MATRIX STRUCTURAL ANALYSIS PROJECT

ASTORIA-MEGLER BRIDGE 2D MODEL

GROUP 11

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EXECUTIVE SUMMARY

- In the project, we have analyzed the Astoria-Megler bridge, by making a 2-D model for it. We plotted the deflected shape of the bridge under realistic loading and calculated the bending moment, axial force, and shear force in each member using Matlab.

- All this analysis will provide us with how we can increase the safety of the bridge and optimize it economically.

- The deflected shape will help us select supports so that we can minimize the deflection.

- The bridge is deforming more in the middle span so we can provide support to reduce the deflection.

SALIENT FEATURES

- Total Length: 21,474 feet (6,545 meters)
- Main Span: 1,232 feet (376 meters)
- Width: 28 feet (8.5 meters)
- Number of Lanes: 2
- Construction Period: November 5, 1962 - August 27, 1966

Key Features of the Cantilever Design

- Continuous Truss Structure: The Astoria-Megler Bridge is notable for being the longest continuous truss bridge in North America. This design allows for a seamless distribution of loads across the entire structure, enhancing stability and reducing stress concentrations typically found in traditional cantilever designs, where spans are separate.

- Main Span Configuration: The bridge's main span measures 1,233 feet (376 meters) and is supported by cantilever arms. This central navigation span is unique in that it initially functioned as a cantilever during construction, with the suspended span being temporarily held by the cantilever arms. Once completed, this suspended span was riveted to the cantilever arms, transforming it into a continuous truss rather than an independent suspended structure.

- Innovative Construction Technique: The construction involved an unusual method where segments were fabricated upstream and then barged downstream for assembly. Hydraulic jacks were employed to lift these segments into place, allowing for a more efficient construction process in challenging environmental conditions.

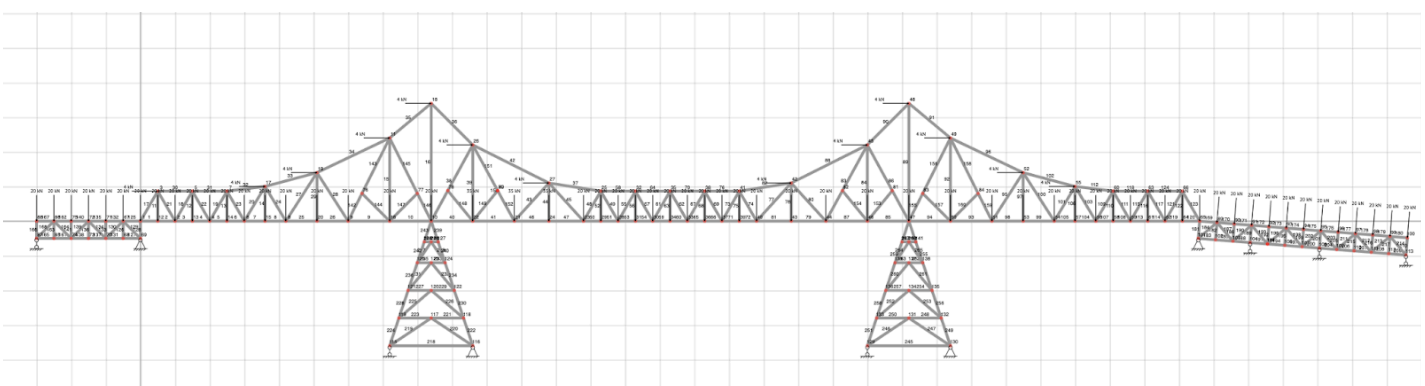
- Robust Wind and Current Resistance: Designed to withstand wind gusts of up to 150 mph (240 km/h) and river currents of 9 mph (14 km/h), the bridge's cantilever structure is engineered for resilience against extreme weather conditions typical of the Pacific Northwest.

PROBLEM DETAILS

- We have replicated a 2D truss structure by analyzing the side view geometry of the Astoria - Megler Bridge constructed in Astoria, USA. There are a total of 141 nodes and 266 members. The Loads and supports have been mentioned with a view of realistic conditions.

- Loads:-
  1. Dead load - the weight of the road
  2. Live load - weight of vehicles
  3. Wind load - force on truss due to wind

- The 2-D structure is shown below with the loads applied:-



- The real image of the bridge is shown below:-

OBJECTIVE

To find:-

1. Deflected shape of truss
2. Unknown reactions
3. Bending moment, shear force, and axial force in each member

SOLUTION APPROACH

COLLECTION OF THE STRUCTURE DATA:

1. Joint Coordinates1 sheet: Identify the number of joints and name them 1 to Number_of_Nodes. For each joint get x and y coordinates, their expected settlement, concentrated forces, and moments.

2. Member Connectivity sheet: Name the members from 1 to Number_of_members. For each member get the 2 joints it connects. Determine its Area, Modulus of Elasticity, Moment of Inertia, and the distributed force acting on it. For each member define the JOINT_CASE based on the method of release of moment.

CREATION OF THE CODE:

1. **Initialize Workspace**
   - Clear any previous variables and set up a clean environment.
2. **Read Input Data**
   - **Node Coordinates:** Read joint coordinates (including positions and applied forces/moments) from an Excel sheet.
   - **Member Connectivity:** Read member properties (connectivity, material properties, joint types, and applied loads) from an Excel sheet.
3. **Setup Global Stiffness Matrix and Load Vectors**
   - Initialize the global stiffness matrix K_global, fixed-end force vector, nodal forces vector, and settlements vector to zero.
4. **Iterate Over Members**

   For each member:
   - Extract member properties: area, elasticity, inertia, load, joint case, and the nodes it connects.

- Compute **member length** and **orientation** using the coordinates of the connected nodes.
- Compute **local stiffness matrix** and **fixed-end forces** based on the joint case (e.g., fully fixed, hinged, etc.).
- Form the **transformation matrix** to convert local stiffness and forces to global coordinates.
- Assemble the member's global stiffness matrix and force contributions into the global system.

5. **Apply for Settlements**
   - Incorporate node settlements into the global system by adding the corresponding displacement terms and their effects on forces.
6. **Boundary Conditions**
   - Remove degrees of freedom (DOFs) associated with restrained nodes by modifying the global stiffness matrix and force vectors.
7. **Solve for Displacements**
   - Compute the displacements of the free DOFs by solving the reduced system: K_reduced×U_free = F_reduced
   - Reconstruct the full displacement vector, including zero displacements for restrained DOFs.
8. **Calculate Member Forces**
   For each member:
   - Use the member's displacements and the stiffness matrix to compute forces at each end of the member in the global coordinate system.
   - Apply fixed-end forces and distributed loads.
9. **Output Results**
   - Write the computed member forces, displacements, and other relevant data in an Excel file.
10. **Plotting**

- From the original coordinates of nodes and displacements for each node obtained from the solution, get the deformed coordinates of the nodes. Plot both deformed and undeformed shapes. Use a scaling factor to visualize the deformed shape of the structure.

