Additional Topics I: Support Settlements

Lesson Objectives:

1) Derive the methodology to analyze structures for various member releases and secondary effects.
2) Derive the member local stiffness modifications to account for member releases.
3) Compute the structure fixed-joint force vector to account for support settlements.
4) Compute the member fixed-end force vector to account for temperature changes and fabrication errors.

Background Reading:

1) Read __Kassimali – Chapter 7 (focus on 7.3 and 9.3)_____

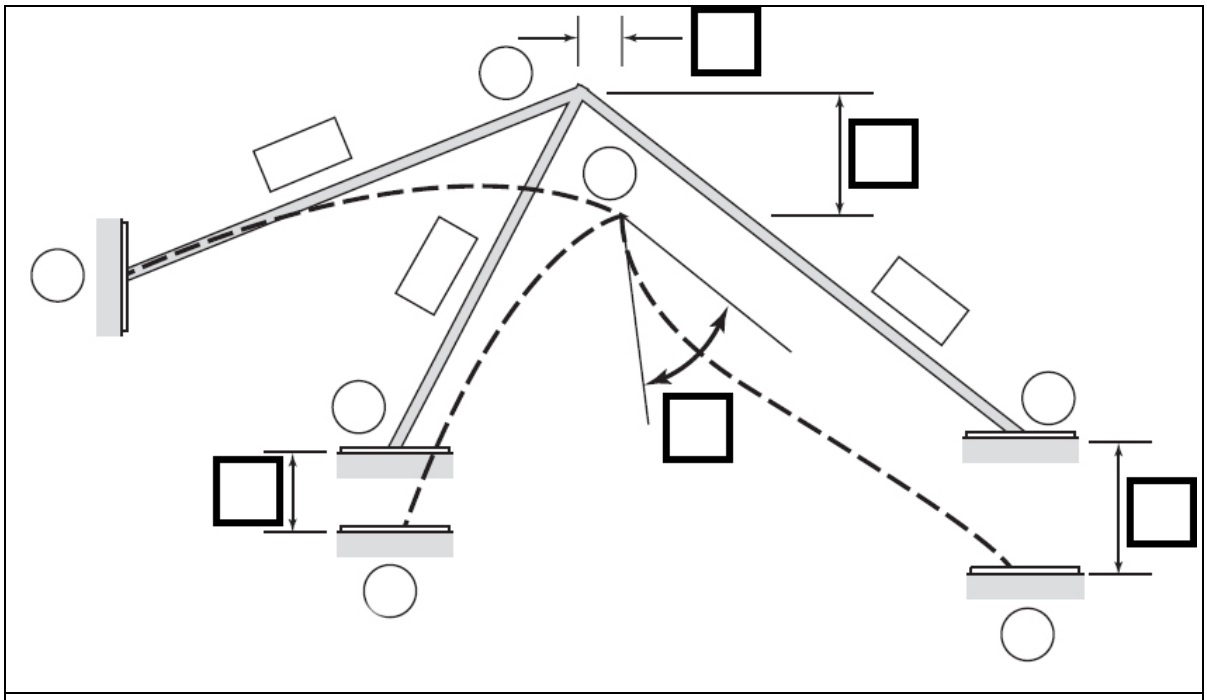
Introduction:

1) Support settlements may subjected on a structure due to _____ _____.
2) Two methods exists for analyzing structures with support settlements:
   a. Concept of _____.
   b. Use of the complete or entire _____.

