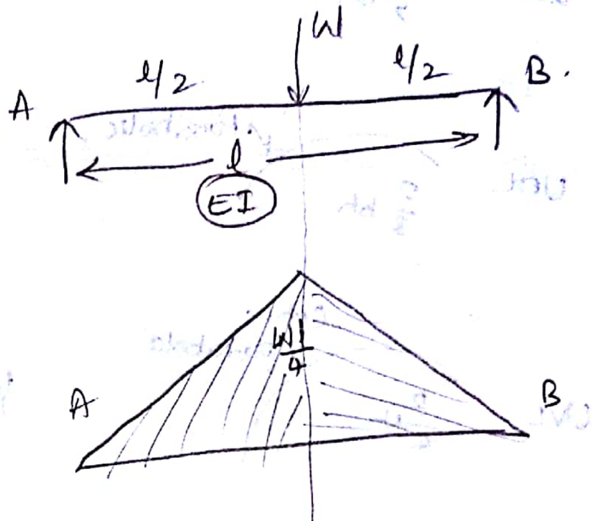


$$f = \frac{l}{EI}\begin{bmatrix} 1/3 & 1/6 \\ 1/6 & 1/3 \end{bmatrix}$$

~~Calculation~~ Evaluation of ~~general~~ Standard formulae for displacement

Calculation:

(i) SSB with centre load.

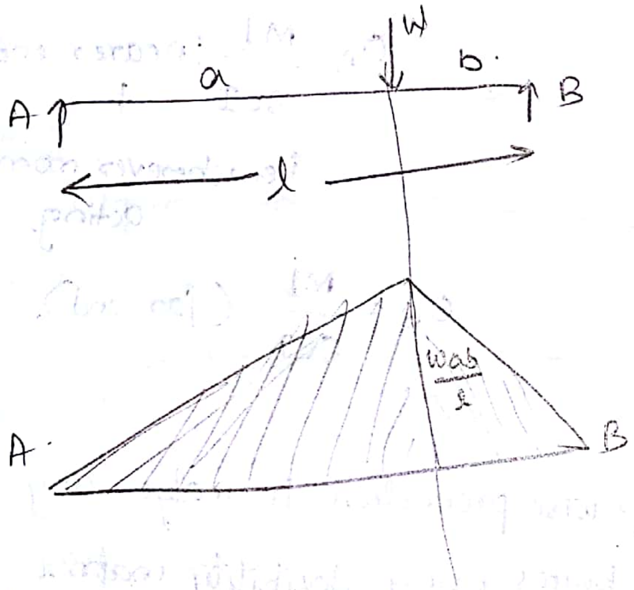


$$\theta_a = \frac{A}{EI}$$

$$= \frac{1}{EI}\left[\frac{1}{2} \times \frac{l}{2} \times \frac{Wl}{4}\right]$$

$$\theta_b = \theta_a = \frac{Wl^2}{4}$$

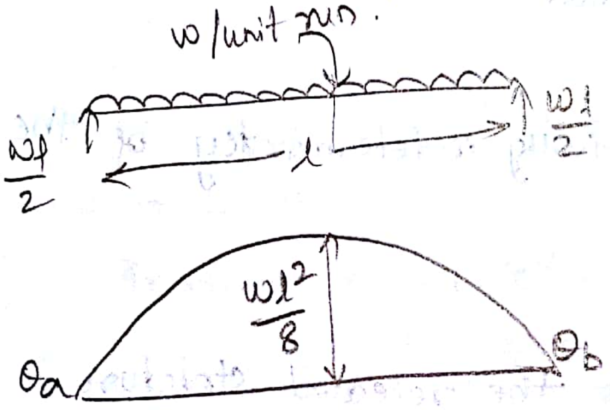
(ii) SSB with eccentrical point loading.



$$\theta_a = \frac{wab}{6EIl}(l+a)$$

$$\theta_b = \frac{wab}{6EIl}(l+b).$$

(iii) SSB carrying UDL.



Area under UDL is

$$= \frac{1}{2}\left[\frac{2}{3} \times l \times \frac{wl^2}{8EI}\right]$$

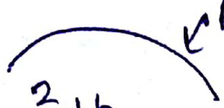
$$= \frac{wl^3}{24EI}.$$

Linear

Point load $\frac{1}{2}bh.$

$1/3$

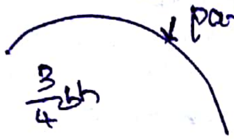
Parabolic



UDL $\frac{2}{3}bh$

$1/4$

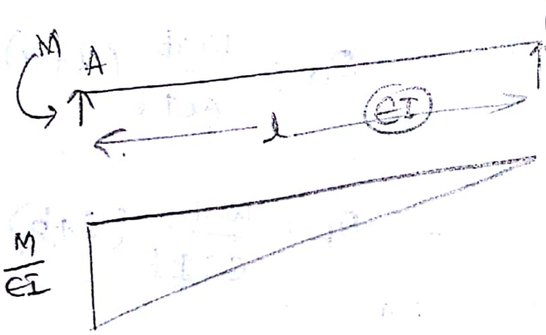
Cubic parabola.



UVL $\frac{3}{4}bh$

$1/5$

(iv) SSB subjected to couple.



$\theta_A = \frac{Ml}{3EI}$ (nearer end)

i.e., wherever moment is acting.

$\theta_b = \frac{Ml}{6EI}$ (far end).

State/describe the step wise procedure to analyse any statically indeterminate beams using flexibility matrix method or force method.

Step 1:

Determine the statically indeterminacy of the given structure.

Step-2:

Note down or show the released structure.

Step-3: Determine the joint displacements at ends or joints that is rotations (angular displacements)

Step-4: Generate or develop the flexibility matrix using ~~assigned~~ assigned coordinates

Note: The size of flexibility matrix always depends on statical indeterminacy.

Step 5: Use the general equation or notation for formula to calculate redundant forces.

$$f(\alpha) = \frac{\delta}{P}$$

$$[f]\{P\} = \{\delta\}_0 - \{\delta\}_L$$

where δ_0 = original displacements.

δ_L = displacements caused due to external loads

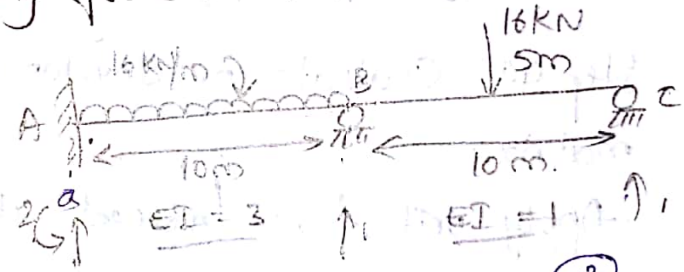
Step 6: Evaluate the subsidiary quantities i.e., support reaction.

$\frac{wl^2}{24EI}$

→ Evaluate the given beam or analyse the continuous beam using force method.

Step 1:

Statical indeterminacy of the structure is



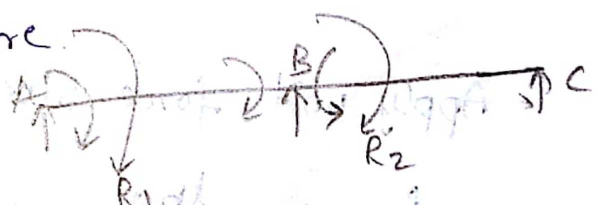
$= (2+4+1) - 2$

$= 2$

Step 2:

As the no. of redundants are 2 then size of flexibility matrix is 2×2.

Instead of fixity we consider released end moments therefore supported moments are induced.



R_1 and R_2 are the redundants at supports A and B.

$R_1 = M_{AB}$ = Support moments at A

$R_2 = M_B$ = Support moments at B.

Step 3: Determine joint displacements under external loading.

$$\delta l_1 = \theta_a = \frac{Wl^3}{24(EI)_{ab}} = \frac{16 \times 10^3}{24(3EI)} = \frac{222.22}{EI}$$

at A

$$\delta l_2 = \frac{W(l_{ab})^3}{24(EI)_{ab}} + \frac{Wl^2}{16EI}$$

$$= \frac{222.22}{EI} + \frac{16 \times (10)^2}{16 \times EI}$$

$$\theta_b = \frac{322.22}{EI}.$$

Step 4: Evaluate or develop or generate the flexibility matrix.

Apply unit force/moment along coordinate 1

$\frac{l}{3EI}$ (near)

$\frac{l}{6EI}$ (far)

$$f_{11} = \frac{(l_{ab})}{3(EI)_{ab}} = \frac{10}{9EI}$$

$$f_{21} = \frac{l_{ab}}{6(EI)_{ab}} = \frac{10}{6(3EI)} = \frac{10}{18EI}$$

Apply unit force along coordinate 2.

$$f_{12} = \frac{l_{ba}}{6(EI)_{ba}} = \frac{10}{6(3EI)} = \frac{10}{18EI}.$$

$$f_{22} = \frac{l_{ba}}{3(EI)_{ba}} + \frac{l_{bc}}{3(EI)_{bc}} =$$

$$= \frac{10}{3(3EI)} + \frac{10}{3(EI)}$$

$$= \frac{10}{9EI} + \frac{10}{3EI}$$

$$= \frac{40}{9EI}.$$

Step 5: Evaluate the redundants using the known relationships

$$[f]\{P\} = \{\delta\}_0 - \{\delta\}_L$$

$$\frac{1}{EI}\begin{bmatrix} \frac{10}{9} & \frac{10}{18} \\ \frac{10}{18} & \frac{40}{9} \end{bmatrix} \begin{Bmatrix} R_1 \\ R_2 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix} - \begin{Bmatrix} \frac{222.22}{EI} \\ \frac{322.22}{EI} \end{Bmatrix}$$

$$\begin{bmatrix} 10/9 & 10/18 \\ 10/18 & 40/9 \end{bmatrix} \begin{Bmatrix} R_1 \\ R_2 \end{Bmatrix} = - \begin{Bmatrix} 222.22 \\ 322.22 \end{Bmatrix}$$

$$\frac{10}{9} R_1 + \frac{10}{18} R_2 = -222.22$$

1.11

0.55

4.44

$$\frac{10}{18} R_1 + \frac{40}{9} R_2 = -322.22$$

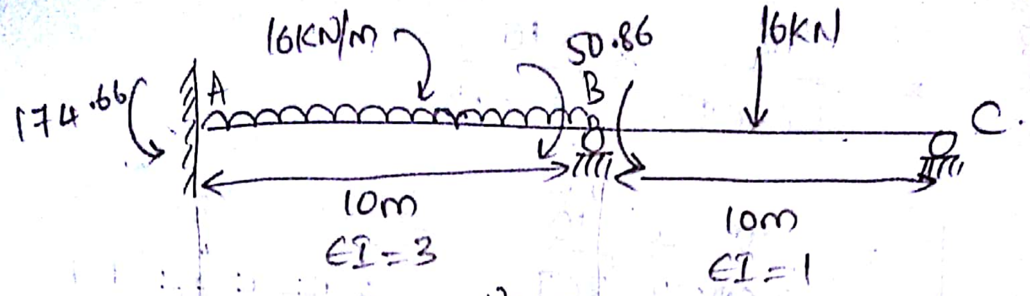
$$R_1 = -174.97 \text{ KN-m}.$$

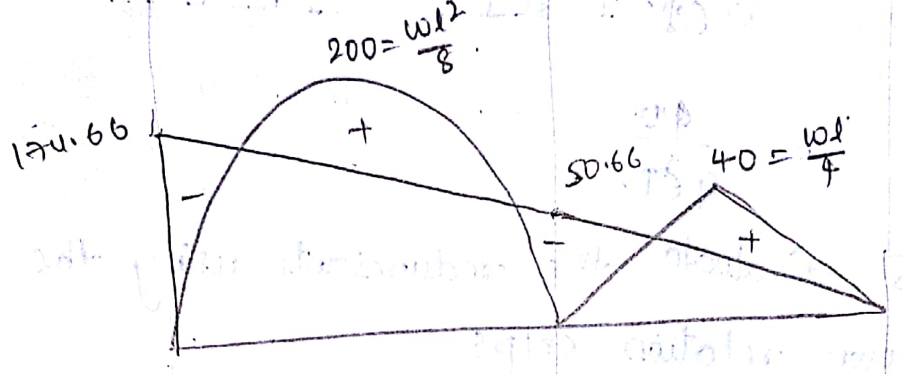
$$R_2 = -50.896 \text{ KN-m}.$$

$\frac{\text{MBC}}{\text{a}}$ $\frac{1}{6EI}$

3EI

F-1

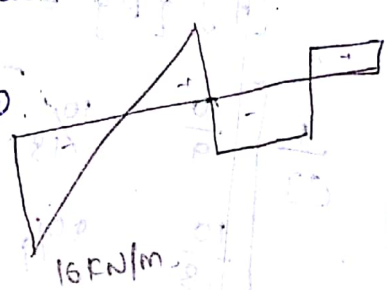




Step6: Evaluate support reaction;

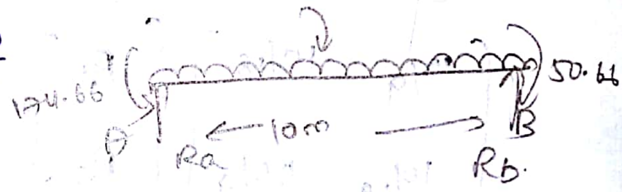
$\cancel{M_B = 0 \Rightarrow R_A} = \cancel{R_A(10) - \frac{wl}{2}} = 0$