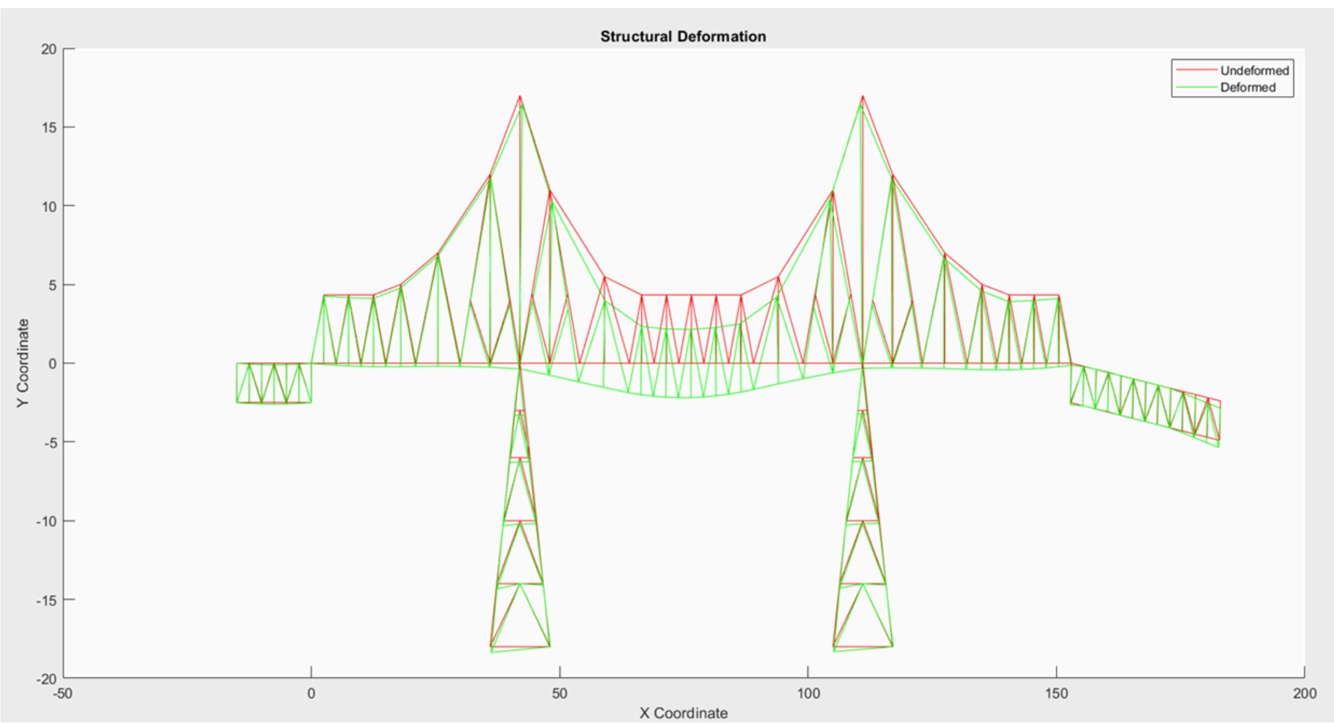
IMPROVEMENT

- In this approach, we won't be able to get the deformed shape of each member. In order to do so we can further divide each member into smaller members considering a sufficient number of nodes along the length of the member. This will give us a better visualization of how each member is deforming.

FINAL RESULTS

The deflected shape obtained shows nodal displacements

Red color - undeformed shape; Green color - Deformed shape



(i) We can clearly see here that the large deformations in the middle span are due to the absence of ground support in the middle, pointing to lower stiffness.

(ii) The triangular design of trusses provides excellent stability by efficiently transferring loads from the deck to the bridge supports.

(iii) As we have applied different types of loads at various points and members it demonstrates a highly efficient and stable structure, capable of withstanding environmental forces while providing safe and reliable transportation.

EXCEL SHEET FOR MEMBER CONNECTIVITY

	A	B	C	D	E	F	G	H
1	Member	Joint 1	Joint 2	Area	E	I	W	JOINT_CASE
2	1	1	12	0.86	2E+11	0.00002	0	1
3	2	12	2	0.86	2E+11	0.00002	0	1
4	3	2	13	0.86	2E+11	0.00002	0	1
5	4	13	4	0.86	2E+11	0.00002	0	1
6	5	4	14	0.86	2E+11	0.00002	0	1
7	6	14	6	0.86	2E+11	0.00002	0	1
8	7	6	15	0.86	2E+11	0.00002	0	1
9	8	15	8	0.86	2E+11	0.00002	0	1
10	9	9	16	0.86	2E+11	0.00002	0	1
11	10	16	10	0.86	2E+11	0.00002	0	1
12	11	12	3	0.86	2E+11	0.00002	0	1
13	12	13	5	0.86	2E+11	0.00002	0	1
14	13	14	7	0.86	2E+11	0.00002	0	1
15	14	15	17	0.86	2E+11	0.00002	0	1
16	15	16	11	0.86	2E+11	0.00002	0	1
17	16	10	18	0.86	2E+11	0.00002	0	1
18	17	1	3	0.86	2E+11	0.00002	0	1
19	18	2	5	0.86	2E+11	0.00002	0	1
20	19	4	7	0.86	2E+11	0.00002	0	1
21	20	6	17	0.86	2E+11	0.00002	0	1
22	21	3	2	0.86	2E+11	0.00002	0	1
23	22	5	4	0.86	2E+11	0.00002	0	1
24	23	7	6	0.86	2E+11	0.00002	0	1
25	24	17	8	0.86	2E+11	0.00002	0	1
26	25	8	20	0.86	2E+11	0.00002	0	1
27	26	20	9	0.86	2E+11	0.00002	0	1
28	27	8	19	0.86	2E+11	0.00002	0	1
29	28	19	9	0.86	2E+11	0.00002	0	1
30	29	20	19	0.86	2E+11	0.00002	0	1
31	30	3	5	0.86	2E+11	0.00002	0	1
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33	32	7	17	0.86	2E+11	0.00002	0	1
34	33	17	19	0.86	2E+11	0.00002	0	1
35	34	19	11	0.86	2E+11	0.00002	0	1

36	35	11	18	0.86	2E+11	0.00002	0	1
37	36	18	26	0.86	2E+11	0.00002	0	1
38	37	27	25	0.86	2E+11	0.00002	0	1
39	38	10	26	0.86	2E+11	0.00002	0	1
40	39	22	26	0.86	2E+11	0.00002	0	1
41	40	10	22	0.86	2E+11	0.00002	0	1
42	41	22	21	0.86	2E+11	0.00002	0	1
43	42	26	27	0.86	2E+11	0.00002	0	1
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45	44	24	27	0.86	2E+11	0.00002	0	1
46	45	27	23	0.86	2E+11	0.00002	0	1
47	46	21	24	0.86	2E+11	0.00002	0	1
48	47	24	23	0.86	2E+11	0.00002	0	1
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50	49	25	28	0.86	2E+11	0.00002	0	1
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53	52	29	25	0.86	2E+11	0.00002	0	1
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230	229	121	117	0.86	2E+11	0.00002	0	1