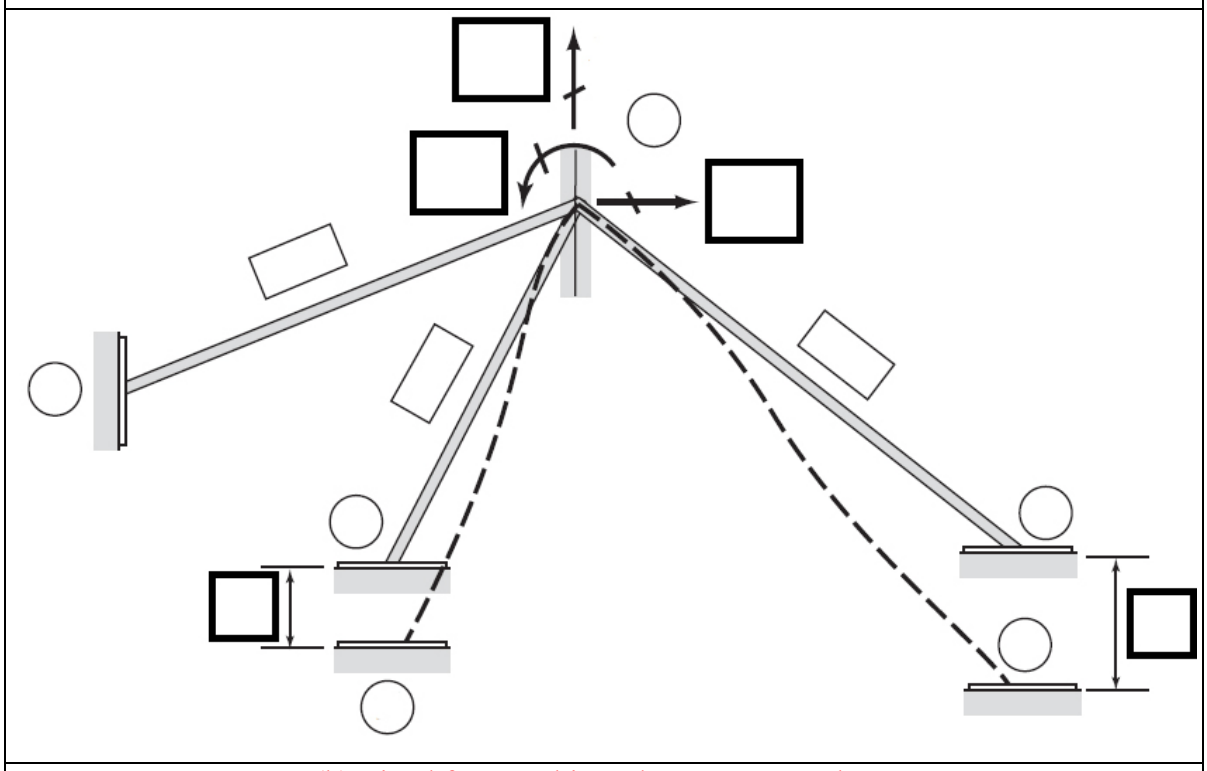
Equivalent Nodal Load Method:

1) Consistent with the matrix analysis procedure outlined previously, the initial focus is on the method that invokes _____.
2) In an approach similar to analyzing structures that have loads applied along the member lengths, the _____ (previously it was member loads, now it is _____) are applied to the structure.
   a. This structure is _____, using imaginary restraints.