$\cancel{R_A(10) - \frac{16\times10}{2}}$

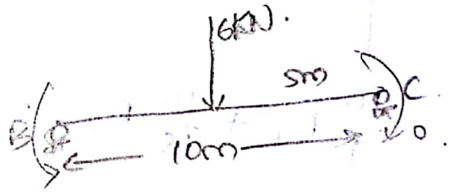


$-174.66 + R_a(10) - 16\times10\times\frac{10}{2}$

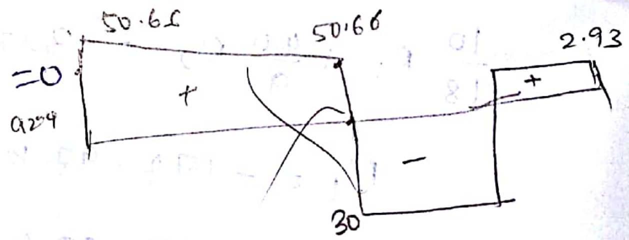
$+50.66 = 0$



$R_a = 92.4$ KN-m



$\Sigma M_B = 0 \Rightarrow R_c = 0.$



$+50.66 + R_c\times10 - 16\times5 = 0$

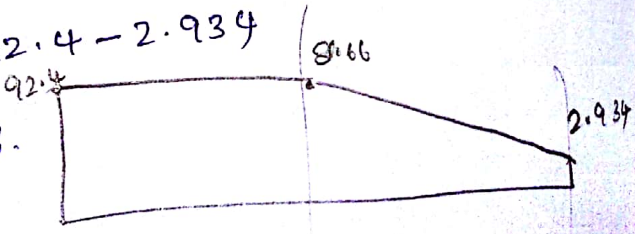
$R_c = 2.934,$

$\Sigma V = 0$

$R_a + R_b + R_c = (16\times10) + 16 = 176$

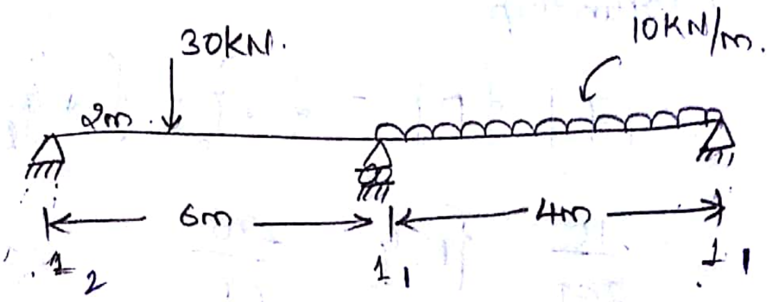
$R_b = 176 - 92.4 - 2.934$

$R_b = 80.66.$



→ Analyse the continuous beam using force method. Take EI as constant

Step 1:



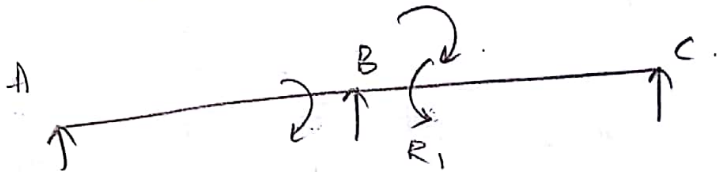
Evaluate or determine the statical indeterminacy of the structure.

$$SID = S_D = (1+1+1)-2 = 1$$

the size of flexibility matrix is 1.

Step 2:

Provide release structure and support moments.



Step 3: Evaluate or determine the joint displacement under external loading.

$$\delta_L = \frac{wab}{6(EIl)_{ba}}(l+a) + \frac{wl^3_{bc}}{24EI}.$$

$$= \frac{30\times2\times4}{6\times EI\times6}(6+2) + \frac{10\times4^3}{24\times EI}$$

$$= \frac{80}{EI}.$$

Step 4: Evaluate flexibility matrix or flexibility matrix coefficients

Apply unit force (moment)

$$f_{11} = \frac{l_{ab}}{3EI} + \frac{l_{bc}}{3EI} = \frac{6}{3EI} + \frac{4}{3EI}$$

$$= \frac{10}{3EI}.$$

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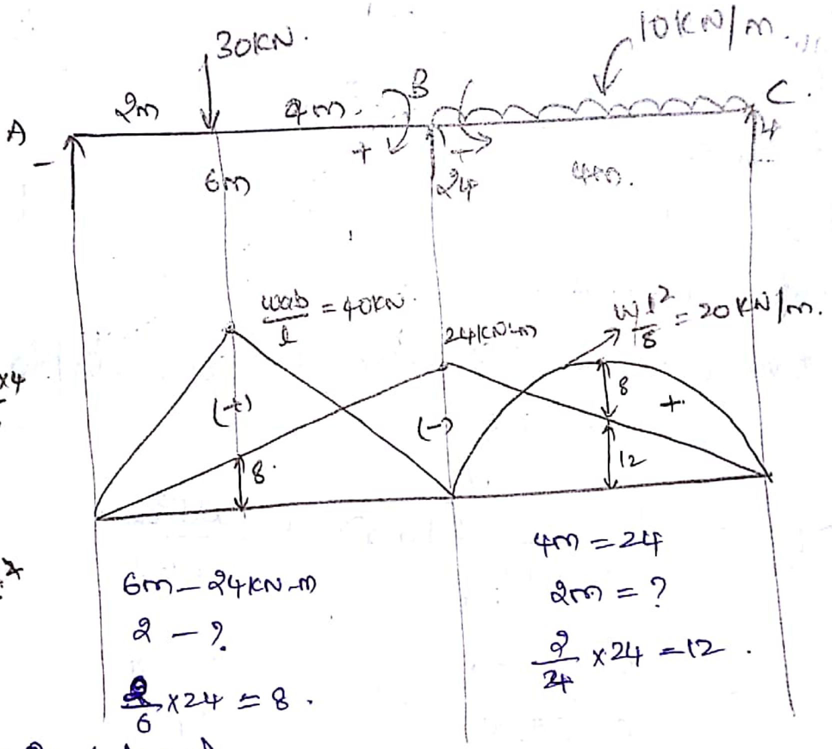
Step 5: Evaluate the redundants using known relationship

$$[f]\{P\} = \{\delta\}_0 - \{\delta\}_L.$$

$$\frac{10}{3EI}\cdot\{R_1\} = \frac{-80}{EI}$$

$\cancel{R_P} = -8 \quad R_1 = -24\ KN\text{-}m.$

Step 6: Draw BMD.



$\frac{wab}{l} = \frac{\overset{10}{\cancel{30}} \times 2 \times 4}{\cancel{6}3}$

$= 40$

$\frac{wl^2}{8} = \frac{\overset{5}{\cancel{10}} \times 4^2}{\cancel{8}_2}$

6m — 24KN-m

2 — ?

$\frac{2}{6} \times 24 = 8.$

4m = 24

2m = ?

$\frac{2}{4} \times 24 = 12.$

$\Sigma M_B = 0.$ (left)

$R_a = 0$

$+24 + R_a \times 6 - 30 \times 4 = 0$

$R_a = \frac{120 - 24}{6}$

$R_a = 16\ KN.$

$\Sigma M_B = 0$ (Right)

$R_C = 0$

$R_C \times 4 - 10 \times 4 \times \frac{4}{2} + 24 = 0.$

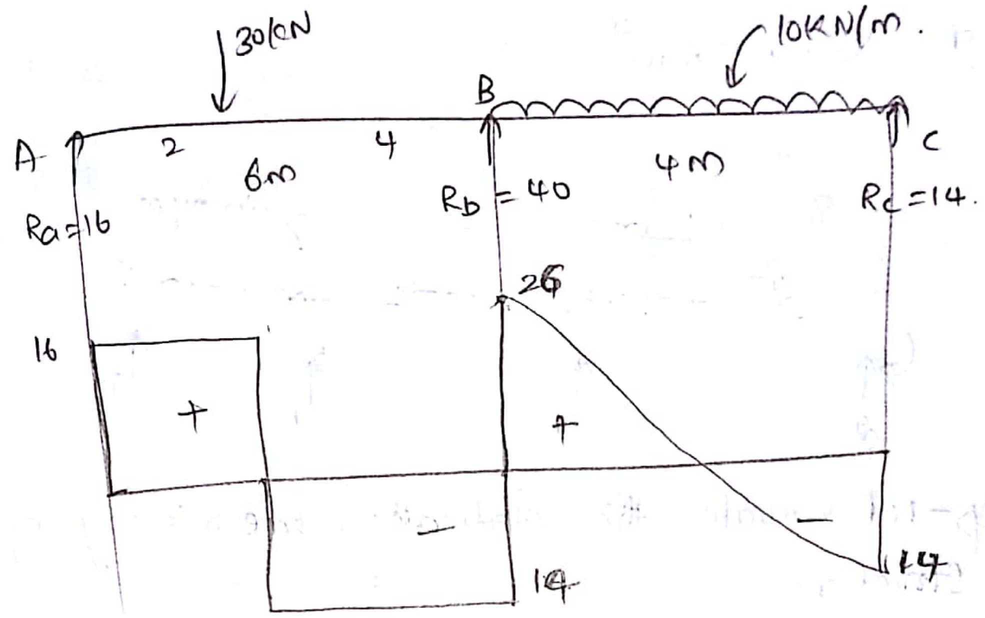
$R_C = 14$

$\Sigma V = 0.$

$R_a + R_b + R_c = (30) + (10 \times 4)$

$R_b = -30 + 30 + 40$

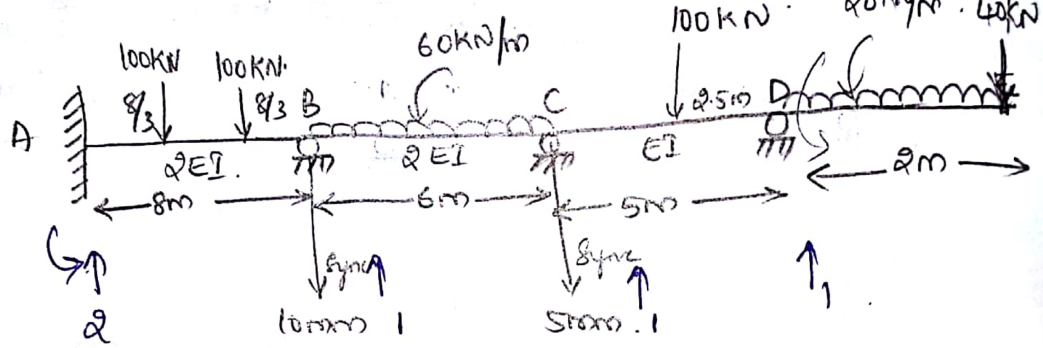
$R_B = 40.$



~~Syncing of Sy~~

Syncing of Supports. (Rotation of any supports or syncing of supports).

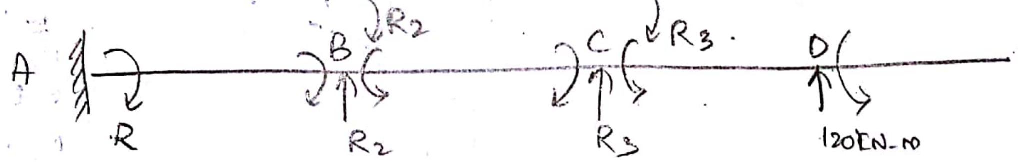
→ Analyse the continuous beam as shown in the fig. using force method. draw the BM and Shear force dia. also during the loading, the supports B and C sync by 10mm & 5mm respectively. Take / Assume $E = 200\,GPa$ and $I = 80 \times 10^6\ mm^4$



Step-1: Evaluate the statical indeterminacy of the structure

$$SID = S_d = (2+1+1+1) - 2 = 3.$$

Step 2: Arrangement of redundants.



$R_1 = M_A$

$R_2 = M_B$

$R_3 = M_C$.

$$M_D = (40 \times 2) + (20 \times 2) * \frac{2}{2}$$

$= 80 + 40$

$= 120$ kN.m (Anti-clockwise

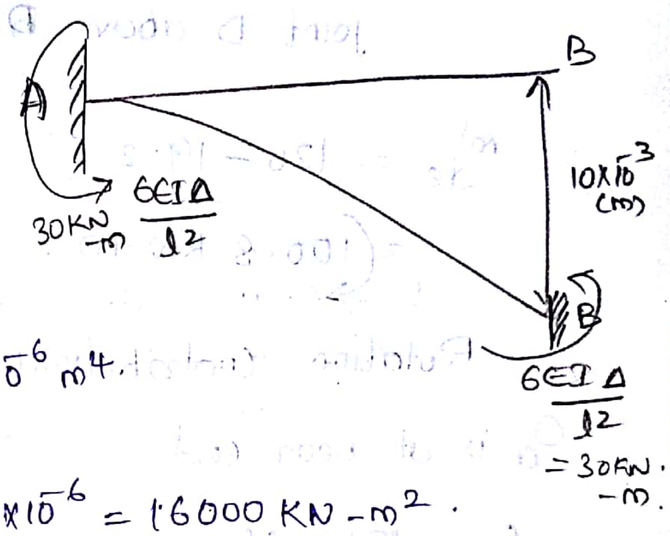
step 3: Evaluation of joint displacements (δ_L)

Note: In this problem, joint displacements occur not only due to external loads but also external moments caused by settlement of supports.

External moments classification.

$E = 200$ GPA

$= \frac{200 \times 10^9}{10^3}$ KN.



$I = 80 \times 10^6$ mm^4

$= \frac{80 \times 10^6}{(10^3)^4} = 80 \times 10^{-6}$ m^4.