230	229	121	117	0.86	2E+11	0.00002	0	1
231	230	120	122	0.86	2E+11	0.00002	0	1
232	231	122	121	0.86	2E+11	0.00002	0	1
233	232	122	123	0.86	2E+11	0.00002	0	1
234	233	123	121	0.86	2E+11	0.00002	0	1
235	234	124	122	0.86	2E+11	0.00002	0	1
236	235	120	124	0.86	2E+11	0.00002	0	1
237	236	124	125	0.86	2E+11	0.00002	0	1
238	237	125	123	0.86	2E+11	0.00002	0	1
239	238	10	126	0.86	2E+11	0.00002	0	1
240	239	126	123	0.86	2E+11	0.00002	0	1
241	240	125	126	0.86	2E+11	0.00002	0	1
242	241	124	127	0.86	2E+11	0.00002	0	1
243	242	127	10	0.86	2E+11	0.00002	0	1
244	243	127	125	0.86	2E+11	0.00002	0	1
245	244	128	129	0.86	2E+11	0.00002	0	1
246	245	128	130	0.86	2E+11	0.00002	0	1
247	246	130	129	0.86	2E+11	0.00002	0	1
248	247	130	131	0.86	2E+11	0.00002	0	1
249	248	131	129	0.86	2E+11	0.00002	0	1
250	249	132	130	0.86	2E+11	0.00002	0	1
251	250	128	132	0.86	2E+11	0.00002	0	1
252	251	132	133	0.86	2E+11	0.00002	0	1
253	252	133	131	0.86	2E+11	0.00002	0	1
254	253	133	134	0.86	2E+11	0.00002	0	1
255	254	47	134	0.86	2E+11	0.00002	0	1
256	255	134	131	0.86	2E+11	0.00002	0	1
257	256	135	133	0.86	2E+11	0.00002	0	1
258	257	132	135	0.86	2E+11	0.00002	0	1
259	258	135	47	0.86	2E+11	0.00002	0	1
260	259	135	136	0.86	2E+11	0.00002	0	1
261	260	136	134	0.86	2E+11	0.00002	0	1
262	261	136	137	0.86	2E+11	0.00002	0	1
263	262	138	136	0.86	2E+11	0.00002	0	1
264	263	138	139	0.86	2E+11	0.00002	0	1
265	264	139	137	0.86	2E+11	0.00002	0	1
266	265	139	140	0.86	2E+11	0.00002	0	1
267	266	141	139	0.86	2E+11	0.00002	0	1

EXCEL SHEET FOR JOINT COORDINATES

1	Joint	X	Y	SETTLEMENT -X	SETTLEMENT -Y	CONC_FORCE_X	CONC_FORCE_Y	CONC_MOMENT_Z
2	1	0	0	0	0	0	-20000	0
3	2	5	0	0	0	0	-20000	0
4	3	2.5	4.33	0	0	4000	0	0
5	4	10	0	0	0	0	-20000	0
6	5	7.5	4.33	0	0	0	0	0
7	6	15	0	0	0	0	-20000	0
8	7	12.5	4.33	0	0	0	0	0
9	8	21	0	0	0	0	-20000	0
10	9	30	0	0	0	0	-20000	0
11	10	42	0	0	0	0	-20000	0
12	11	36	12	0	0	4000	0	0
13	12	2.5	0	0	0	0	-20000	0
14	13	7.5	0	0	0	0	-20000	0
15	14	12.5	0	0	0	0	-20000	0
16	15	18	0	0	0	0	-20000	0
17	16	36	0	0	0	0	-20000	0
18	17	18	5	0	0	4000	0	0
19	18	42	17	0	0	4000	0	0
20	19	25.5	7	0	0	4000	0	0
21	20	25.5	0	0	0	0	-20000	0
22	21	54	0	0	0	0	-35000	0
23	22	48	0	0	0	0	-35000	0
24	23	64	0	0	0	0	-20000	0
25	24	59	0	0	0	0	-35000	0
26	25	66.5	4.33	0	0	0	0	0
27	26	48	11	0	0	4000	0	0
28	27	59	5.5	0	0	4000	0	0
29	28	69	0	0	0	0	-20000	0
30	29	66.5	0	0	0	0	-20000	0
31	30	74	0	0	0	0	-20000	0
32	31	71.5	0	0	0	0	-20000	0
33	32	71.5	4.33	0	0	0	0	0
34	33	79	0	0	0	0	-20000	0
35	34	76.5	0	0	0	0	-20000	0
36	35	76.5	4.33	0	0	0	0	0
37	36	81.5	0	0	0	0	-20000	0

38	37	84	0	0	0	0	-20000	0
39	38	81.5	4.33	0	0	0	0	0
40	39	86.5	0	0	0	0	-20000	0
41	40	89	0	0	0	0	-20000	0
42	41	86.5	4.33	0	0	0	0	0
43	42	94	5.5	0	0	4000	0	0
44	43	94	0	0	0	0	-20000	0
45	44	99	0	0	0	0	-20000	0
46	45	105	11	0	0	4000	0	0
47	46	105	0	0	0	0	-20000	0
48	47	111	0	0	0	0	-20000	0
49	48	111	17	0	0	4000	0	0
50	49	117	12	0	0	4000	0	0
51	50	117	0	0	0	0	-20000	0
52	51	123	0	0	0	0	-20000	0
53	52	127.5	7	0	0	4000	0	0
54	53	127.5	0	0	0	0	-20000	0
55	54	132	0	0	0	0	-20000	0
56	55	135	5	0	0	4000	0	0
57	56	138	0	0	0	0	-20000	0
58	57	135	0	0	0	0	-20000	0
59	58	140.5	0	0	0	0	-20000	0
60	59	143	0	0	0	0	-20000	0
61	60	140.5	4.33	0	0	0	0	0
62	61	145.5	0	0	0	0	-20000	0
63	62	148	0	0	0	0	-20000	0
64	63	145.5	4.33	0	0	0	0	0
65	64	150.5	0	0	0	0	-20000	0
66	65	153	0	0	0	0	-20000	0
67	66	150.5	4.33	0	0	0	0	0
68	67	-2.5	0	0	0	0	-20000	0
69	68	-2.5	-2.5	0	0	0	0	0
70	69	0	-2.5	0	0	0	0	0
71	70	-5	-2.5	0	0	0	0	0
72	71	-5	0	0	0	0	-20000	0
73	72	-7.5	0	0	0	0	-20000	0
74	73	-7.5	-2.5	0	0	0	0	0

75	74	-10	-2.5	0	0	0	0	0
76	75	-10	0	0	0	0	-20000	0
77	76	32	4	0	0	0	0	0
78	77	40	4	0	0	0	0	0
79	78	44.4	4.4	0	0	0	0	0
80	79	51.6	4.4	0	0	0	0	0
81	80	108.6	4.4	0	0	0	0	0
82	81	101.4	4.4	0	0	0	0	0
83	82	113	4	0	0	0	0	0
84	83	121	4	0	0	0	0	0
85	84	-12.5	-2.5	0	0	0	0	0
86	85	-12.5	0	0	0	0	0	0
87	86	-15	-2.5	0	0	0	-20000	0
88	87	-15	0	0	0	0	0	0
89	88	155.5	-0.2	0	0	0	-20000	0
90	89	158	-0.4	0	0	-1595	-19936	0
91	90	160.5	-0.6	0	0	-1595	-19936	0
92	91	163	-0.8	0	0	-1595	-19936	0
93	92	165.5	-1	0	0	-1595	-19936	0
94	93	168	-1.2	0	0	-1595	-19936	0
95	94	170.5	-1.4	0	0	-1595	-19936	0
96	95	173	-1.6	0	0	-1595	-19936	0
97	96	175.5	-1.8	0	0	-1595	-19936	0
98	97	178	-2	0	0	-1595	-19936	0
99	98	180.5	-2.2	0	0	-1595	-19936	0
100	99	183	-2.4	0	0	-1595	-19936	0
101	100	152.8	-2.5	0	0	-1595	-19936	0
102	101	155.3	-2.7	0	0	0	0	0
103	102	157.8	-2.9	0	0	0	0	0
104	103	160.3	-3.1	0	0	0	0	0
105	104	162.8	-3.3	0	0	0	0	0
106	105	165.3	-3.5	0	0	0	0	0
107	106	167.8	-3.7	0	0	0	0	0
108	107	170.3	-3.9	0	0	0	0	0
109	108	172.8	-4.1	0	0	0	0	0
110	109	175.3	-4.3	0	0	0	0	0
111	110	177.8	-4.5	0	0	0	0	0