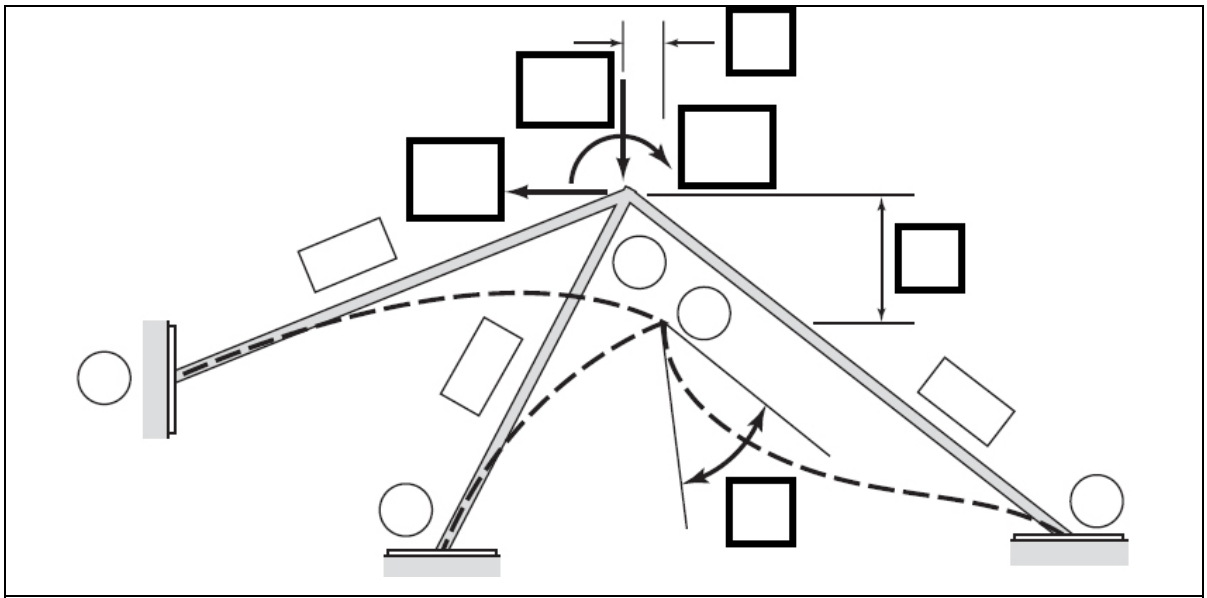
3) The required forces to develop these actions are defined as _____ _____ (in the hypothetical fixed structure).
4) Using these derived forces, the direction _____ to create equivalent nodal loads.
5) Then solve the structure with the known equivalent nodal loads.
6) This is detailed in Figure 1 below. In this figure, a _____ frame undergoes small settlements _____ and _____ at joints _____ and _____, respectively.
    a. This creates displacements _____, _____, and _____ at note 1.
    b. To determine response of the frame, first restrain _____ through use of an imaginary restraint.
    c. Then, impose the support settlements and find the _____ that develop.
        i. Details on this will follow.
    d. Next, apply the _____ as external loads and solve the example frame structure.
7) Comparing Figure 1, the actual frame subjected to support settlements (part a) is equal to parts (b) and (c) are superimposed.
    a. Note the fixed-joint forces in part b are cancelled out by using the opposite direction (_____) applied as a load (_____).
    b. Since negative valued fixed-joint forces create displacements at the same location and direction of the frame's _____, these forces can be considered as _____.
    c. Note that only the _____ are equivalent.
        i. Member end forces and support reactions of the frame must be obtained by _____ _____.
8) Recall that for member loads, the response of the fixed structure was evaluated using fixed-force expression for various loading scenarios.
    a. The fixed-joint vector (_____) can be obtained by algebraic summation of the member fixed-end forces.
        i. _____.



(a) Support settlements on example frame.



(b) Fixed frame subjected to support settlements.



(c) Equivalent nodal loads acting on example frame.

Figure 1. Example frame structure subjected to support settlements[1].

Evaluation of Structure Fixed-Joint Forces Resulting from Support Displacements:

1) Let's use the example frame structure in Figure 1 for evaluation.
   a. This frame is subjected to _____ and _____.
   b. In this example, NDOF = _____ and NR = _____.
   c. Using the coordinate numbers (Figure 2), the imposed support settlements are identified as:

2) Using the support settlements, the procedure for the fixed-joint forces that develop within the imaginary restraints is:

[1] All figures in Additional Topics I modified from: Kassimali, Aslam. (2012). *Matrix Analysis of Structures*. 2nd edition. Cengage Learning.

a. In this equation, _____, represents the member global fixed-end displacement vector due to support displacements.

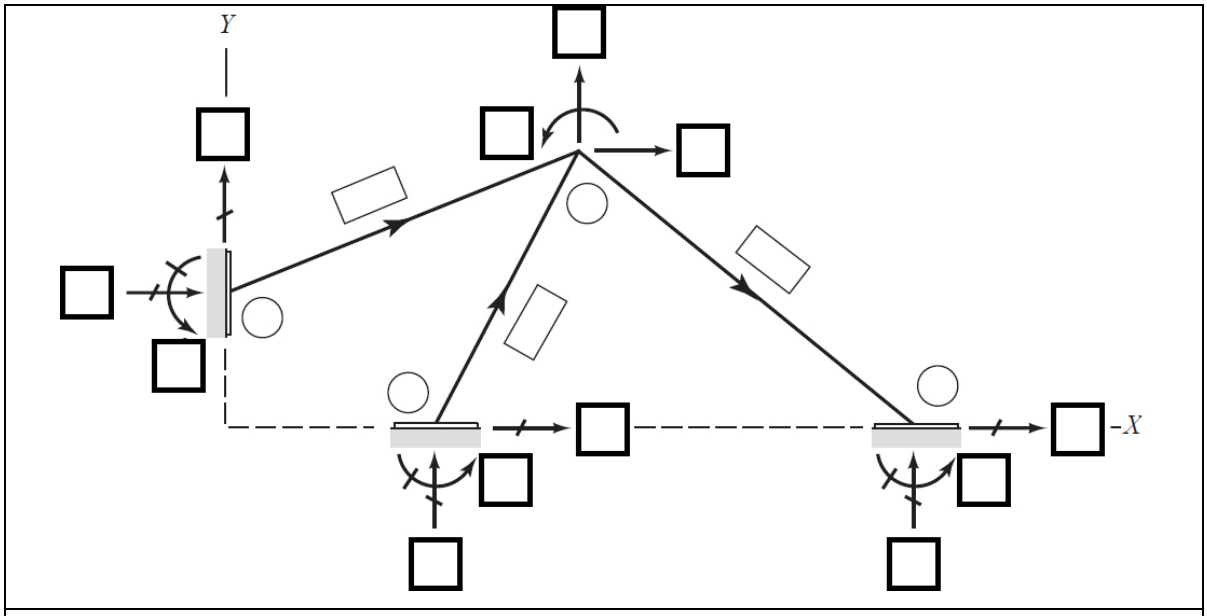
b. The only new variable, _____, represents the member global fixed-end force vector due to support displacements.