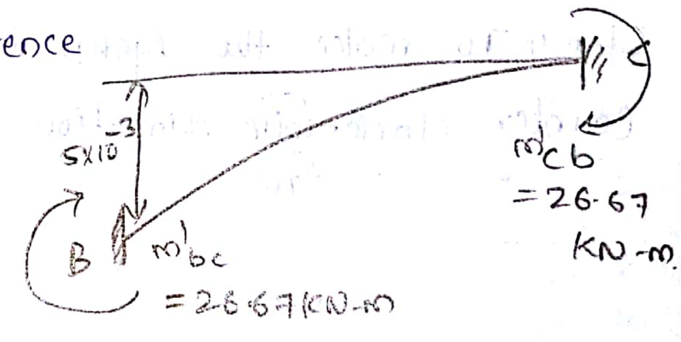
$EI = \frac{200 \times 10^9}{10^3} \times 80 \times 10^{-6} = 16000$ KN-m^2.

$$m'_{ab} = \frac{6 \times 2 \times 16000 \times 10 \times 10^{-3}}{8^2} = 30 \text{ KN-m}.$$

Relative level difference

b/w B and C = 10-5

= 5mm

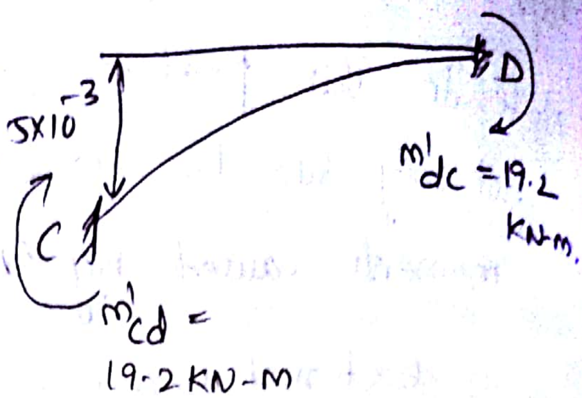


$$m'_{cb} = \frac{6EI}{l^2}$$

$$= \frac{6 \times 2 \times 16000 \times 5 \times 10^{-3}}{6^2}$$

$$= 26.67 \text{ KN-m}$$

$m'_{cd} = \frac{6 \times 16000 \times 5 \times 10^{-3}}{5^2}$



$= 19.2$ KN-m.

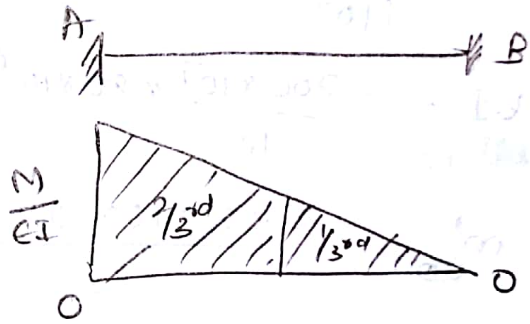
But m'_{de} = net BM at joint D above DE

$m'_{de} = 120 - 19.2$

$= 100.8$ KN-m.

Rotation contributions due to external moments

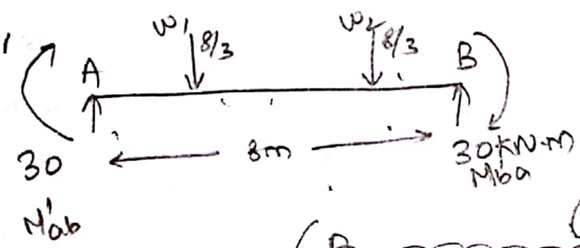
θ_a is at near end



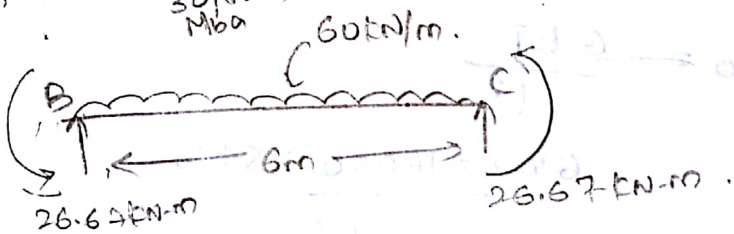
$\theta_a = \frac{Ml}{3EI}$. (for near end)

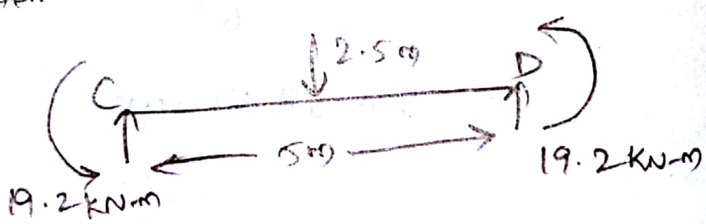
$\theta_b = \frac{Ml}{6EI}$. (for far end).

Step-4 To make the system balanced take the counter clockwise direction



~~395.06~~
316.049
40





(δL_1) is rotation contribution at joint 1.

$$(\delta l_1) = \theta_a$$

$$= \frac{W_1 ab}{6(EI)_{ab}}(l+b) + \frac{W_2 ab}{6(EI\,l)_{ab}}(l+b) + \frac{m'_{ab}(l_{ab})}{3(EI)_{ab}} - \frac{m'_{ba}(l_{ba})}{6(EI)_{ab}}$$

$$= \frac{100 \times \frac{8}{3} \times \frac{16}{3}}{6 \times 2 \times 16000 \times 8}\left(8+\frac{16}{3}\right) + \frac{100 \times \frac{16}{3} \times \frac{8}{3}}{6 \times 2 \times 16000 \times 8}\left(8+\frac{8}{3}\right)$$

$$\boxed{\left[\frac{3380}{9EI}\right]} \quad + \frac{30 \times 8}{3 \times 2 \times 16000} - \frac{30 \times 8}{6 \times 2 \times 16000}$$

(0.02347) $= \cancel{0.01234 + 0.00987 + 0.0025} \cancel{- 0.0125}$

$= \cancel{0.03721} = 0.02347.$

$\cancel{192.930}$
$\cancel{158.02}$
$\cancel{40}$
$\cancel{20}$

$$(\delta l_2) = \theta_b = \theta_{ba} + \theta_{bc}$$

$$= \left[\frac{wl^3}{24(EI)_{bc}} - \frac{m'_{bc}\, l_{bc}}{3(EI)_{bc}} + \frac{m'_{cb}\cdot l_{cb}}{6(EI)_{cb}}\right]_{bc}$$

$$+ \left[\frac{w_1 ab}{6(EI)_{ab}}(l+a) + \frac{w_2 ab}{6(EI\,l)_{ab}}(l+a) + \frac{m'_{ab}\cdot l_{ab}}{6(EI)_{ab}} - \frac{m'_{ba}\cdot l_{ba}}{6(EI)_{ba}}\right]_{ab}.$$

$$= \left[\frac{60\times6^3}{24\times2\times16000} - \frac{26.67\times6}{3\times2\times16000} + \frac{26.67\times6}{6\times2\times16000} \right]$$

$$+ \left[\frac{100\times\frac{8}{3}\times\frac{16}{3}}{6\times2\times16000\times8}\left(8+\frac{8}{3}\right) + \frac{100\times\frac{16}{3}\times\frac{8}{3}}{6\times2\times16000\times8}\left(8+\frac{16}{3}\right) \right.$$

$$\left. + \frac{30\times8}{6\times2\times16000} - \frac{30\times8}{3\times2\times16000} \right]$$

$$= 0.01604 + 0.02347$$

$$\boxed{\frac{5330}{9EI}}$$

$$= 0.03951 \quad (0.3701)$$

$$(\delta L)_3 = \theta_c = \theta_{cb} + \theta_{cd}$$

$$= \left[\frac{w l_{cb}^3}{24(EI)_{cb}} - \frac{m'_{bc} l_{cb}}{6(EI)_{cb}} + \frac{m'_{cb} l_{cb}}{3(EI)_{cb}} \right]_{cb}$$

$$+ \left[\frac{\cancel{wd}\, l_{cd}^2}{16(EI)_{cd}} - \frac{m'_{cd}\cdot l_{cd}}{3(EI)_{cd}} + \frac{m'_{dc}\cdot l_{dc}}{6(EI)_{dc}} \right]_{cd}$$

$$= \left[\frac{60\times6^3}{24\times2\times16000} - \frac{26.67\times6}{6\times2\times16000} + \frac{26.67\times6}{3\times2\times16000} \right]$$

$$+ \left[\frac{100\times5^2}{16\times16000} - \frac{19.2\times5}{3\times16000} + \frac{100.8\times5}{6\times16000} \right]$$

$$\boxed{\frac{11649}{36EI}} \quad 491.585$$

$$= 0.03072 \quad\quad 0.01947$$

Step 5: Evaluate flexibility matrix Coefficients.

Apply unit force along the coordinate 1.

$$f_{11} = \frac{l_{ab}}{3(EI)_{ab}} = \frac{8}{3(2EI)} = \frac{8}{6EI}.$$

$$f_{21} = \frac{l_{ba}}{6(EI)_{ba}} = \frac{8}{6(2EI)} = \frac{8}{12EI}$$

$$f_{31} = 0$$

Apply unit force (moment) along coordinate 2. to get 2nd column of flexibility matrix.

$$f_{12} = \frac{l_{ab}}{6(EI)_{ab}} = \frac{8}{6(2EI)} = \frac{8}{12EI}.$$

$$f_{22} = \frac{l_{ba}}{3(EI)_{ba}} + \frac{l_{bc}}{3(EI)_{bc}}.$$

$$= \frac{8}{3(2EI)} + \frac{6}{3(2EI)} = \frac{14}{6EI}.$$

$$f_{32} = \frac{l_{cb}}{6(EI)_{cb}} = \frac{6}{6(2EI)} = \frac{1}{2EI}$$

Hey apply unit force along coordinate 3 to get the 3rd column of flexibility matrix

$$f_{13} = 0$$

$$f_{23} = \frac{l_{bE}}{6(EI)_{bE}} = \frac{6}{6(2EI)} = \frac{1}{2EI}.$$

$$f_{33} = \frac{l_{cb}}{3(EI)_{cb}} + \frac{l_{cd}}{3(EI)_{cd}}$$

$$= \frac{6}{3(2EI)} + \frac{5}{3EI} = \frac{8}{3EI}.$$

Step 6: Evaluate the unknown values (Redundants) i.e., R_1, R_2, R_3 are determined using known relationship.

$$[f]\{R\} = \{\delta\}_D - \{\delta\}_L$$

$$\frac{1}{\cancel{EI}}\begin{bmatrix} 8/6 & 8/12 & 0 \\ 8/12 & 14/6 & 1/2 \\ 0 & 1/2 & 8/3 \end{bmatrix}\begin{bmatrix} R_1 \\ R_2 \\ R_3 \end{bmatrix} = \begin{Bmatrix} 0 \\ 0 \\ 0 \end{Bmatrix} - \frac{1}{\cancel{EI}}\begin{bmatrix} \frac{3380}{9} \\ \frac{5330}{9} \\ \frac{11649}{36} \end{bmatrix}$$

$$\overset{1.333}{\frac{8}{6}} R_1 + \overset{0.666}{\frac{8}{12}} R_2 + 0 = -\frac{3380}{9} \quad 375.555$$

$$\overset{0.666}{\frac{8}{12}} R_1 + \overset{2.333}{\frac{14}{6}} R_2 + \overset{0.5}{\frac{1}{2}} R_3 = -\frac{5330}{9} \quad 592.222$$

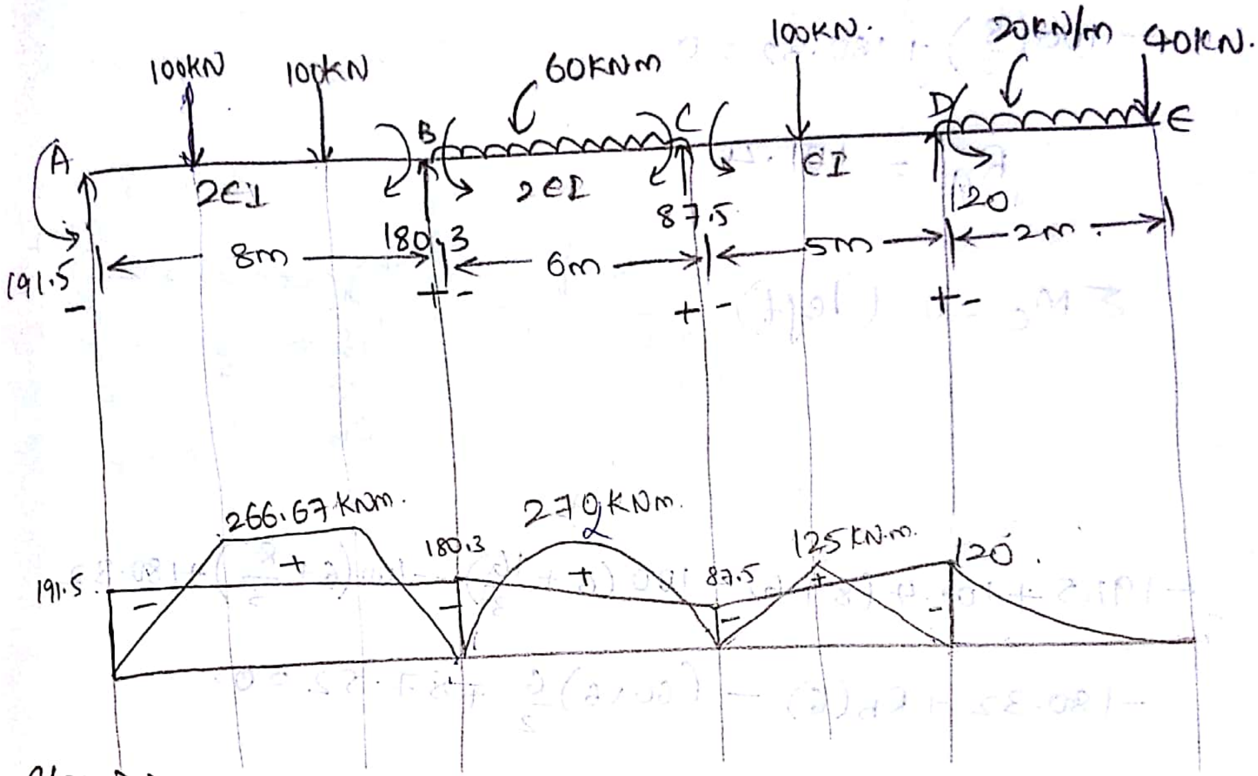
$$0 + \overset{0.5}{\frac{1}{2}} R_2 + \overset{2.667}{\frac{8}{3}} R_3 = -\frac{11649}{36} \quad 323.58$$

By solving above equations :

$R_1 = -191.6 \, KN\text{-}m$

$R_2 = -180.38 \, KN\text{-}m$

$R_3 = -87.54 \, KN\text{-}m.$



Step 2:

For BMD.