112	111	180.3	-4.7	0	0	0	0	0
113	112	182.8	-4.9	0	0	0	0	0
114	113	162.8	-3.3	0	0	0	0	0
115	114	36	-18	0	0	0	0	0
116	115	48	-18	0	0	0	0	0
117	116	42	-14	0	0	0	0	0
118	117	46.667	-14	0	0	0	0	0
119	118	37.333	-14	0	0	0	0	0
120	119	42	-10	0	0	0	0	0
121	120	38.667	-10	0	0	0	0	0
122	121	45.333	-10	0	0	0	0	0
123	122	42	-6	0	0	0	0	0
124	123	44	-6	0	0	0	0	0
125	124	40	-6	0	0	0	0	0
126	125	42	-3	0	0	0	0	0
127	126	43	-3	0	0	0	0	0
128	127	41	-3	0	0	0	0	0
129	128	105	-18	0	0	0	0	0
130	129	117	-18	0	0	0	0	0
131	130	111	-14	0	0	0	0	0
132	131	115.667	-14	0	0	0	0	0
133	132	106.333	-14	0	0	0	0	0
134	133	111	-10	0	0	0	0	0
135	134	114.333	-10	0	0	0	0	0
136	135	107.667	-10	0	0	0	0	0
137	136	**111**	-6	0	0	0	0	0
138	137	113	-6	0	0	0	0	0
139	138	109	-6	0	0	0	0	0
140	139	111	-3	0	0	0	0	0
141	140	112	-3	0	0	0	0	0
142	141	110	-3	0	0	0	0	0

CALCULATED VALUES OF AXIAL FORCE, SHEAR FORCE AND BENDING MOMENTS

F_x_NODEi - Axial Force
F_y_NODEi - Shear Force
M_z_NODEi - Bending Moment

MEMBER_NUMBER	F_x_NODEi	F_y_NODEi	M_z_NODEi	F_x_NODEj	F_y_NODEj	M_z_NODEj	Length	Uniformly_distributed_Load
1	-60.01	0.05	0.08	60.01	-0.05	0.04	2.5	0
2	-60.02	-0.01	-0.02	60.02	0.01	0	2.5	0
3	-182.77	0.01	0.01	182.77	-0.01	0.01	2.5	0
4	-182.77	0	-0.01	182.77	0	0	2.5	0
5	-143.86	0	0	143.86	0	0.01	2.5	0
6	-143.85	-0.01	-0.01	143.85	0.01	0	2.5	0
7	80.55	0	-0.01	-80.55	0	0	3	0
8	80.55	0	-0.01	-80.55	0	0	3	0
9	700.39	0	0	-700.39	0	0	6	0
10	700.39	0	0	-700.39	0	-0.01	6	0
11	-59.95	-0.01	-0.02	59.95	0.01	-0.01	4.33	0
12	-59.99	0	0	59.99	0	0	4.33	0
13	-59.99	0	0.01	59.99	0	0.01	4.33	0
14	-60	0	0.01	60	0	0.01	5	0
15	-100	0	0	100	0	-0.01	12	0
16	1103.75	0	0	-1103.75	0	0	17	0
17	238.16	0.01	0.03	-238.16	-0.01	0.01	4.99989	0
18	76.55	0	0	-76.55	0	0	4.99989	0
19	-85.1	0	0	85.1	0	0	4.99989	0
20	-268.02	0	0	268.02	0	0	5.83095189	0
21	-168.94	0	0	168.94	0	0	4.99989	0
22	-7.28	0	0	7.28	0	0	4.99989	0
23	173	0	0	-173	0	0.01	4.99989	0
24	279.05	0	0.01	-279.05	0	0.01	5.83095189	0
25	429.37	0	-0.01	-429.37	0	-0.01	4.5	0
26	429.37	0	0	-429.37	0	0	4.5	0
27	-379.56	0	0	379.56	0	0	8.32165849	0
28	240.31	0	0.01	-240.31	0	0.01	8.32165849	0
29	-60.01	0	0.01	60.01	0	0.01	7	0
30	219.55	0	0	-219.55	0	0.01	5	0
31	261.47	0	0	-261.47	0	0	5	0
32	133.39	0	-0.01	-133.39	0	-0.01	5.54065881	0
33	-133.57	0	-0.01	133.57	0	-0.01	7.76208735	0
34	-492.06	0	-0.01	492.06	0	-0.02	11.6297033	0
35	-792.22	0.01	0.04	792.22	-0.01	0.04	7.81024968	0
36	-843.72	-0.01	-0.04	843.72	0.01	-0.04	8.48528137	0
37	483.54	0	0.01	-483.54	0	0.02	7.59071143	0
38	189.87	0	0.02	-189.87	0	0.01	12.5299641	0
39	-174.99	0	0	174.99	0	0	11	0
40	430.39	0.01	0.04	-430.39	-0.01	0.01	6	0

42	41	430.39	0	0	-430.39	0	0	6	0
43	42	-253.35	0	0.02	253.35	0	0.01	12.2983739	0
44	43	452.72	0	-0.01	-452.72	0	-0.01	7.43303437	0
45	44	-105	-0.01	-0.02	105	0.01	-0.02	5.5	0
46	45	-564.65	0	0	564.65	0	0	7.43303437	0
47	46	-133.22	0	0	133.22	0	0.01	5	0
48	47	-133.23	0.01	0.01	133.23	-0.01	0.01	5	0
49	48	390.07	0	-0.02	-390.07	0	0	4.99989	0
50	49	-234.74	0	-0.01	234.74	0	0	4.99989	0
51	50	-708.09	0.01	0	708.09	-0.01	0.02	2.5	0
52	51	-708.1	0	-0.01	708.1	0	0.01	2.5	0
53	52	-59.99	-0.01	-0.01	59.99	0.01	-0.01	4.33	0
54	53	-896.65	0.01	0	896.65	-0.01	0.02	2.5	0
55	54	-896.65	0	-0.01	896.65	0	0.01	2.5	0
56	55	142.35	0	-0.01	-142.35	0	0	4.99989	0
57	56	-59.99	0	-0.01	59.99	0	0	4.33	0
58	57	-73.08	0	-0.01	73.08	0	0	4.99989	0
59	58	790.18	0	0	-790.18	0	0.02	5	0
60	59	-923.54	0	-0.01	923.54	0	0.02	2.5	0
61	60	-923.54	-0.01	-0.02	923.54	0.01	0	2.5	0
62	61	-19.3	0	-0.01	19.3	0	0.01	4.99989	0
63	62	88.57	0	0	-88.57	0	0.01	4.99989	0
64	63	-59.99	0	0	59.99	0	0	4.33	0
65	64	897.9	0	-0.01	-897.9	0	0.01	5	0
66	65	-788.78	0	-0.01	788.78	0	0.01	2.5	0
67	66	-788.77	-0.01	-0.02	788.77	0.01	0	2.5	0
68	67	-180.95	0	0	180.95	0	0.01	4.99989	0
69	68	-59.99	0	0.01	59.99	0	0.01	4.33	0
70	69	250.22	0	0	-250.22	0	0.01	4.99989	0
71	70	843.97	0	-0.02	-843.97	0	0	5	0
72	71	-492.35	0	-0.01	492.35	0	0	2.5	0
73	72	-492.34	-0.01	-0.02	492.34	0.01	0	2.5	0
74	73	-342.61	0	0	342.61	0	0.01	4.99989	0
75	74	453.38	0.01	0.01	-453.38	-0.01	0.02	4.99989	0
76	75	-59.99	0.01	0.02	59.99	-0.01	0.02	4.33	0
77	76	628.37	-0.01	-0.02	-628.37	0.01	-0.01	5	0
78	77	-638.75	0	0	638.75	0	0	7.43303437	0
79	78	-60.01	0.01	0.02	60.01	-0.01	0.02	5.5	0
80	79	164.03	0	0	-164.03	0	0	5	0
81	80	378.2	0	0.01	-378.2	0	0.01	7.43303437	0
82	81	164.03	-0.01	-0.02	-164.03	0.01	-0.02	5	0
83	82	233.14	-0.01	-0.02	-233.14	0.01	-0.02	7.59071143	0
84	83	-409.89	0	0	409.89	0	-0.01	12.5299641	0
85	84	-99.99	0	0	99.99	0	-0.01	11	0