c. _____.

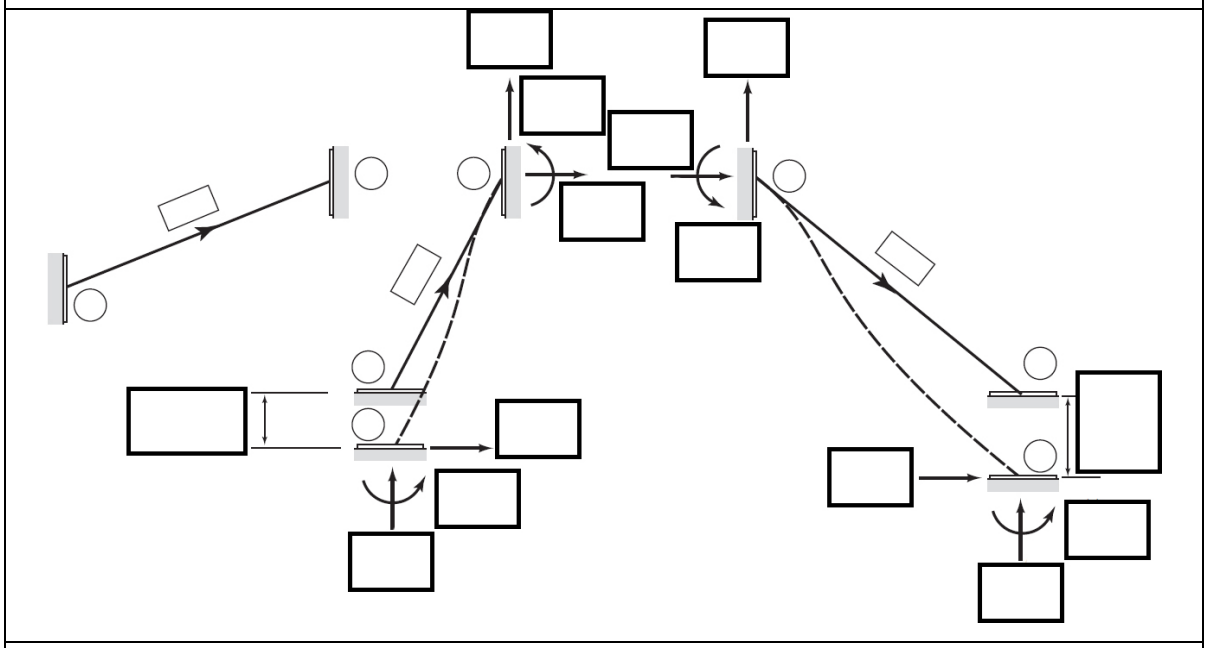
3) Now with the member global fixed-end forces known, the structure fixed end forces (____) due to the support displacements can be found using joint equilibrium.