Span AB.

$m_f = m_g = 100 \times \frac{8}{3} = 266.67 \, KN\text{-}m.$ $\quad \frac{wa^2b}{l^2}$

Span BC.

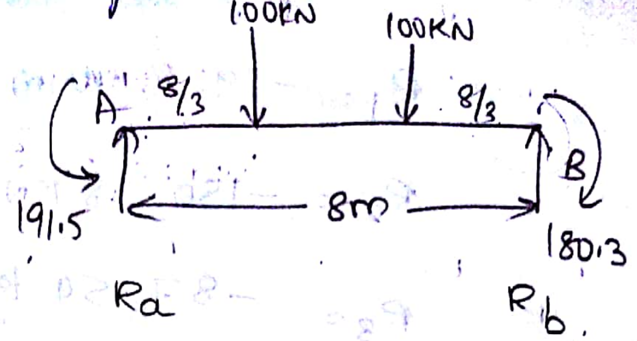
$\frac{wl^2}{8} = \frac{60 \times 6^2}{8} = 272 \, KN\text{-}m.$ $\quad \frac{wl^2}{8}$

Span CD

$m_D = \frac{wl}{4} = \frac{100 \times 5}{4} = 125 \, KN\text{-}m$

Step 8: for shear force diagram.

$\Sigma M_b = 0$ (left)

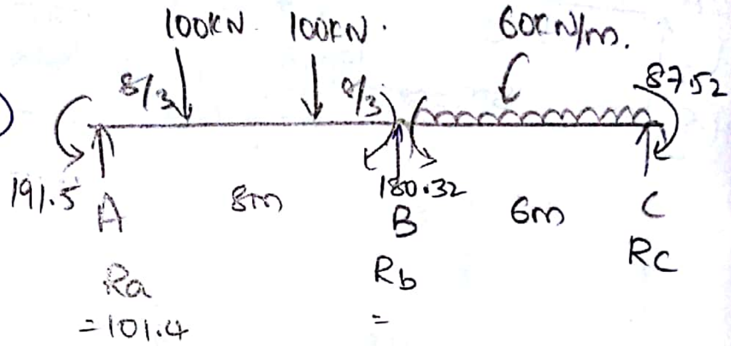


$-191.5 + Ra(8) - 100\left(\frac{16}{3}\right)$

$-100\left(\frac{8}{3}\right) + 180.32 = 0$

$Ra = 101.4$

$\Sigma M_c = 0$ (left)

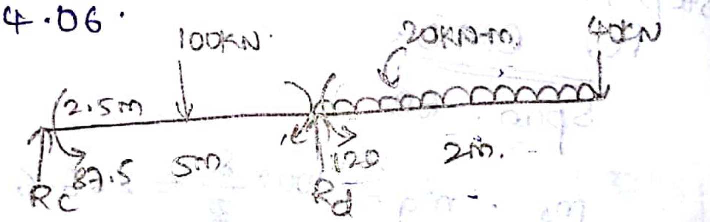


$-191.5 + 101.4(8+6) - 100\left(6 + \frac{16}{3}\right) - 100\left(6 + \frac{8}{3}\right) + 180.32$

$-180.32 + Rb(6) - (60 \times 6)\frac{6}{2} + 87.52 = 0.$

$Rb = 294.06.$

$\Sigma M_c = 0$ (Right)



$-40 \times 7 - (20 \times 2)\left(5 + \frac{2}{2}\right) + 120 - 120 + R_d(5) - 100(2.5) + 87.52 = 0$

$R_d = 136.5.$

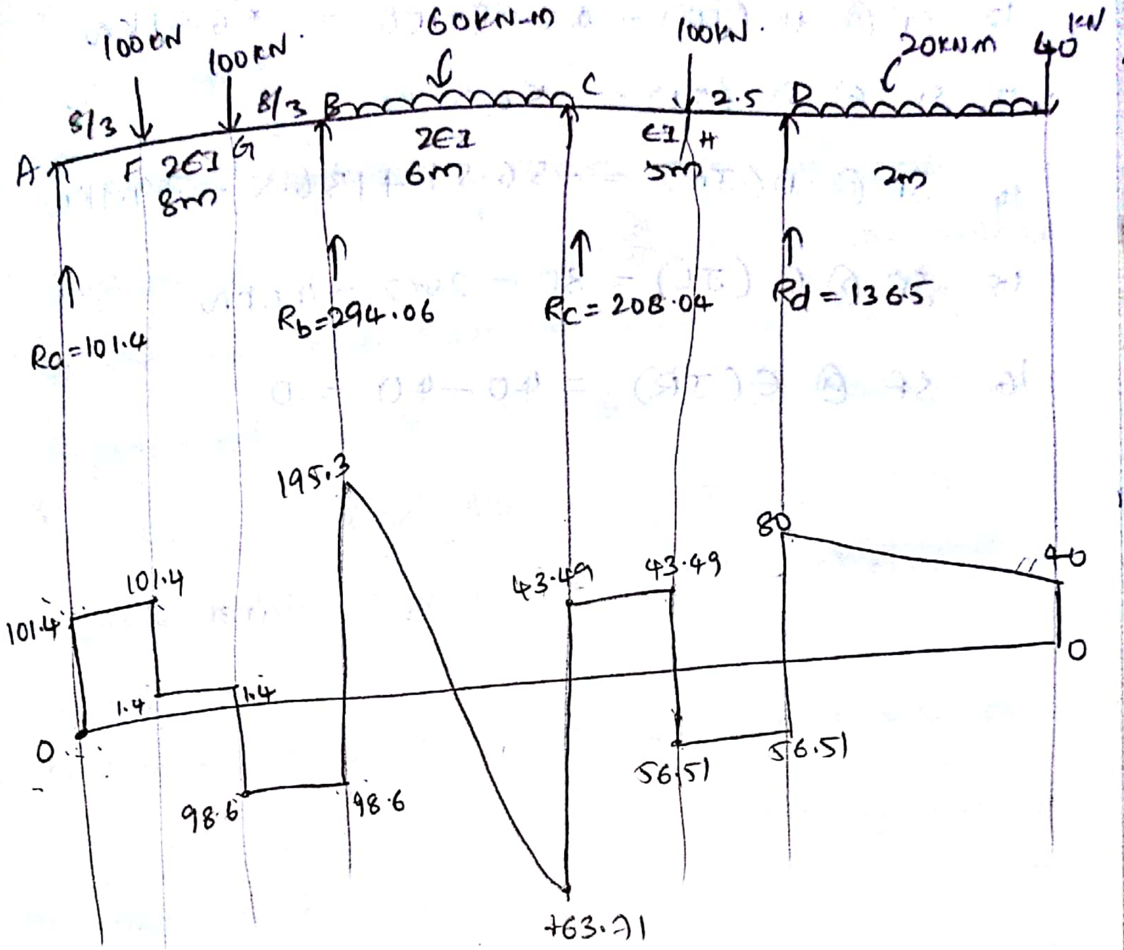
$\Sigma V = 0$

$Ra + Rb + Rc + Rd = 100 + 100 + (60 \times 6) + 100 * (20 \times 2) + 40$

$531.96 + Rc = 740$

$Rc = 208.04.$

Shear force diagram:



1. SF @ A (JL) = 0.

2. SF @ A (JR) = 0+101.4 = 101.4 KN.

3. SF @ F (JL) = 101.4 KN.

4. SF @ F (JR) = 101.4 − 100 = 1.4 KN.

5. SF @ G (JL) = 1.4 KN.

6. SF @ G (JR) = 1.4 − 100 = −98.6 KN.

7. SF @ B (JL) = −98.6 KN.

8. SF @ B (JR) = −98.6 + 293.89 = 195.29 KN.

9. SF @ C (JL) = 195.29 − (60×6) = −164.71 KN.

10. SF @ C (JR) = −164.71 + 208.2 = 43.49 KN.

11. SF @ H (JL) = 43.49 KN.

12. SF @ H (JR) = 43.49 − 100 = −56.51 KN.

13. SF @ D (JL) = −56.51 KN

14. SF @ D (JR) = −56.51 + 136.5 = 79.9 KN.

15. SF @ E (JL) = 80 − 20×2 = 40 KN.

16. SF @ E (JR) = 40 − 40 = 0.

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UNIT - IV

30/10/18

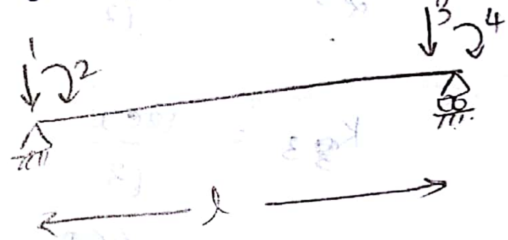
Static Condensation:

Static condensation means bring out of zero displacements or known displacements at the bottom of the displacements at ~~the~~ vector and unknown displacements at the top of displacement vector

Now, rearrange the total stiffness vector matrix (column matrix) according to the above displacement vector

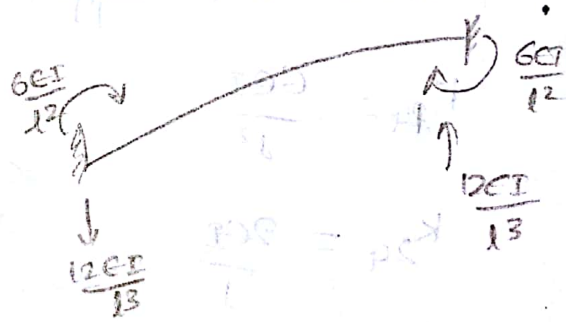
Explanation of Static Condensation with suitable ex.

let us consider a SSB having degrees of freedom as shown in the fig.



As the given DOF is 4, the size of stiffness matrix is 4x4

Evaluate the stiffness of matrix along coordinate 1.



$$k_{11} = \frac{12EI}{l^3}$$

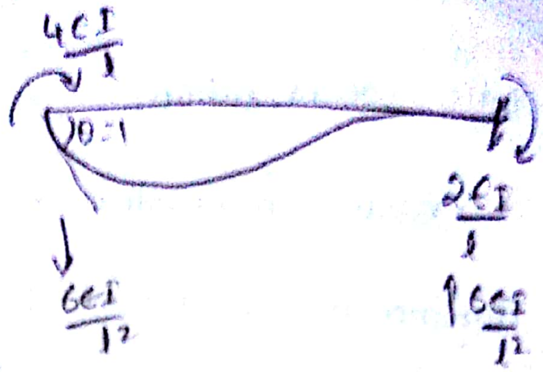
$$k_{21} = \frac{6EI}{l^2}$$

$$k_{31} = \frac{-12EI}{l^3}$$

$$k_{41} = \frac{6EI}{l^2}$$

Evaluate stiffness matrix along coordinate 2.

$k_{12} = \frac{6EI}{l^2}$



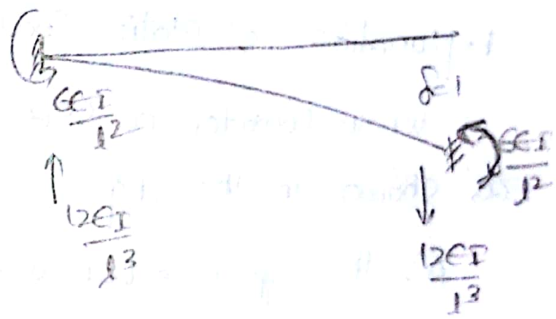
$k_{22} = \frac{4EI}{l}$

$k_{32} = \frac{-6EI}{l^2}$

$k_{42} = +\frac{2EI}{l}$

Evaluate stiffness matrix along coordinate 3.

$k_{13} = -\frac{12EI}{l^3}$



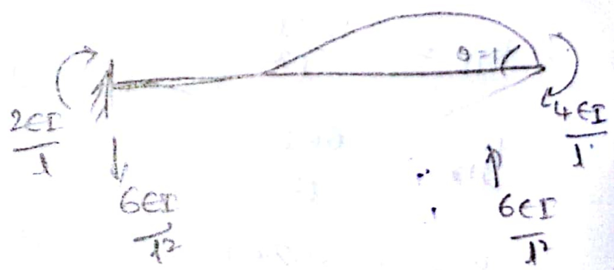
$k_{23} = -\frac{6EI}{l^2}$

$k_{33} = \frac{12EI}{l^3}$

$k_{43} = \frac{-6EI}{l^2}$

Evaluate the stiffness matrix along coordinate 4

$k_{14} = \frac{6EI}{l^2}$



$k_{24} = \frac{2EI}{l}$

$k_{34} = -\frac{6EI}{l^2}$

$k_{44} = \frac{4EI}{l}$

$$K = \begin{bmatrix} \frac{12EI}{l^3} & \frac{6EI}{l^2} & \frac{-12EI}{l^3} & \frac{6EI}{l^2} \\ \frac{6EI}{l^2} & \frac{4EI}{l} & \frac{-6EI}{l^2} & \frac{2EI}{l} \\ \frac{-12EI}{l^3} & \frac{-6EI}{l^2} & \frac{12EI}{l^3} & \frac{-6EI}{l^2} \\ \frac{6EI}{l^2} & \frac{2EI}{l} & \frac{-6EI}{l^2} & \frac{4EI}{l} \end{bmatrix} \begin{Bmatrix} \Delta_1 \\ \Delta_2 \\ \Delta_3 \\ \Delta_4 \end{Bmatrix} \longrightarrow (1)$$

By knowing the boundary condition of SSB.