86	85	614.71	-0.01	0	-614.71	0.01	-0.03	6	0
87	86	49.17	0	-0.02	-49.17	0	-0.02	12.5299641	0
88	87	614.71	0	0	-614.71	0	0	6	0
89	88	-484.92	0	-0.01	484.92	0	-0.02	12.2983739	0
90	89	1151.48	0	0	-1151.48	0	0	17	0
91	90	-895.96	0.01	0.05	895.96	-0.01	0.04	8.48528137	0
92	91	-809.07	-0.01	-0.04	809.07	0.01	-0.04	7.81024968	0
93	92	-100	0	0	100	0	0.01	12	0
94	93	377.66	0	0	-377.66	0	0	6	0
95	94	377.66	0	0.02	-377.66	0	0	6	0
96	95	219.19	0	0	-219.19	0	0	8.32165849	0
97	96	-488.58	0	0.02	488.58	0	0.01	11.6297033	0
98	97	-60	0	-0.01	60	0	-0.01	7	0
99	98	126.95	0	0	-126.95	0	0	4.5	0
100	99	126.94	0	0.01	-126.94	0	0.01	4.5	0
101	100	-364.06	0	0	364.06	0	0	8.32165849	0
102	101	263.84	0	-0.01	-263.84	0	0	5.83095189	0
103	102	-109.41	0	0.01	109.41	0	0.01	7.76208735	0
104	103	-252.29	0	0	252.29	0	0	5.83095189	0
105	104	-205.67	0	0	205.67	0	0	3	0
106	105	-205.67	0.01	0.01	205.67	-0.01	0.01	3	0
107	106	-60	0	-0.01	60	0	-0.01	5	0
108	107	-414.19	0.01	0.01	414.19	-0.01	0.02	2.5	0
109	108	-414.2	0	-0.01	414.2	0	0	2.5	0
110	109	157.42	0	-0.01	-157.42	0	0	4.99989	0
111	110	-59.99	0	-0.01	59.99	0	0	4.33	0
112	111	-62.86	0	0	62.86	0	0	4.99989	0
113	112	181.16	0	0.01	-181.16	0	0.01	5.54065881	0
114	113	-430.87	0.01	0	430.87	-0.01	0.01	2.5	0
115	114	-430.86	-0.01	-0.02	430.86	0.01	0	2.5	0
116	115	-29.52	0	0	29.52	0	0	4.99989	0
117	116	-59.99	0	0	59.99	0	0	4.33	0
118	117	98.79	0	0	-98.79	0	0.01	4.99989	0
119	118	289.99	0	0	-289.99	0	0.01	5	0
120	119	-285.88	0	0	285.88	0	0	2.5	0
121	120	-285.88	0	-0.01	285.88	0	0	2.5	0
122	121	-191.17	0	0	191.17	0	0	4.99989	0
123	122	-60	0	0.01	60	0	0	4.33	0
124	123	260.46	0	0	-260.46	0	0.01	4.99989	0
125	124	225.83	0	-0.01	-225.83	0	-0.01	5	0
126	125	59.04	-0.04	-0.03	-59.04	0.04	-0.07	2.5	0
127	126	0	0.01	0.02	0	-0.01	0.02	2.5	0
128	127	-242.49	-0.01	-0.02	242.49	0.01	0	2.5	0
129	128	286.34	-0.02	-0.01	-286.34	0.02	-0.05	2.5	0

130	129	259.44	0	0	-259.44	0	0.01	3.53553391	0
131	130	-118.07	0	0	118.07	0	0.01	3.53553391	0
132	131	-242.51	0	-0.01	242.51	0	0	2.5	0
133	132	326	0	-0.01	-326	0	0	2.5	0
134	133	60	0	0.01	-60	0	0.01	2.5	0
135	134	33.23	0	-0.01	-33.23	0	0	3.53553391	0
136	135	326	0	-0.01	-326	0	0.01	2.5	0
137	136	0.01	0	0	-0.01	0	0	2.5	0
138	137	-349.5	0	-0.01	349.5	0	0	2.5	0
139	138	-349.5	0.01	0	349.5	-0.01	0.01	2.5	0
140	139	108.18	0	0	-108.18	0	0.01	3.53553391	0
141	140	273	0	0	-273	0	0.01	2.5	0
142	141	59.99	-0.01	-0.01	-59.99	0.01	-0.01	2.5	0
143	142	-315.44	-0.01	-0.01	315.44	0.01	-0.01	4.47213595	0
144	143	-315.44	0	0	315.44	0	-0.01	8.94427191	0
145	144	0	0	0.01	0	0	0.01	5.65685425	0
146	145	96.76	0	-0.01	-96.76	0	0	8.94427191	0
147	146	96.76	0	0.01	-96.76	0	0	4.47213595	0
148	147	0	0	0	0	0	0	5.65685425	0
149	148	0	0	0	0	0	0	5.68506816	0
150	149	0	0	-0.01	0	0	-0.01	5.68506816	0
151	150	-541.05	0	0.01	541.05	0	0	7.51797845	0
152	151	-541.04	0	0.01	541.04	0	0.01	5.01198563	0
153	152	0	0	0	0	0	0	5.68506816	0
154	153	0	0	0	0	0	0	5.68506816	0
155	154	63.16	0	0.01	-63.16	0	0	4.47213595	0
156	155	63.16	0	0	-63.16	0	0.01	8.94427191	0
157	156	0	0	0	0	0	0	5.65685425	0
158	157	-295.58	0	0.01	295.58	0	0	8.94427191	0
159	158	-295.58	0	0.01	295.58	0	0	4.47213595	0
160	159	0	0	-0.01	0	0	-0.01	5.65685425	0
161	160	-136.51	0.01	0.01	136.51	-0.01	0.02	2.5	0
162	161	272.99	0.01	0.01	-272.99	-0.01	0.02	2.5	0
163	162	0	-0.01	-0.02	0	0.01	-0.02	2.5	0
164	163	-193.02	0	0	193.02	0	0	3.53553391	0
165	164	-136.49	0.01	0.01	136.49	-0.01	0.01	2.5	0
166	165	-196.49	-0.01	-0.01	196.49	0.01	-0.02	2.5	0
167	166	0.01	0.01	0.02	-0.01	-0.01	0.02	2.5	0
168	167	193.01	0	0	-193.01	0	0	3.53553391	0
169	168	-130.82	-0.05	-0.06	130.82	0.05	-0.07	2.50798724	0
170	169	-198.42	0.04	0.06	198.42	-0.04	0.04	2.50798724	0
171	170	-198.39	-0.01	0	198.39	0.01	-0.02	2.50798724	0
172	171	184.43	0.04	0.06	-184.43	-0.04	0.04	2.50798724	0
173	172	184.43	-0.02	-0.03	-184.43	0.02	-0.01	2.50798724	0