4) For the example frame considered herein, the structure fixed-joint force vector can be expressed as:

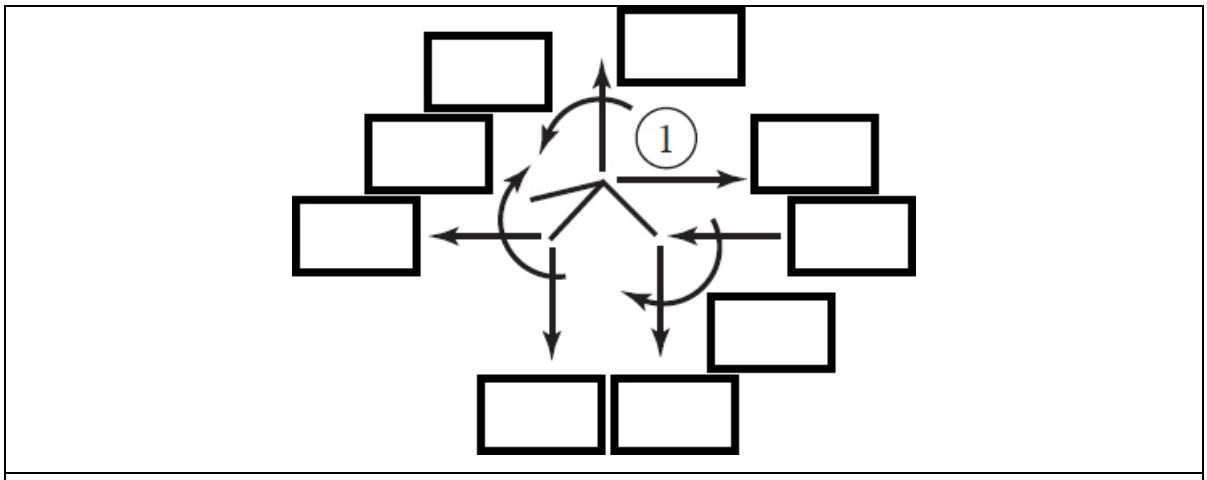
5) A generalized procedure is noted in the next section.



(a) Discretized model.



(b) Member global fixed-end displacements and forces.



(c) Free body diagram of joint 1.

Figure 2. Determining fixed-force for the example frame structure with support settlements.

General Procedure for Analysis for Support Settlements (Equivalent Nodal Load Method):

A modification is made to the generalized procedure to matrix method to analysis structures with support settlements. The general steps can be summarized as:

1) Discretize an analytical model to represent the structure.
    a. Identity the degrees of freedom and the restrained coordinates.
    b. Construct the structure stiffness matrix, [S], joint load vector [P], and fixed-joint force vector [P_f].
2) Calculate the structure fixed-joint force vector (_____) due to support settlements. If member loads exist, store the member fixed-end forces in the previously formed _____ vector.
    a. Identify code numbers for each member and form the global fixed-end displacement vector (_____).
        i. If you are considering a beam structure, form _____.

b. Evaluate the member global fixed-end force vector:

c. Using member code numbers, store the required elements in the structure fixed-joint vector _____.

3) Determine the unknown displacements:

4) Compute the member end displacements and end forces:

a. Obtain member displacements in the global system from _____, _____, and the specified support displacements _____ using code numbers.

b. Determine member end displacements in local coordinates:

c. Calculate member end forces in local coordinates:

d. Compute member end forces in global coordinates:

e. Find the reactions.

Complete Structure Stiffness Method:

1) A complete structure stiffness contains elements for all _____ _____.
    a. _____.
    b. _____.
2) One method to obtain the entire structure stiffness is to use the direct stiffness method.
    a. What is this? _____.
3) The equation solved is therefore represented as:

4) NC = _____.

5) The matrix equation can be partitioned into the following fashion:

6) _____ represents structure fixed-joint forces that correspond to the restrained coordinates.
7) _____ represents restrained (or support) displacement vector.
8) The effects of support displacements are incorporated into using _____.
    a. Note they are not incorporated into _____ neither _____.
9) To simply the analysis, the partitioned matrices are pre-multiplied on the right hand side to obtain the expression of:

10) Rearranging yields:

11) If no support settlement is present, _____, and these equations simplify as:

Complete Structure Stiffness Method Notes:

1) Advantages of the entire structure stiffness matrix:
   a. _____.
   b. _____.
   c. _____
   _____.
2) However the disadvantages include:
   a. _____
   _____`.
   b. _____.