$\Delta_1 = 0$, $\Delta_3 = 0$. So that we arrange in ~~the~~ both the displacements in stiffness matrix as per static Condensation.

$$\begin{array}{c c} & \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{array}{c} 2 \\ 4 \\ 1 \\ 3 \end{array} & \begin{bmatrix} \frac{6EI}{l^2} & \frac{4EI}{l} & -\frac{6EI}{l^2} & \frac{2EI}{l} \\ \frac{6EI}{l^2} & \frac{2EI}{l} & -\frac{6EI}{l^2} & \frac{4EI}{l} \\ \frac{12EI}{l^3} & \frac{6EI}{l^2} & -\frac{12EI}{l^3} & \frac{6EI}{l^2} \\ -\frac{12EI}{l^3} & -\frac{6EI}{l^2} & \frac{12EI}{l^3} & -\frac{6EI}{l^2} \end{bmatrix} \end{array} \begin{Bmatrix} \Delta_2 \\ \Delta_4 \\ \Delta_1 \\ \Delta_3 \end{Bmatrix}$$

$$\begin{array}{c} \begin{array}{cccc} 2 & 4 & 1 & 3 \end{array} \\ \left[\begin{array}{cc|cc} \frac{4EI}{l} & \frac{2EI}{l} & \frac{6EI}{l^2} & -\frac{6EI}{l^2} \\ & K_{11} & & K_{12} \\ \frac{2EI}{l} & \frac{4EI}{l} & \frac{6EI}{l^2} & -\frac{6EI}{l^2} \\ \hline \frac{6EI}{l^2} & \frac{6EI}{l^2} & \frac{12EI}{l^3} & -\frac{12EI}{l^3} \\ & K_{21} & & K_{22} \\ -\frac{6EI}{l^2} & -\frac{6EI}{l^2} & -\frac{12EI}{l^3} & \frac{12EI}{l^3} \end{array}\right] \end{array} \left\{\begin{array}{c} \Delta_2 \\ (\delta_1) \\ \Delta_4 \\ \hline \Delta_1 \\ (\delta_2) \\ \Delta_3 \end{array}\right\} \begin{array}{l} \text{unknown displacement} \\ \uparrow \\ \downarrow \\ \text{known displacements} \end{array} \longrightarrow (2)$$

As per basics

$$\{\bar{P}\} = \{k\}\{\bar{U}\} \rightarrow (3)$$

In above expression

$$\{\bar{P}\} = \left\{\begin{array}{c} P_2 \\ P_4 \\ \hdashline P_1 \\ P_3 \end{array}\right\} \begin{array}{l} \rightarrow (\bar{P}_1) \\ \\ \rightarrow (\bar{P}_2) \end{array}$$

In equation 2, the Δ_4, Δ_3 are known displacements

$[\,] \rightarrow$ square matrix

$\{\,\} \rightarrow$ column.

and

$$[k_{11}]\{\delta_1\} + [k_{12}]\{\delta_2\} = \{\bar{P}_1\} \rightarrow (4)$$

$$[k_{21}]\{\delta_1\} + [k_{22}]\{\delta_2\} = \{\bar{P}_2\} \rightarrow (5)$$

In above expression ~~$k_{12}\delta_2$~~

$$[K_{12}]\{\delta_2\} \; \& \; [k_{22}]\{\delta_2\} = 0.$$

It is known from the above relationships i.e., from support conditions so that the resultant of the stiffness matrix can be obtained by deleting the corresponding rows and columns from the original matrix.

$$[K_B]^* = \begin{bmatrix} \frac{4EI}{l} & \frac{2EI}{l} \\ \frac{2EI}{l} & \frac{4EI}{l} \end{bmatrix}$$

The Vertical reaction $\bar{P}_1, \bar{P}_2$ can be calculated from the above relationship.

$$[k_{21}] = \begin{bmatrix} \frac{6EI}{l^2} & \frac{6EI}{l^2} \\ -\frac{6EI}{l^2} & -\frac{6EI}{l^2} \end{bmatrix}$$

~~The~~ If the forces are known to be zero at the same coordinate i.e., the displacements can be taken or placed freely at roller support.

$$[k_{11}]\{\delta_1\} + [k_{12}]\{\delta_2\} = P_1 \longrightarrow (4)$$

$$[k_{21}]\{\delta_1\} + [k_{22}]\{\delta_2\} = P_2 = 0. \longrightarrow 5a.$$

from the above expression.

$$[k_{21}]\{\delta_1\} = -[k_{22}]\{\delta_2\} \longrightarrow (6).$$

where $\delta_2 = -[k_{22}]^{-1}[k_{21}]\{\delta_1\}$

Now substitute the δ_2 value in expression (4)

$$[k_{11}]\{\delta_1\} + [k_{12}]\left\{-[k_{22}]^{-1}[k_{21}]\{\delta_1\}\right\} = \{\bar{P}_1\}$$

$$\{\delta_1\}\underbrace{\left[[k_{11}] - [k_{12}][k_{22}]^{-1}[k_{21}]\right]}_{K^*} = \{\bar{P}_1\}$$

K^* is called static condensation matrix.

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What are the effects in structures due to thermal stress

Thermal stresses:

One of the properties of metal is that they transfer heat. Physical changes that occur with this transfer include that expansion when temperature increases and shrinkage when temperature decreases. This happens in all 3-dimensions.

Thermal stresses occur as a result of thermal expansion of metallic structural members with the temperature changes. changes in temperature cause thermal deformation to the structural members. The value of this deformation can be described using the following formula

$$\delta_t = \alpha \times L \times \underbrace{(T - T_0)}_{\Delta t}$$

where,

δ_t = the deformation of the structural member due to change in temperature

α = temperature coefficient of expansion, a material measured in units /°K.

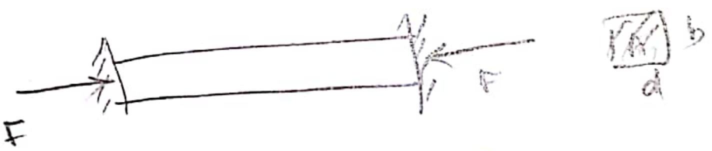
L = original length of the structural member.

T = final temperature measured in units. (K or °C)

T_0 = Initial temperature or original temperature (K or °C) when a structural member is free to move and expand, there is no stress extend on it. However, when movement and expansion are restricted, then thermal stress occurs. when motion is restricted in the direction of expansion, the value of reaction force is equal to the value of the free necessary to compress a beam in the opposite direction, and by the same amount of deformation. we can use the following formula, to describe the relation ship.

$$F = \frac{\delta EA}{L}$$

Here, δ = deformation of the beam due to reaction force which is equal to the deflection of beam due to thermal expansion but in the opp direction



A = C/S area of beam.

E = youngs modulus of the material (N/m²)

L = length of the beam.

Putting together our understanding, of thermal expansion and the forces involve, we can now solve for thermal stresses, represented by following relationship

$$\delta_t = \delta_f$$

$$\alpha L(T - T_0) = \frac{F \cdot L}{A \quad E}$$

$$= \sigma \cdot \frac{L}{E}$$

$$= \alpha.$$

5/11/18

UNIT-V

SHEAR WALLS:

what is a shear wall and their advantages.

Shear wall is a reinforced Concrete wall often have vertical plate like RC walls called as shear walls in addition to slabs, beams and Columns. These walls generally start at foundation level and are continuous throughout the building height, their thickness can be ~~up~~ 150mm - 400mm thick according to the height of the building.

Shear walls are provided along the length and width of the building. shear walls are like vertical oriented wide beam that carry earthquake load downwards to foundations

(Slab is considered as wider beam, b = 1000mm)

Advantages:

1. These walls have better resistance to earthquake loads.
2. They provide high resistance against lateral loads caused by wind.
3. They provide good architectural appearance.

Explain different types of shear walls.

1. Overall geometry walls: (1 dimension of the c/s is much longer than other).

Shear walls are oblong. in cross-section i.e., one dimension of the cross-section is much longer than the other.

→ (rectangular cross-section is common).

→ L, U. shaped cross-section are commonly used.

Scanned by CamScanner

2 Thinwalled Hallow RC shafts:

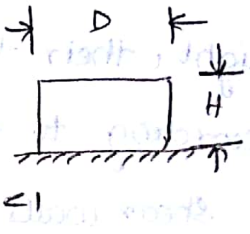
These are around the elevators i.e., lifts, cores of buildings also, These walls also act as shear walls and should be resistant to the earthquake loads.

what is monolithic shear walls: and Explain

Monolithic shear walls are classified as:

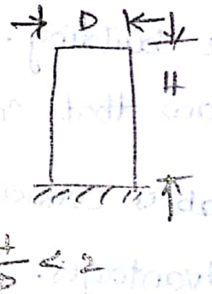
1. ~~Shaf~~ short shear wall.

If $\frac{h}{D} < 1$ then it is called short shear wall.



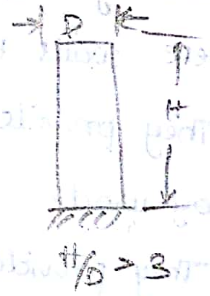
2. Squat shear wall

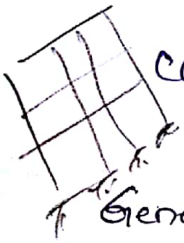
when $\frac{h}{D}$ is between [1 2]



3. Cantilever shear wall.

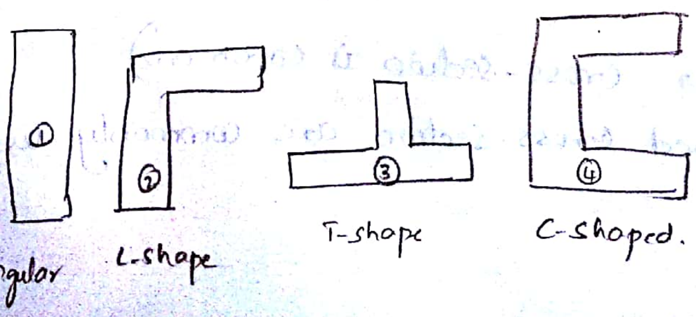
when $\frac{h}{D} > 3$ it is called Cantilever.





Generalise the shear wall shapes:

Generally the shear walls are either plaine or flanged by core walls consist of the channel sections

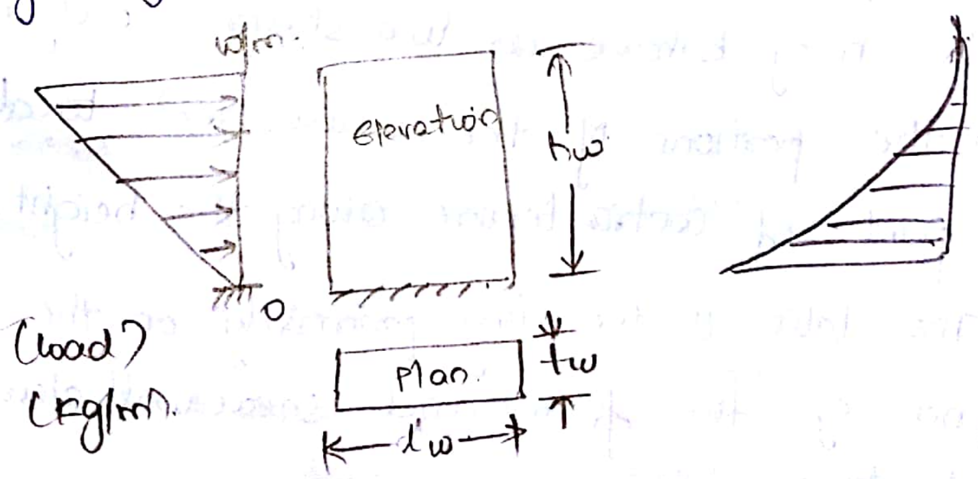


12/11/18 Explain the behaviour of shear walls:

1. Behavior of shear walls with particular reference to their mode of failure as in the case of beams. influenced by their properties as well as support conditions.

2. ~~Alo~~ low shear walls are known as squat walls. These are ~~carac~~ characterized relatively small height to length ratio. (h/d ratio), mainly expected to fail in shear just like deep beams.

3. Shear walls occurring in high-rise buildings are other than generally behave as vertically cantilever beams with their strength controlled by flexure rather than shear., such walls are subjected to bending moments, shear originating from lateral loads. and axial compression caused by gravity.



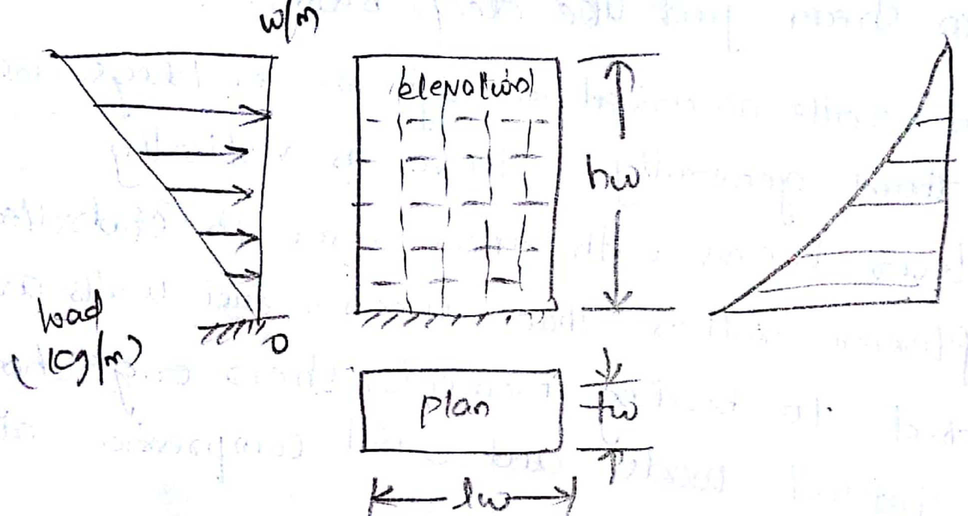
$$\left(\frac{1}{2} \times w \times h_w\right) \frac{2}{3} h_w$$

$$\frac{w h_w^2}{3}$$

Behaviour of Cantilever shear walls:

Shear walls are critical for walls with relatively low height and length ratios, tall shear walls controlled mainly by flexural requirements. as shown in fig below.