174	173	-87.76	-0.01	-0.01	87.76	0.01	-0.01	2.50798724	0
175	174	-87.78	-0.01	-0.02	87.78	0.01	-0.02	2.50798724	0
176	175	-679.93	-0.03	-0.02	679.93	0.03	-0.05	2.50798724	0
177	176	-679.94	0.03	0.05	679.94	-0.03	0.02	2.50798724	0
178	177	-180	0.01	0.02	180	-0.01	0.01	2.50798724	0
179	178	-179.99	0.01	0.01	179.99	-0.01	0.01	2.50798724	0
180	179	0	0	0	0	0	0	2.50798724	0
181	180	316.95	0.04	0.05	-316.95	-0.04	0.04	2.50798724	0
182	181	777.98	0	0	-777.98	0	0	2.50798724	0
183	182	376.92	-0.06	-0.06	-376.92	0.06	-0.09	2.50798724	0
184	183	-533	0	0.01	533	0	-0.01	3.54682957	0
185	184	542.82	0.06	0.09	-542.82	-0.06	0.06	2.50798724	0
186	185	59.95	-0.03	-0.04	-59.95	0.03	-0.04	2.50798724	0
187	186	-426.12	0.01	0.02	426.12	-0.01	0	3.54682957	0
188	187	0.04	0	0	-0.04	0	0	2.50798724	0
189	188	-0.02	-0.04	-0.05	0.02	0.04	-0.06	2.50798724	0
190	189	341.44	-0.01	-0.02	-341.44	0.01	-0.03	3.54682957	0
191	190	0	0.02	0.05	0	-0.02	0	2.50798724	0
192	191	59.94	-0.01	-0.01	-59.94	0.01	-0.01	2.50798724	0
193	192	-199.89	0.02	0.04	199.89	-0.02	0.03	3.54682957	0
194	193	-41.85	-0.01	-0.01	41.85	0.01	0	2.50798724	0
195	194	0	0.01	0.02	0	-0.01	0.02	2.50798724	0
196	195	-121.75	0	-0.01	121.75	0	0	3.54682957	0
197	196	-41.84	-0.01	-0.01	41.84	0.01	-0.01	2.50798724	0
198	197	263.18	0	0	-263.18	0	0	3.54682957	0
199	198	59.99	0.02	0.02	-59.99	-0.02	0.02	2.50798724	0
200	199	390.36	-0.01	-0.01	-390.36	0.01	-0.02	2.50798724	0
201	200	0.02	0.03	0.04	-0.02	-0.03	0.04	2.50798724	0
202	201	-348.01	0	0	348.01	0	0	3.54682957	0
203	202	489.37	-0.01	0	-489.37	0.01	-0.02	3.54682957	0
204	203	390.39	-0.03	-0.02	-390.39	0.03	-0.06	2.50798724	0
205	204	60.06	0	0	-60.06	0	0	2.50798724	0
206	205	380.01	0.03	0.05	-380.01	-0.03	0.02	2.50798724	0
207	206	379.98	0.01	0.01	-379.98	-0.01	0.01	2.50798724	0
208	207	40.01	0.01	0.01	-40.01	-0.01	0.01	2.50798724	0
209	208	40	0	0	-40	0	0	2.50798724	0
210	209	40	0	0	-40	0	0	2.50798724	0
211	210	424.17	0.01	0.02	-424.17	-0.01	0	3.54682957	0
212	211	-282.81	0	0	282.81	0	0	3.54682957	0
213	212	197.96	0	0	-197.96	0	0	3.54682957	0
214	213	-56.56	0	0	56.56	0	0	3.54682957	0
215	214	0.02	-0.03	-0.04	-0.02	0.03	-0.03	2.50798724	0
216	215	59.99	-0.01	-0.02	-59.99	0.01	-0.02	2.50798724	0
217	216	0.01	-0.01	-0.01	-0.01	0.01	-0.01	2.50798724	0

218	217	484.13	0	0.01	-484.13	0	0	12	0
219	218	-748.05	-0.01	-0.03	748.05	0.01	-0.04	7.21110255	0
220	219	-1015.19	0.01	0.03	1015.19	-0.01	0.03	7.21110255	0
221	220	-0.25	0.04	0.11	0.25	-0.04	0.1	4.667	0
222	221	1140.45	-0.02	-0.04	-1140.45	0.02	-0.03	4.21626482	0
223	222	-0.17	-0.04	-0.08	0.17	0.04	-0.1	4.667	0
224	223	437.38	0.01	0.02	-437.38	-0.01	0.02	4.21626482	0
225	224	0.12	0	0.02	-0.12	0	0.01	6.14661606	0
226	225	-0.06	-0.01	-0.02	0.06	0.01	-0.02	6.14661606	0
227	226	0.05	-0.02	-0.03	-0.05	0.02	-0.04	3.333	0
228	227	437.36	0.02	0.04	-437.36	-0.02	0.02	4.21658108	0
229	228	0.19	0.03	0.05	-0.19	-0.03	0.05	3.333	0
230	229	1140.62	-0.02	-0.03	-1140.62	0.02	-0.04	4.21658108	0
231	230	0.08	0	0	-0.08	0	-0.01	5.20661973	0
232	231	0.18	0	-0.01	-0.18	0	0	5.20661973	0
233	232	-0.22	0.12	0.12	0.22	-0.12	0.12	2	0
234	233	1140.41	-0.01	-0.03	-1140.41	0.01	-0.02	4.21626482	0
235	234	-0.16	-0.09	-0.08	0.16	0.09	-0.1	2	0
236	235	437.29	0.01	0.01	-437.29	-0.01	0.01	4.21626482	0
237	236	0.46	0	0.01	-0.46	0	-0.01	3.60555128	0
238	237	0.56	-0.01	-0.03	-0.56	0.01	-0.02	3.60555128	0
239	238	1140.55	-0.04	-0.07	-1140.55	0.04	-0.06	3.16227766	0
240	239	1140.06	-0.06	-0.12	-1140.06	0.06	-0.07	3.16227766	0
241	240	-0.17	0.46	0.28	0.17	-0.46	0.18	1	0
242	241	436.98	0.03	0.05	-436.98	-0.03	0.05	3.16227766	0
243	242	437.39	0.03	0.09	-437.39	-0.03	0.02	3.16227766	0
244	243	-0.13	-0.39	-0.14	0.13	0.39	-0.24	1	0
245	244	404.91	0	0.01	-404.91	0	0	12	0
246	245	-625.63	-0.01	-0.02	625.63	0.01	-0.03	7.21110255	0
247	246	-904.78	0.01	0.02	904.78	-0.01	0.02	7.21110255	0
248	247	-0.24	0.04	0.1	0.24	-0.04	0.09	4.667	0
249	248	1100.48	-0.01	-0.03	-1100.48	0.01	-0.03	4.21626482	0
250	249	-0.15	-0.03	-0.07	0.15	0.03	-0.09	4.667	0
251	250	365.8	0.01	0.01	-365.8	-0.01	0.01	4.21626482	0
252	251	0.11	0	0.02	-0.11	0	0.01	6.14661606	0
253	252	-0.05	0	-0.01	0.05	0	-0.01	6.14661606	0
254	253	0.18	0.02	0.04	-0.18	-0.02	0.03	3.333	0
255	254	1100.6	0	0.01	-1100.6	0	0.01	10.5408201	0
256	255	1100.63	-0.02	-0.04	-1100.63	0.02	-0.04	4.21658108	0
257	256	0.06	-0.02	-0.04	-0.06	0.02	-0.04	3.333	0
258	257	365.78	0.01	0.04	-365.78	-0.01	0.01	4.21658108	0
259	258	365.79	0	0.02	-365.79	0	0.02	10.5408201	0
260	259	0	0	0	0	0	0	5.20661973	0
261	260	0	0	0	0	0	-0.01	5.20661973	0
262	261	0	0	0	0	0	0	2	0
263	262	0	0	0	0	0	0	2	0
264	263	0	0	0	0	0	0	3.60555128	0
265	264	0	0	0	0	0	0	3.60555128	0
266	265	0	0	0	0	0	0	1	0
267	266	0	0	0	0	0	0	1	0