The fig shows a typical shear wall of height hw, length lw and thickness tw.



A portion of shear wall which interact with frames may behave as low shear wall depending upon the portions of the walls and location of the point of contraflexure along the height of walls.

The later is depending primarily on the relative stiffness of the frame and shear wall elements in a structure.

14/11/18

Explain the methods of analysis of a structure with shear walls.

1. Perforated shear wall method.
2. Segmented shear wall method.
3. Shear through panel rotation
4. Ni-Karacabeyli's method.
5. Alternate rotational Analysis.

1. Perforated shear wall method: (applicable when $F \leq 1$ only).

This method relates shear capacity of a wall with perforations (openings) (ex: doors, windows or both) to a wall of identical configuration without perforations through an empirical reduction factor (F). This value is determined as follows.

$$F = \frac{r}{3-2r} \rightarrow (1)$$

This is called reduction factor

$$\text{where, } r = \frac{1}{1+\frac{A_0}{H \sum l_i}} \rightarrow (2)$$

where, A_0 = total area of openings

H = height of wall.

l_i = Summation of length of all full height wall segments

r = shear area ratio.

In this method, the designer shall multiply the shear wall resistance calculated based on the total wall length (including the length of perforations) by the reduction factor.

If $F \leq 1$, determine the F value with the help of equation 1 $\left[F = \frac{r}{3-2r}\right]$

The total shear resistance of a shear wall is determined as follows.

$$V = FLv \rightarrow (3)$$

where V = total lateral resistance of a perforated shear wall line

F = reduction parameter according to eq(1)

L = total length of shear wall line including length of perforations.

v = unit shear resistance determined from appendix B.

The method requires that the overturning restrain are installed at the wall ends that typically coinside with building corners. (the max wall unit shear capacity i.e., unfractured not exceeding $1200 \frac{lb}{ft}$)

2. Segmented shear wall method:

This method uses resistance of fully sheathed segments located between wall openings. each segment should be fully restrained against overturning. The contribution of the components above and below openings are ignored. The unit shear resistance is multiplied by the segment length to determine shear resistance of the segment. The total shear resistance of shear wall line is determined as a sum of resistance of all individual segments as follows.

$$V = \sum_{i=1}^{n} l_i v_i \rightarrow (1).$$

where, V = total lateral resistance of shear wall line

l_i = length of an individual shear wall segment

v_i = unit shear resistance of an individual shear wall segment determined from appendix B

n = no. of shear wall segments in shear wall line.

If $F \le 1$ then perforated shear wall method is used. There is no chance of $F > 1$, if such happens segmented shear wall method is adopted

16/11/18

3. Shear through panel rotation :

This method is used to determine the shear resistance of a fully restrained lighter frame non-perforated shear wall segment through modelling the rotation response of individual sheating panels that are fastened to the wall framing with nails (or) screws.

This method is formulated with an assumption that a sheating panel rotates around its center as rigid body. The configuration of an individual nail to the total shear resistance is determined based on the distance from the nail to the center of panel rotation and relative nail displacement.

The unit shear wall of an individual shear panel is determined as follows.

$$V = C_N \cdot \sum_{i=1}^{n(total)} k_i$$

where, $k_i = \sin\beta \sqrt{\left(\frac{x_i}{B}\cos\beta\right)^2 + \left(\frac{y_i}{H}\sin\beta\right)^2}$

C_N = Peak resistance of individual sheating.

B = width of sheating panel.

H = height of sheating panel.

β = angle b/w the diagonal and vertical edge of individual sheating panel

i = sheating fastener enumerator.

x_i = horizontal coordinate of ith fastener relative to the panel center.

y_i = vertical coordinate of ith fastener relative to the panel centre.

k_i = geometric characteristic of fastening schedule of a sheating panel.

4. Ni - karacabeyli's method:

These mechanics based method is formulated such that the resistance of a non-perforated shear wall segment with a partial over-turning restraint is expressed as a fraction of the resistance of an identical shear wall segment with full restraint. This shear capacity ratio for a wall with a partial overturning restraint and the full overturning restraint can be determined as follows

$$\alpha = \sqrt{1+2\varphi r+r^2} - r \rightarrow (1)$$

$$\varphi = \frac{R}{m C_N} \rightarrow (2) \quad [0 < \varphi \leq 1]$$

(small phi)

where, α = ratio of lateral load capacity of a wall segment with partial uplift restraint to the capacity of wall segment with full uplift restraint.

R = uplift restraint force on the end stud of shear wall that include contribution of partial overturning restraint, gravity load, corner effect and other system effect.

r = wall segment aspect ratio : $\left(\frac{b}{h}\right)\left(\frac{\text{breadth}}{\text{height}}\right)$

φ = uplift restraint effect which is equal to unity for the walls. fully restraint against overturning.

m = total no. of nails along the end stud of shear wall segment.

C_N = capacity of single nail connection that can be measured experimentally or estimated using the connection yield theory.

The total resistance of shear wall line is determined as sum of the resistances of all individual segments as follows.

$$V = \sum_{i=1}^{n(total)} \alpha_i l_i v_i$$

where, V = total lateral resistance of shear wall line

α = It is described in eq ①.

l_i = length of an individual shear wall segment

v_i = unit shear resistance of an individual shear wall segment determined from appendix B

n = no. of shear wall segments in a shear wall line

5. Alternate rational analysis:

This section is not intended to limit the use of alternate design methods that use recognized principles of mechanics and engineering.

Examples of such methods include finite element analysis, matrix analysis, energy based formulations, solution in another way.

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Department of Civil Engineering

MATRIX METHODS OF STRUCTURAL ANALYSIS (GR22D5001)

COURSE FILE CHECK LIST

S.No.	Name of the Format	Page
1.	Syllabus	
2.	Time Table	
3.	Program educational Objectives	
4.	Program objectives	
5.	Course Objectives	
6.	Course Outcomes	
7.	Students Roll List	
8.	Guide lines to study the course books & references, course design & delivery	
9.	Course schedule	
10.	Unit plan/Course Plan	
11.	Evaluation Strategy	
12.	Assessment in relation to COB's and Co's	
13.	Tutorial Sheets	
14.	Assignment Sheets	
15.	Rubric for Course	
16.	Mappings of CO's and Po's	
17.	Model question papers	
18.	Mid-I and Mid-II question papers	
19.	Mid –I marks	
20.	Mid –II marks	
21.	Sample answer scripts and Assignments	
22.	Course materials like notes, PPT's, Videos etc.,	

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COURSE COMPLETION STATUS

-**A**cademic **Y**ear : 2022-23

Semester : I

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: **Matrix Methods in Structural Analysis** Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana Dept.: Civil Engineering

Designation: PROFESSOR

Actual Date of Completion & Remarks, if any

Units	Remarks	No. of Objectives Achieved	No. of Outcomes Achieved
Unit 1	Introduction to Matrix methods of Analysis	1	1
Unit 2	Assembly of stiffness matrices	2	2
Unit 3	Introduction about Flexibility matrix method(Force Method) And application to indeterminate beams	3	3
Unit 4	Introduction about Special analysis procedures	4	4
Unit 5	Special analysis procedures	5	5

Signature of HOD

Signature of faculty

Date:

Date:

Note: After the completion of each unit mention the number of Objectives & Outcomes Achieved.

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LESSON PLAN

Academic Year : 2022-23 Date: 26-10-2022

Semester : I **Unit – I Introduction to Matrix methods of Analysis**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: **Matrix Methods in Structural Analysis** Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 1 Duration of Lesson: 1hr

Lesson Title: Introduction about Matrix methods of analysis

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Definition of structure and its importance.

2. Analyze the different parameters induced in the structure during loading.

3. Analyze different structures with different end conditions.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Definition of a structure
- Differentiate between link and mechanism
- Different types of structures

Assignment / Questions: (1 & 1) 1. What is a structure?
(1 & 1) 2. Explain link and hinge where they are used.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic Year : 2022-23 Date: 27-10-2022

Semester : I **Unit – I Introduction to Matrix methods of Analysis**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: **Matrix Methods in Structural Analysis** Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 2 Duration of Lesson: 1hr

Lesson Title: Determination of Static indeterminacy of structures

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Definition of static indeterminacy.

2. Basic formulas for various structures come under static indeterminate.

3. Tips in determination of static indeterminacy.

TEACHING AIDS : white board, Different color markers
TEACHING POINTS :

- Definition of static indeterminacy.
- Differentiate between link and hinge in a structure.
- Formula for static indeterminacy for external and internal indeterminacy of various structures.

Assignment / Questions: (1 & 1) 1. What is redundant?
(1 & 1) 2. Explain in determination of static indeterminacy of a structure.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic Year : 2022-23 Date: 31-10-2022

Semester : I **Unit – I Introduction to Matrix methods of Analysis**

Name of the Program: M.Tech(Structural Engineering) Year: I

Course/Subject:**Matrix Methods in Structural Analysis** Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 3 Duration of Lesson: <u>1hr</u>

Lesson Title: Determination of Kinematic indeterminacy of structures

<u>INSTRUCTIONAL/LESSON OBJECTIVES:</u>

On completion of this lesson the student shall be able to:

1. Determination of Kinematic indeterminacy of structures.
2. Degrees of freedom at various supports.
3. Difference between DOF's and redundants.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Definition of kinematic indeterminacy.
- Differentiate between static and kinematic indeterminacy.
- Evaluation of kinematic indeterminacy with different methods.

Assignment / Questions: (1 & 1) 1. Explain the procedure in evaluation of kinematic indeterminacy?
(1 & 1) 2. Explain the difference between static and kinematic indeterminate structures.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic Year : 2022-23 Date: 01-11-2022

Semester : II **Unit – I Introduction to Matrix methods of Analysis**

Name of the Program: M.Tech(Structural Engineering) Year: I

Course/Subject: **Matrix Methods in Structural Analysis** Course Code: **GR22D5001**

Name of the Faculty:.Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 4 Duration of Lesson: 1hr

Lesson Title: Determination of DOF of given structures

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Determine the DOF at different supports.

2. Analyze different structures with different end conditions

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Definition of a cantilever method in determination of KID.
- Differentiate between vertical and horizontal shear release at supports.

Assignment / Questions: (1 & 1) 1. What is angular and linear translation at pin and rigid joints?
(1 & 1) 2. Explain the cantilever method or tree method to evaluate the KID of structure..

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 02-11-2022

Semester : I **Unit – I Introduction to Matrix methods of Analysis**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject:**Matrix Methods in Structural Analysis** Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 5 Duration of Lesson: 1hr

Lesson Title: Co-Ordinate sysytems

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Wha are the different co-ordinate systems?

2. How to change the local co-ordinates into global co-ordinate system.

3. Importance of transformation matrix.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Definition of transformation matrix.
- How to change local co-ordinates in to global co-ordinates?

Assignment / Questions: (1 & 1) 1. What is use of transformation matrix?
(1 & 2) 2. Explain the differences between local and global co-ordinate system.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic Year : 2022-23 Date: 03-11-2022

Semester : I **Unit – I Introduction to Matrix methods of Analysis**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject:**Matrix Methods in Structural Analysis** Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 6 Duration of Lesson: 1hr

Lesson Title: Structure idealize

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. How to idealize the structure under different co-ordinate systems?

2. What is structure idealization?

3. State the importance of structural idealization

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Definition of transformation matrix.
- How to change local co-ordinates in to global co-ordinates?

Assignment / Questions: (1 & 1) 1. What is use of structural idealization?
(1 & 2) 2. Explain the importance of structural idealization.

.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic Year : 2022-23 Date: 08-11-2022

Semester : I **Unit – I Introduction to Matrix methods of Analysis**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject:**Matrix Methods in Structural Analysis** Course Code: **GR22D5001**

Name of the Faculty:Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 7 Duration of Lesson: 1hr

Lesson Title: Differentiate & relation between Stiffness & Flexibility Matrix methods

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Understand about the structure idealization.
3. Suitability of structure idealization in Structural Analysis.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Explain the procedure of structure idealization.

Assignment / Questions: (1 & 1) 1. Explain about the structure idealization.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic Year : 2022-23 Date: 08-11-2022

Semester : I **Unit – I Introduction to Matrix methods of Analysis**

Name of the Program: M.Tech (Structural Engineering) Year: II

Course/Subject:**Matrix Methods in Structural Analysis** Course Code: **GR22D5001**

Name of the Faculty:Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 8 Duration of Lesson: 1hr

Lesson Title: Differentiate and relation between Flexibility & stiffness matrix methods

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Derive the general relationship between Flexibility & stiffness matrix methods

2. Explain the differences between Flexibility & stiffness matrix methods

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- How to evaluate the general relationship between Flexibility & stiffness matrix methods
- Explain the differences between Flexibility & stiffness matrix methods

Assignment / Questions: (1 & 1) 1. Derive the relationship between Flexibility & stiffness matrix Methods.
(1 & 1) 2. List out the differences between Flexibility & stiffness matrix Methods.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic Year : 2022-23 Date: 09-11-2022

Semester : I **Unit – I Introduction to Matrix methods of Analysis**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: **Matrix Methods in Structural Analysis** Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 9 Duration of Lesson: 1hr

Lesson Title: Derive displacement equations for truss, beam and torsional element.
.

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Calculation of displacement equations for truss, beam and torsional elements.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Evaluate the displacement equations for truss, beam and orsional element.

Assignment / Questions: (1 & 1) 1. How to calculate the displacement equations for truss, beam and torsional elements?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 10-11-2022

Semester : I **Unit- I Introduction to Matrix methods of Analysis**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 10 Duration of Lesson: 1hr

Lesson Title: Discuss on local and Global co-ordinates

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Understand about the local and Global co-ordinates
1. Differences between local and natural co-ordinate systems.
2. Explain the procedure in calculation of global stiffness matrx and displacement vectors

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Explain about local stiffness matrices and Global and displacement and load vectors

Assignment / Questions: (1 & 1) 1. How to generate local and global stiffness, displacement and load vectors?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 14-11-2022

Semester : I **Unit- I Introduction to Matrix methods of Analysis**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 11 Duration of Lesson: 1hr

Lesson Title: Discuss on questions in unit-1from old question papers .

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Understand the basic concepts of MMSA
2. Evaluate the global stiffness matrix from individual stiffness matrices.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Assembling of global stiffness matrix from individual stiffness matrices.
- Evaluate the size of global stiffness matix.

Assignment / Questions: (1 & 1) 1. Evaluate the global stiffness matrices from individual stiffness matrices

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

Gokaraju Rangaraju Institute of Engineering and Technology
(Autonomous)
Bachupally, Kukatpally, Hyderabad – 500 090. (040) 6686 4440

LESSON PLAN

Academic **Y**ear : 2022-23 Date: 15-11-2022

Semester : I **Unit- I Introduction to Matrix methods of Analysis**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 12 Duration of Lesson: 1hr

Lesson Title: Discuss on questions in unit-1from old question papers .

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Determination of static and kinematic in determinacy of given structures.
2. How to calculate dofs of any structure?

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Evaluate the static and kinematic in determinacy of given structures.
- Evaluate the dofs of any structure?

Assignment / Questions: (1 & 1) 1. Evaluate the static and kinematic in determinacy of given structures and dofs of any structure?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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(Autonomous)
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LESSON PLAN

Academic Year : 2022-23 Date: 16-11-2022

Semester : I **Unit- II Assembly of stiffness matrices**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 13 Duration of Lesson: 1hr

Lesson Title: Explain assembly of stiffness matrices.

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Understand the procedure in determination local and global stiffness matrices.
2. Understand the properties of stiffness matrix.

TEACHING AIDS : white board, Different colour markers

TEACHING POINTS :

- What is local and global stiffness matrices in case rotation and how to assembly the local matrices in to global matrix.
- Properties and its role in stiffness matrices in structural analysis.

Assignment / Questions: (2 & 2) 1. Discuss the how to assembly the local stiffness matrices into global stiffness matrix.
(2 & 2) 2. List out the properties stiffness matrix.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 17-11-2022

Semester : I **Unit- II Assembly of stiffness matrices**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 14 Duration of Lesson: 1hr

Lesson Title: General procedure for assembly stiffness matrices

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Understand the procedure in assembling of stiffness matrices.
2. Understand the importance of assembling of stiffness matrices.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- The steps involved in assembling of stiffness matrices.

Assignment / Questions: (2 & 2) 1. Derive the global stiffness matrix using assembling of element stiffness matrices.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic Year : 2022-23 Date: 21-11-2022

Semester : I **Unit- II Assembly of stiffness matrices**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 15 Duration of Lesson: 1hr

Lesson Title: Displacement vectors

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Understand the procedure in assessment of displacements at different nodes.
2. How to calculate the unknowns (displacements) using known relationship?

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- The steps involved in assessment of displacements at different nodes using known relationship.

Assignment / Questions: (2 & 2) 1. Derive the displacements at different nodes using known relationship .

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 21-11-2022

Semester : I **Unit- II Assembly of stiffness matrices**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 16 Duration of Lesson: 1hr

Lesson Title: Discuss on direct stiffness method.

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Understand the basic steps involved in derivation of stiffness matrix using direct stiffness approach.

TEACHING AIDS : white board, Different colour markers

TEACHING POINTS :

- Explain the procedure in determination of stiffness matrix using direct stiffness method..

Assignment / Questions: (2 & 2) 1. How to generate stiffness matrix using direct stiffness method.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic Year : 2022-23 Date: 23-11-2022

Semester : I **Unit- II Assembly of stiffness matrices**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 17 Duration of Lesson: 1hr

Lesson Title: General procedure for assembly stiffness matrices

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

3. Understand the procedure in assembling of stiffness matrices.
4. Understand the importance of assembling of stiffness matrices.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- The steps involved in assembling of stiffness matrices.

Assignment / Questions: (2 & 2) 1. Derive the global stiffness matrix using assembling of element stiffness matrices.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 24-11-2022

Semester : I **Unit- II Assembly of stiffness matrices**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 18 Duration of Lesson: 1hr

Lesson Title: Discuss on direct stiffness method.

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Understand the basic steps involved in derivation of stiffness matrix using direct stiffness approach.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Explain the properties of various support conditions and boundary conditions using in analysis of structures.

Assignment / Questions: (2 & 2) 1. List of properties of supports and boundary conditions.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 28-11-2022

Semester : I **Unit- II Assembly of stiffness matrices**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 19 Duration of Lesson: 1hr

Lesson Title: Discuss on questions in unit-2 from old question papers .

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Determination of stiffness matrix using direct stiffness matrix approach of given structures.
2. How to calculate the rotations and deformations at nodal joints?

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Evaluate the stiffness matrix using direct stiffness matrix approach of given structures.
- Evaluate the dofs of any structure?

Assignment / Questions: (2 & 2) 1. Evaluate the stiffness matrix using direct stiffness matrix approach of given structures.?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 29-11-2022

Semester : I **Unit- II Assembly of stiffness matrices**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 20 Duration of Lesson: 1hr

Lesson Title: Discuss on questions in unit-2 from old question papers .

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

2. Determination of static and kinematic in determinacy of given structures.
2. How to calculate dofs of any structure?

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Evaluate the global stiffness matrix from local stiffness matrices

Assignment / Questions: (2 & 2) 1. Evaluate the global stiffness matrix from local stiffness matrices?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

Gokaraju Rangaraju Institute of Engineering and Technology (Autonomous)
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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 30-11-2022

Semester : I **Unit-III Introduction about Flexibility matrix method**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 21 Duration of Lesson: 1hr

Lesson Title: Introduction about flexibility matrix or force method

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Understand the procedure to analyze any continuous beam having static indeterminate structure.
2. Calculate redundants using flexibility matrix method.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Analyze the continuous beams using flexibility matrix method
- Evaluate the support reactions and moments using flexibility matrix method

Assignment / Questions: (3 & 3) 1. Evaluate the support reactions and moments for given loading using Force method.
(3 & 3) 2. Draw BMD and SFD for analyzed continuous beams.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 01-12-2022

Semester : I **Unit-III Introduction about Flexibility matrix method**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 22 Duration of Lesson: 1hr

Lesson Title: Flexibility matrix approach for statically in determinate beams force method

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. How to calculate the static indeterminacy of given structure?
2. How to calculate redundants using flexibility matrix method.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Analyze the continuous beams using flexibility matrix method
- Evaluate the support reactions and moments using flexibility matrix method

Assignment / Questions: (3 & 3) 1. Evaluate the support reactions and moments for given loading using Force method.
(3 & 3) 2. Draw BMD and SFD for analyzed continuous beams.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 05-12-2022

Semester : I **Unit-III Introduction about Flexibility matrix method**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 23 Duration of Lesson: 1hr

Lesson Title: Methodology to calculate the redundants of beam at joints using force method

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Understand the procedure to analyze any continuous beam having static indeterminate structure.
2. Calculate redundants using flexibility matrix method.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Analyze the continuous beams using flexibility matrix method
- Evaluate the support reactions and moments using flexibility matrix method

Assignment / Questions: (3 & 3) 1. Evaluate the support reactions and moments for given loading using Force method.
(3 & 3) 2. Draw BMD and SFD for analyzed continuous beams.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic Year : 2022-23 Date: 06-12-2022

Semester : I **Unit-III Introduction about Flexibility matrix method**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 24 Duration of Lesson: 1hr

Lesson Title: Methodology to calculate the redundants of beam at joints using force method

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Understand the procedure to analyze any continuous beam having static indeterminate structure.

3. Calculate redundants using flexibility matrix method.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Analyze the continuous beams using flexibility matrix method
- Evaluate the support reactions and moments using flexibility matrix method

Assignment / Questions: (3 & 3) 1. Evaluate the support reactions and moments for given loading using Force method.
(3 & 3) 2. Draw BMD and SFD for analyzed continuous beams.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 07-12-2022

Semester : I **Unit-III Introduction about Flexibility matrix method**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 25 Duration of Lesson: 1hr

Lesson Title: method Analyze continuous beams using flexibilty matrix method carrying with different loads.

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Understand the procedure to analyze any continuous beam using force method having statically indeterminate.

2. Calculate redundants using flexibility matrix method.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Analyze the continuous beams using flexibility matrix method
- Evaluate the support reactions and moments using flexibility matrix method

Assignment / Questions: (3 & 3) 1. Evaluate the support reactions and moments for given loading using Force method.
(3 & 3) 2. Draw BMD and SFD for analyzed continuous beams.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 08-12-2022

Semester : I **Unit-III Introduction about Flexibility matrix method**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 26 Duration of Lesson: 1hr

Lesson Title: method Analyze continuous beams using flexibty matrix method carrying with different loads.

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Understand the procedure to analyze any continuous beam using force method having statically indeterminate.

2. Calculate redundants using flexibility matrix method.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Analyze the continuous beams using flexibility matrix method
- Evaluate the support reactions and moments using flexibility matrix method

Assignment / Questions: (3 & 3) 1. Evaluate the support reactions and moments for given loading using Force method.
(3 & 3) 2. Draw BMD and SFD for analyzed continuous beams.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

Gokaraju Rangaraju Institute of Engineering and Technology (Autonomous)
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LESSON PLAN

Academic Year : 2022-23 Date: 12-12-2022

Semester : I **Unit-III Introduction about Flexibility matrix method**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 27 Duration of Lesson: 1hr

Lesson Title: method Analyze continuous plane truss using flexibility matrix method carrying with different loads.

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Understand the procedure to analyze any plane truss using force method having statically Indeterminacy up to 2.
2. Calculate redundant forces using flexibility matrix method.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Analyze the plane truss using flexibility matrix method
- Evaluate the redundant forces in a plane truss using flexibility matrix method

Assignment / Questions: (3 & 3) 1. Evaluate the redundant force in a plane truss for given loading using Force method.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

Gokaraju Rangaraju Institute of Engineering and Technology (Autonomous)
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LESSON PLAN

Academic Year : 2022-23 Date: 13-12-2022

Semester : I **Unit-III Introduction about Flexibility matrix method**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 28 Duration of Lesson: 1hr

Lesson Title: Analyze continuous plane frame using flexibility matrix method carrying with different loads.

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Understand the procedure to analyze any plane frame using force method having statically Indeterminacy up to 3.
2. Calculate redundant forces and moments using flexibility matrix method.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Analyze the plane frame using flexibility matrix method
- Evaluate the redundant forces in a plane frame using flexibility matrix method

Assignment / Questions: (3 & 3) 1. Evaluate the redundant force in a plane frame for given loading using Force method.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

Gokaraju Rangaraju Institute of Engineering and Technology
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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 14-12-2022

Semester : I **Unit-III Introduction about Flexibility matrix method**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 29 Duration of Lesson: 1hr

Lesson Title: Discuss on questions in unit-3 from old question papers .

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Determination of unknown reactions of a continuous beam using flexibility matrix method..
2. Draw SFD and BMDs of given continuous beam.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Evaluate the unknown reactions of a continuous beam using flexibility matrix method..
- Draw SFD and BMDs of given continuous beam.

Assignment / Questions: (3 & 3) 1. Analyse the continuous beam using flexibility matrix approach.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

Gokaraju Rangaraju Institute of Engineering and Technology (Autonomous)
Bachupally, Kukatpally, Hyderabad – 500 090. (040) 6686 4440

LESSON PLAN

Academic Year : 2022-23 Date: 15-12-2022

Semester : I **Unit-III Introduction about Flexibility matrix method**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 30 Duration of Lesson: 1hr

Lesson Title: Discuss on questions in unit-3 from old question papers .

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Determination of redundant forces in a statically indeterminate plane truss using flexibility matrix method.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Evaluate of redundant forces in a statically indeterminate plane truss using flexibility matrix method.

Assignment / Questions: (3 & 3) 1. Evaluate of redundant forces in a statically indeterminate plane truss using flexibility matrix method.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

Gokaraju Rangaraju Institute of Engineering and Technology
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LESSON PLAN

Academic Year : 2022-23 Date: 19-12-2022

Semester : I **Unit-III Introduction about Flexibility matrix method**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 31 Duration of Lesson: 1hr

Lesson Title: Discuss on questions in unit-3 from old question papers .

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1.. Determination of redundant forces in a statically indeterminate plane frame using flexibility matrix method.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Evaluate of redundant forces in a statically indeterminate plane frame using flexibility matrix method.

Assignment / Questions: (3 & 3) 1. Evaluate of redundant forces in a statically indeterminate plane truss using flexibility matrix method

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

Gokaraju Rangaraju Institute of Engineering and Technology (Autonomous)
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LESSON PLAN

Academic Year : 2022-23 Date: 20-12-2022

Semester : I **Unit-IV Introduction about stiffness matrix method**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 32 Duration of Lesson: 1hr

Lesson Title: Introduction about stiffness matrix or displacement method and applications to Kinematically indeterminate structures

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Understand the procedure to analyze any continuous beam with kinematic indeterminate structure.
2. Calculate the dof's of any given structure.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Analyze the continuous beams using stiffness matrix method
- Evaluate the support moments using stiffness matrix method

Assignment / Questions: (4 & 4) 1. Evaluate the support moments for given loading using displacement Method.
(4 & 4) 2. Draw BMD and SFD for analyzed continuous beams.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

Gokaraju Rangaraju Institute of Engineering and Technology
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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 21-12-2022

Semester : I **Unit-IV Introduction about stiffness matrix method**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 33 Duration of Lesson: 1hr

Lesson Title: Stiffness matrix approach to kinematically indeterminate beams.