APPENDIX

MATLAB CODE

```
% Initialize workspace
clear; clc;

% Define scale factor for plotting
applied_scale_factor = 2000;

% Specify restrained degrees of freedom (DOFs)
restrained_dofs = [205, 206, 260, 301, 302, 311, 323, 338, 344, 346, 347, 386, 388, 389];


% Read joint coordinates and member connectivity from Excel
Node_Coordinates = xlsread("DRSR.xlsx", "Joint Coordinates1");
Member_Connectivity = xlsread("DRSR.xlsx", "Member Connectivity1");

% Get the number of joints and members
[num_joints, ~] = size(Node_Coordinates);
[num_members, ~] = size(Member_Connectivity);




% Initialize global stiffness matrix and force vectors
K_global = zeros(3 * num_joints);
fixed_end_forces = zeros(3 * num_joints, 1);
nodal_forces = zeros(3 * num_joints, 1);
settlements = zeros(3 * num_joints, 1);

% Assemble global stiffness matrix and load vectors
for member = 1:num_members
    % Extract member properties
    area = Member_Connectivity(member, 4);
    elasticity = Member_Connectivity(member, 5);
    inertia = Member_Connectivity(member, 6);
    load_w = Member_Connectivity(member, 7);
    joint_case = Member_Connectivity(member, 8);
    node_i = Member_Connectivity(member, 2);
    node_j = Member_Connectivity(member, 3);

    % Extract settlements
    settlement_x_i = Node_Coordinates(node_i, 4);
    settlement_y_i = Node_Coordinates(node_i, 5);
    settlement_x_j = Node_Coordinates(node_j, 4);
    settlement_y_j = Node_Coordinates(node_j, 5);
```

```
% Extract concentrated forces and moments
conc_force_x_i = Node_Coordinates(node_i, 6);
conc_force_y_i = Node_Coordinates(node_i, 7);
conc_moment_z_i = Node_Coordinates(node_i, 8);
conc_force_x_j = Node_Coordinates(node_j, 6);
conc_force_y_j = Node_Coordinates(node_j, 7);
conc_moment_z_j = Node_Coordinates(node_j, 8);

% Coordinates of nodes
x_i = Node_Coordinates(node_i, 2);
y_i = Node_Coordinates(node_i, 3);
x_j = Node_Coordinates(node_j, 2);
y_j = Node_Coordinates(node_j, 3);

% Calculate member length and orientation
member_length = sqrt((x_j - x_i)^2 + (y_j - y_i)^2);
cos_theta = (x_j - x_i) / member_length;
sin_theta = (y_j - y_i) / member_length;

% Determine local stiffness matrix and fixed-end forces based on joint case
switch joint_case
    case 1
        kloc = ((inertia * elasticity) / member_length^3) * ...
            [(area * member_length^2) / inertia, 0, 0, -(area * member_length^2) / inertia, 0, 0;
             0, 12, 6 * member_length, 0, -12, 6 * member_length;
             0, 6 * member_length, 4 * member_length^2, 0, -6 * member_length, 2 * member_length^2;
             -(area * member_length^2) / inertia, 0, 0, (area * member_length^2) / inertia, 0, 0;
             0, -12, -6 * member_length, 0, 12, -6 * member_length;
             0, 6 * member_length, 2 * member_length^2, 0, -6 * member_length, 4 * member_length^2];
        Q = [0; (load_w * member_length) / 2; (load_w * member_length^2) / 12; 0; (load_w * member_length) / 2; -(load_w * member_length^2) / 12];
    case 2
        kloc = ((inertia * elasticity) / member_length^3) * ...
            [(area * member_length^2) / inertia, 0, 0, -(area * member_length^2) / inertia, 0, 0;
             0, 3, 0, 0, -3, 3 * member_length;
             0, 0, 0, 0, 0, 0;
             -(area * member_length^2) / inertia, 0, 0, (area * member_length^2) / inertia, 0, 0;
             0, -3, 0, 0, 3, -3 * member_length;
             0, 3 * member_length, 0, 0, -3 * member_length, 3 * member_length^2];
        Q = [0; (load_w * member_length) / 2 - (1.5 / member_length) * (load_w * member_length^2) / 12; 0; 0; (load_w * member_length) / 2 + (1.5 / member_length) * (load_w *
            member_length^2) / 12; -(load_w * member_length^2) / 12 - 0.5 * (load_w * member_length^2) / 12];
    case 3
        kloc = ((inertia * elasticity) / member_length^3) * ...
            [(area * member_length^2) / inertia, 0, 0, -(area * member_length^2) / inertia, 0, 0;
             0, 3, 3 * member_length, 0, -3, 0;
             0, 3 * member_length, 3 * member_length^2, 0, -3 * member_length, 0;
             -(area * member_length^2) / inertia, 0, 0, (area * member_length^2) / inertia, 0, 0;
             0, -3, -3 * member_length, 0, 3, 0;

             0, 0, 0, 0, 0, 0];
        Q = [0; (load_w * member_length) / 2 - (1.5 / member_length) * (-load_w * member_length^2) / 12; (load_w * member_length^2) / 12 - 0.5 * (-load_w * member_length^2) / 12; 0;
            (load_w * member_length) / 2 + (1.5 / member_length) * (-load_w * member_length^2) / 12; 0];
    case 4
        kloc = (elasticity * area) / member_length * ...
            [1, 0, 0, -1, 0, 0;
             0, 0, 0, 0, 0, 0;
             0, 0, 0, 0, 0, 0;
             -1, 0, 0, 1, 0, 0;
             0, 0, 0, 0, 0, 0;
             0, 0, 0, 0, 0, 0];
        Q = [0; (load_w * member_length) / 2; 0; 0; (load_w * member_length) / 2; 0];
    otherwise
        error('Invalid joint case specified.');
end

% Transformation matrix
T = [cos_theta, sin_theta, 0, 0, 0, 0;
    -sin_theta, cos_theta, 0, 0, 0, 0;
     0, 0, 1, 0, 0, 0;
     0, 0, 0, cos_theta, sin_theta, 0;
     0, 0, 0, -sin_theta, cos_theta, 0;
     0, 0, 0, 0, 0, 1];

% Global stiffness matrix for the member
k_global_member = T' * kloc * T;

% Global DOF indices
global_dof = [3 * (node_i - 1) + 1, 3 * (node_i - 1) + 2, 3 * (node_i - 1) + 3, 3 * (node_j - 1) + 1, 3 * (node_j - 1) + 2, 3 * (node_j - 1) + 3];

% Assemble into global stiffness matrix
K_global(global_dof, global_dof) = K_global(global_dof, global_dof) + k_global_member;

% Account for settlements
delta = zeros(6, 1);
delta(1) = settlement_x_i;
delta(2) = settlement_y_i;
delta(4) = settlement_x_j;
delta(5) = settlement_y_j;
settlements(global_dof([1, 2, 4, 5])) = [settlement_x_i; settlement_y_i; settlement_x_j; settlement_y_j];
z = k_global_member * delta;
fixed_end = T' * Q + z;

% Assemble fixed-end forces
fixed_end_forces(global_dof) = fixed_end_forces(global_dof) + fixed_end;
```

```
    % Assemble nodal forces
    nodal_forces(global_dof) = nodal_forces(global_dof) + [conc_force_x_i; conc_force_y_i; conc_moment_z_i; conc_force_x_j; conc_force_y_j; conc_moment_z_j];
end

% Apply boundary conditions by removing restrained DOFs
K_reduced = K_global;
nodal_forces_reduced = nodal_forces;
fixed_end_forces_reduced = fixed_end_forces;

for idx = 1:length(restrained_dofs)
    dof = restrained_dofs(idx) - (idx - 1);
    K_reduced(dof, :) = [];
    K_reduced(:, dof) = [];
    nodal_forces_reduced(dof) = [];
    fixed_end_forces_reduced(dof) = [];
end

% Solve for displacements