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Calculate the kinematic indeterminacy (KID) of given beam.
2. Understand in calculation of support rotations and moments using displacement method

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Explain the procedure to evaluate KID of the given beam or any structure.
- Evaluate the support rotations and moments in continuous beams subjected various loading using stiffness matrix method.

Assignment / Questions: (4 & 4) 1. Evaluate support rotations of a given continuous beam using displacement method.

(4 & 4) 2. Evaluate the support moments of a continuous beams using displacement method.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 22-12-2022

Semester : I **Unit-IV Introduction about stiffness matrix method**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 34 Duration of Lesson: 1hr

Lesson Title: Methodology to calculate the support moments of beam joints using stiffness matrix method.

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Analyze the continuous beam using displacement method.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Analyze the kinematically indeterminate of beams.

Assignment / Questions: (4 & 4) 1. Analyze the kinematically indeterminate structure.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

Gokaraju Rangaraju Institute of Engineering and Technology (Autonomous)

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 02-01-2023

Semester : I **Unit-IV Introduction about stiffness matrix method**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 35 Duration of Lesson: 1hr

Lesson Title: Methodology to calculate the redundants forces at beam joints using stiffness matrix method.

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. 1. Analyze the KID structure using displacement method.

TEACHING AIDS : white board, Different colour markers

TEACHING POINTS :

- Analyze the kinematically indeterminate of beams.

1. Assignment / Questions: (4 & 4) 1. Analyze the kinematically indeterminate structure.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date:03-01-2023

Semester : I **Unit-IV Introduction about stiffness matrix method**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 36 Duration of Lesson: 1hr

Lesson Title: Analyze continuous beams using stiffness matrix method carrying with different loads.

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Understand to analyze continuous beams using stiffness matrix method with kinematic indeterminacy 1, 2 or 3.
2. Draw Bending Moment Diagram (BMD) & Shear force diagram (SFD) after analysis.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Evaluation of KID beams.
- Draw BMD and SFD after analysis.

Assignment / Questions: (4 & 4) 1. Analyze KID beams using displacement method under given loading.
(4 & 4) 2. Draw Bending Moment Diagram (BMD) & Shear force diagram (SFD) for frame.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic Year : 2022-23 Date: 04-01-2023

Semester : I **Unit-IV Introduction about stiffness matrix method**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 37 Duration of Lesson: 1hr

Lesson Title: Analyze continuous beams using stiffness matrix method carrying with different loads and sinking supports

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Analyze continuous beams using stiffness matrix method carrying with different loads and sinking supports
2. To draw Bending Moment Diagram (BMD) & Shear force diagram (SFD) after analysis.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Analyze continuous beams using stiffness matrix method carrying with different loads and sinking supports
- Draw BMD and SFD after analysis.

Assignment / Questions: (4 & 4) 1. Analyze continuous beams using stiffness matrix method carrying with different loads and sinking supports
(4 & 4) 2. Draw Bending Moment Diagram (BMD) & Shear force diagram (SFD) for portal frame after analysis.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic Year : 2022-23 Date: 05-01-2023

Semester : I **Unit-IV Introduction about stiffness matrix method**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 38 Duration of Lesson: 1hr

Lesson Title: Analyze plane truss by using stiffness matrix methods carrying with different loads

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Analyze the plane truss by using stiffness matrix methods carrying continuous beams with different loadings.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Analyze the plane truss carrying with different loadings.
- Draw BMD and SFD after analysis.

Assignment / Questions: (3 & 3) 1. Analyze the plane truss by using stiffness matrix methods carrying with different loadings.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 09-01-2023

Semester : I **Unit-IV Introduction about stiffness matrix method**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 39 Duration of Lesson: 1hr

Lesson Title: Analyze plane frame by using stiffness matrix methods carrying with different loads

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Analyze the plane frame by using stiffness matrix methods carrying continuous beams with different loadings.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Analyze the plane frame carrying with different loadings.
- Draw BMD and SFD after analysis.

Assignment / Questions: (3 & 3) 1. Analyze the plane frame by using stiffness matrix methods carrying with different loadings.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic Year : 2022-23 Date: 10-01-2023

Semester : I **Unit-IV Introduction about stiffness matrix method**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 40 Duration of Lesson: 1hr

Lesson Title: Analyze Discus on old question papers

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Analyze the continuous beam from old question papers having KID 2 or 3.
2. Draw Bending Moment Diagram (BMD) & Shear force diagram (SFD) after analysis.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Analyse the continuous beam from old question papers having KID 2 or 3.
- Draw BMD and SFD after analysis.

Assignment / Questions: (4 & 4) 1. Analyze the continuous beam from old question papers having KID 2 or 3.
(4 & 4) 2. Draw Bending Moment Diagram (BMD) & Shear force diagram (SFD) for continuous beam after analysis.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 11-01-2023

Semester : I **Unit-III Introduction about stiffness matrix method**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 41 Duration of Lesson: 1hr

Lesson Title: Solve old question papers

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Analyze the plane frame by using stiffness matrix methods from old question papers.
2. Evaluation of kinematic indeterminacy or total DOF of structure.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

Analyse any kinematic indeterminate plane frame using displacement method of structure.

Assignment / Questions: (4 & 4) 1. Analyze the plane frame by using stiffness matrix methods

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

Gokaraju Rangaraju Institute of Engineering and Technology
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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 12-01-2023

Semester : I **Unit-III Introduction about stiffness matrix method**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 42 Duration of Lesson: 1hr

Lesson Title: Solve old question paper problems in unit-4

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Understand the analysis of KID structures using displacement method.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Explain old question paper problems in unit-3 using displacement methods.

Assignment / Questions: (4 & 4) 1. Determine the kinematic indeterminacy and applied appropriate co-ordinates as per dof.
(4 & 4) 2. Analyse the KID structures using displacement method and draw SFD and BMD’s.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 17-01-2023

Semester : I **Unit-V Introduction about special analysis procedures**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 43 Duration of Lesson: 1hr

Lesson Title: Introduction about special analysis procedures

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Understand the importance and role of special procedure in analysis of structures.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Explain the methodology of special procedures in analysis of structures.

Assignment / Questions: (5 & 5) 1. State the need of special procedures in analysis of structures.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

Gokaraju Rangaraju Institute of Engineering and Technology
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LESSON PLAN

Academic Year : 2022-23 Date: 18-01-2023

Semester : I **Unit-IV Introduction about special analysis procedures**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 44 Duration of Lesson: 1hr

Lesson Title: What is Static condensation of structures?

INSTRUCTIONAL/LESSON OBJECTIVES:
On completion of this lesson the student shall be able to:
1. Understand the importance of Static condensation of structures
2. Analyze the given structures using Static condensation procedure.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Explain the term Static condensation of structures
- Explain the procedure in analysis of structures using Static condensation.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :
Assignment / Questions: (4 & 4) 1. What is static condensation?
(4 & 4) 2. Explain Static condensation and its suitability in analysis of structures.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

Gokaraju Rangaraju Institute of Engineering and Technology
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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 19-01-2023

Semester : I **Unit-IV Introduction about special analysis procedures**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 45 Duration of Lesson: 1hr

Lesson Title: Explain Static condensation with suitable example structures

INSTRUCTIONAL/LESSON OBJECTIVES:
On completion of this lesson the student shall be able to:

1. Understand the role of Static condensation in analysis of structures

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Explain the Static condensation with suitable example structures

Assignment / Questions: (5 & 5) 1.Explain the term static condensation with suitable example.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 23-01-2023

Semester : I **Unit-IV Introduction about special analysis procedures**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 46 Duration of Lesson: 1hr

Lesson Title: What is sub-structuring?

INSTRUCTIONAL/LESSON OBJECTIVES:
On completion of this lesson the student shall be able to:
1. Understand the principle of sub-structuring.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Explain the procedure of sub-structuring using analysis of structures.

Assignment / Questions: (5 & 5) 1. Explain the sub-structuring procedure in analysis of structures.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 24-01-2023

Semester : I **Unit-IV Introduction about special analysis procedures**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 47 Duration of Lesson: 1hr

Lesson Title: Importance of sub-structuring in structural analysis

INSTRUCTIONAL/LESSON OBJECTIVES:
On completion of this lesson the student shall be able to:

1. Understand about the importance of sub-structuring

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Explain the role of sub-structuring in analysis of structures.

Assignment / Questions: (5 & 5) 1. Explain the role sub-structuring in analysis of structures.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 30-01-2023

Semester : I **Unit-IV Introduction about special analysis procedures**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 48 Duration of Lesson: 1hr

Lesson Title: What is effect due to initial and thermal stresses in structures?

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Understand the effect due to initial and thermal stresses in structures

TEACHING AIDS : white board, Different colour markers

TEACHING POINTS :

- Explain the effects due to initial and thermal stresses in structures

Assignment / Questions: (5 & 5) 1. Describe the effects due to initial and thermal stresses in structures

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

Gokaraju Rangaraju Institute of Engineering and Technology
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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 31-01-2023

Semester : I **Unit-V Shear walls**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 49 Duration of Lesson: 1hr

Lesson Title: – Introduction about shear walls.

INSTRUCTIONAL/LESSON OBJECTIVES:
On completion of this lesson the student shall be able to:

1. Understand the definition of shear walls.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Explain about shear walls.

Assignment / Questions: (5 & 5) 1. Discus about definition of shear walls.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 01-02-2023

Semester : II **Unit-V Shear walls**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 50 Duration of Lesson: 1hr

Lesson Title: Necessity of shear walls in structures and their shapes
.
INSTRUCTIONAL/LESSON OBJECTIVES:
On completion of this lesson the student shall be able to:

- Know about importance of shear walls in building constructions.
- Understand the shapes of shear walls and their role in building constructions.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Explain about importance of shear walls in building constructions.
- Explain various shapes of shear walls used in structures.

Assignment / Questions: (5 & 5) 1. Discuss on various shapes of shear walls used in structures.
- (5 & 5) 2. Discuss on importance of shear walls in building constructions.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic Year : 2022-23 Date:01-02-2023

Semester : I **Unit-V Shear walls**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 51 Duration of Lesson: 1hr

Lesson Title: Importance of shear walls in structures and their location in structures.

STRUCTIONAL/LESSON OBJECTIVES:
On completion of this lesson the student shall be able to:

- Know about the locations of shear walls and role of shear walls against earthquake or lateral loads acting on structures.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Explain about the locations of shear walls and role of shear walls against earthquake or lateral loads acting on structures.

Assignment / Questions: (5 & 5) 1. Write about the locations of shear walls and role of shear walls against earthquake or lateral loads acting on structures.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic Year : 2022-23 Date: 02-02-2023

Semester : I **Unit-V Shear walls**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 52 Duration of Lesson: 1hr

Lesson Title: Structural behaviour of large frames with and without shear walls

INSTRUCTIONAL/LESSON OBJECTIVES:
On completion of this lesson the student shall be able to:

1. Understand the behaviour large frames with and without shear walls

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Explain the behaviour of large frames with and without shear walls.

Assignment / Questions: (5 & 5) 1. Narrate the behaviour of large frames with and without shear walls.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic Year : 2022-23 Date: 06-02-2023

Semester : I **Unit-V Shear walls**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 53 Duration of Lesson: 1hr

Lesson Title: Structural behaviour of large frames with and without shear walls
.

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Understand the behaviour large frames with and without shear walls

TEACHING AIDS : white board, Different colour markers

TEACHING POINTS :

• Explain the behaviour of large frames with and without shear walls.	• Explain

Assignment / Questions: (5 & 5) 1. Narrate the behaviour of large frames with and without shear walls.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 07-02-2023

Semester : I **Unit-V Shear walls**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 54 Duration of Lesson: 1hr

Lesson Title: Approximate methods of analysis for shear walls

.

INSTRUCTIONAL/LESSON OBJECTIVES:
On completion of this lesson the student shall be able to:

1. Understand in methods of analysis against shear walls.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Explain various approximate methods of analysis for shear walls.

Assignment / Questions: (5 & 5) 1. Discuss on various approximate methods of analysis for shear walls.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 08-02-2023

Semester : I **Unit-V Shear walls**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 55 Duration of Lesson: 1hr

Lesson Title: Approximate methods of analysis for shear walls

.

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

2. Understand in methods of analysis against shear walls.

TEACHING AIDS : white board, Different colour markers

TEACHING POINTS :

- Explain various approximate methods of analysis for shear walls.

Assignment / Questions: (5 & 5) 1. Discuss on various approximate methods of analysis for shear walls.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2022-23 Date: 09-02-2023

Semester : I **Unit-V Shear walls**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 56 Duration of Lesson: <u>1hr</u>

Lesson Title: Approximate methods of analysis for shear walls
.

<u>INSTRUCTIONAL/LESSON OBJECTIVES:</u>
On completion of this lesson the student shall be able to:

3. Understand in methods of analysis against shear walls.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Explain various approximate methods of analysis for shear walls.

Assignment / Questions: (5 & 5) 1. Discuss on various approximate methods of analysis for shear walls.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic Year : 2022-23 Date: 13-02-2023

Semester : I **Unit-V Shear walls**

Name of the Program: M.Tech (Structural Engineering) Year: I

Course/Subject: Matrix Methods in Structural Analysis Course Code: **GR22D5001**

Name of the Faculty: Dr.GVV Satyanarayana. Dept.: Civil Engineering

Designation: PROFESSOR

Lesson No: 57 Duration of Lesson: 1hr

Lesson Title: Approximate methods of analysis for shear walls
.
INSTRUCTIONAL/LESSON OBJECTIVES:
On completion of this lesson the student shall be able to:

4. Understand in methods of analysis against shear walls.

TEACHING AIDS : white board, Different colour markers
TEACHING POINTS :

- Explain various approximate methods of analysis for shear walls.

Assignment / Questions: (5 & 5) 1. Discuss on various approximate methods of analysis for shear walls.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.