displacements_reduced = K_reduced \ (nodal_forces_reduced - fixed_end_forces_reduced);

% Reconstruct full displacement vector including restrained DOFs
displacements_full = zeros(3 * num_joints, 1);
free_dofs = setdiff(1:3 * num_joints, restrained_dofs);
displacements_full(free_dofs) = displacements_reduced;
displacements_full = displacements_full + settlements;

% Write member forces to Excel
headers = ["MEMBER_NUMBER", "F_x_NODEi", "F_y_NODEi", "M_z_NODEi", "F_x_NODEj", "F_y_NODEj", "M_z_NODEj", "Length", "Uniformly_distributed_Load"];
writematrix(headers, 'Output DRSR.xlsx', 'Range', 'A1');

for member = 1:num_members
    % Extract member properties
    area = Member_Connectivity(member, 4);
    elasticity = Member_Connectivity(member, 5);
    inertia = Member_Connectivity(member, 6);
    load_w = Member_Connectivity(member, 7);
    joint_case = Member_Connectivity(member, 8);
    node_i = Member_Connectivity(member, 2);
    node_j = Member_Connectivity(member, 3);

    % Coordinates of nodes
    x_i = Node_Coordinates(node_i, 2);
    y_i = Node_Coordinates(node_i, 3);
    x_j = Node_Coordinates(node_j, 2);
    y_j = Node_Coordinates(node_j, 3);
```

```matlab
    % Calculate member length and orientation
    member_length = sqrt((x_j - x_i)^2 + (y_j - y_i)^2);
    cos_theta = (x_j - x_i) / member_length;
    sin_theta = (y_j - y_i) / member_length;

    % Determine local stiffness matrix and fixed-end forces based on joint case
    switch joint_case
        case 1
            kloc = ((inertia * elasticity) / member_length^3) * ...
                [(area * member_length^2) / inertia, 0, 0, -(area * member_length^2) / inertia, 0, 0;
                 0, 12, 6 * member_length, 0, -12, 6 * member_length;
                 0, 6 * member_length, 4 * member_length^2, 0, -6 * member_length, 2 * member_length^2;
                 -(area * member_length^2) / inertia, 0, 0, (area * member_length^2) / inertia, 0, 0;
                 0, -12, -6 * member_length, 0, 12, -6 * member_length;
                 0, 6 * member_length, 2 * member_length^2, 0, -6 * member_length, 4 * member_length^2];
            Q = [0; (load_w * member_length) / 2; (load_w * member_length^2) / 12; 0; (load_w * member_length) / 2; -(load_w * member_length^2) / 12];
        case 2
            kloc = ((inertia * elasticity) / member_length^3) * ...
                [(area * member_length^2) / inertia, 0, 0, -(area * member_length^2) / inertia, 0, 0;
                 0, 3, 0, 0, -3, 3 * member_length;
                 0, 0, 0, 0, 0, 0;
                 -(area * member_length^2) / inertia, 0, 0, (area * member_length^2) / inertia, 0, 0;
                 0, -3, 0, 0, 3, -3 * member_length;
                 0, 3 * member_length, 0, 0, -3 * member_length, 3 * member_length^2];
            Q = [0; (load_w * member_length) / 2 - (1.5 / member_length) * (load_w * member_length^2) / 12; 0; 0; (load_w * member_length) / 2 + (1.5 / member_length) * (load_w *
                member_length^2) / 12; -(load_w * member_length^2) / 12 - 0.5 * (load_w * member_length^2) / 12];
        case 3
            kloc = ((inertia * elasticity) / member_length^3) * ...
                [(area * member_length^2) / inertia, 0, 0, -(area * member_length^2) / inertia, 0, 0;
                 0, 3, 3 * member_length, 0, -3, 0;
                 0, 3 * member_length, 3 * member_length^2, 0, -3 * member_length, 0;
                 -(area * member_length^2) / inertia, 0, 0, (area * member_length^2) / inertia, 0, 0;
                 0, -3, -3 * member_length, 0, 3, 0;
                 0, 0, 0, 0, 0, 0];
            Q = [0; (load_w * member_length) / 2 - (1.5 / member_length) * (-load_w * member_length^2) / 12; (load_w * member_length^2) / 12 - 0.5 * (-load_w * member_length^2) / 12; 0;
                (load_w * member_length) / 2 + (1.5 / member_length) * (-load_w * member_length^2) / 12; 0];
        case 4
            kloc = (elasticity * area) / member_length * ...
                [1, 0, 0, -1, 0, 0;
                 0, 0, 0, 0, 0, 0;
                 0, 0, 0, 0, 0, 0;
                 -1, 0, 0, 1, 0, 0;
                 0, 0, 0, 0, 0, 0;
                 0, 0, 0, 0, 0, 0];
            Q = [0; (load_w * member_length) / 2; 0; 0; (load_w * member_length) / 2; 0];
        otherwise
            error('Invalid joint case specified.');
    end

    % Transformation matrix
    T = [cos_theta, sin_theta, 0, 0, 0, 0;
        -sin_theta, cos_theta, 0, 0, 0, 0;
         0, 0, 1, 0, 0, 0;
         0, 0, 0, cos_theta, sin_theta, 0;
         0, 0, 0, -sin_theta, cos_theta, 0;
         0, 0, 0, 0, 0, 1];

    % Global DOF indices
    global_dof = [3 * (node_i - 1) + 1, 3 * (node_i - 1) + 2, 3 * (node_i - 1) + 3, 3 * (node_j - 1) + 1, 3 * (node_j - 1) + 2, 3 * (node_j - 1) + 3];

    % Extract displacements for member DOFs
    displacements_member = displacements_full(global_dof);

    % Compute member end forces
    member_end_forces = kloc * (T * displacements_member) + Q;

    % Prepare data for writing
    member_forces_output = round(0.001 * member_end_forces, 2);
    data_row = {member, member_forces_output(1), member_forces_output(2), member_forces_output(3), member_forces_output(4), member_forces_output(5), member_forces_output(6),
        member_length, load_w};

    % Write data to Excel
    writecell(data_row, 'Output DRSR.xlsx', 'Range', strcat('A', num2str(member + 1)));
end

% Plot undeformed and deformed structures
x_coords_undeformed = Node_Coordinates(:, 2);
y_coords_undeformed = Node_Coordinates(:, 3);
x_coords_deformed = x_coords_undeformed + displacements_full(1:3:end) * applied_scale_factor;
y_coords_deformed = y_coords_undeformed + displacements_full(2:3:end) * applied_scale_factor;

figure;
hold on;
for member = 1:num_members
    node_i = Member_Connectivity(member, 2);
    node_j = Member_Connectivity(member, 3);
```

```
    % Plot undeformed member
    plot([x_coords_undeformed(node_i), x_coords_undeformed(node_j)], [y_coords_undeformed(node_i), y_coords_undeformed(node_j)], 'r');

    % Plot deformed member
    plot([x_coords_deformed(node_i), x_coords_deformed(node_j)], [y_coords_deformed(node_i), y_coords_deformed(node_j)], 'g');
end
hold off;
legend('Undeformed', 'Deformed');
title('Structural Deformation');
xlabel('X Coordinate');
ylabel('Y Coordinate');
disp('The deformed and undeformed structures have been plotted. The deformation is scaled for visibility.');
fprintf('The deformed shape has been exaggerated %d times for visualization purposes.\n', applied_scale_factor);
```

THANK YOU