17-2C

CONCRETE STRESSES IN PRESENCE OF REBAR AND LONG-TERM EFFECTS

OBJECTIVE AND DESCRIPTION

The objective of this example is to demonstrate the impact on concrete stresses of the effects of rebar, creep, shrinkage, aging of concrete and change in geometry.

In the general case, when a concrete segment is provided with nonprestressed reinforcement, the applied actions at the ends of the segment will be resisted jointly by concrete and reinforcement. The participation of concrete and reinforcement in resisting an applied load depends on their stiffness at the time the load is applied. Subsequently, creep will re-distribute the initial forces between the concrete and steel. At any given time, the resultant of the stresses over a cross-section is in equilibrium with the applied actions (total moment, shear and axial loading) on that section. The distribution of the stress over the cross-section, however, depends on the load history and construction of the associated segment. While the assumption of plane section remains plane and equilibrium are maintained throughout the analysis and can be verified at any given stage of the solution, because of the incremental nature of the problem, creep, shrinkage and aging of concrete, verification of stresses depends on the load and construction history of a segment.

Where rebar is described as discrete bars at specific locations over a segment, the program treats each bar as a "finite element," as is the case for tendons. But, where the reinforcement is specified as uniformly distributed over a cross section (using the p=?? parameter), the program modifies the stiffness of that section according to the amount and the relating moduli of the two materials. The actions reported by the program (moment, axial and shear) are those resisted by the concrete section and the "uniformly distributed" steel. To obtain the stress in concrete, one needs to deduct from the total actions on the section the contribution of the distributed steel. The break down of actions between the steel and concrete can be reported by the program, if the token "rebar" is added to the program command "OUTPUT."

STRUCTURE

The structure is a beam made up of 8 segments with 5% steel distributed over its entire cross-section. The total length of the beam is 4000 mm. Its cross is a 100x100 mm square. The beam is initially constructed with two spans (Fig. 1), and loaded uniformly at an early age. Time is allowed to lapse until day=100. During this period, while the total moment along the beam remains constant (Fig. 2), the distribution of moment between the concerete and the steel changes. Obviously, the steel and concrete at the top fiber over the central span will be in tension,

At day=100, the interior support is removed and substibuted by two other supports at the datum level (Fig. 3). A three span beam is generated. This is intended to illustrate the condition of incrementally launched bridges, where a bridge segment can be over a support at one stage and at mid-span in another stage. In this condition, the bending moment at mid-length of the beam will be positive (Fig. 4). This implies compression stresses at the top fiber.

The example shows that while concrete will be in compression, the steel at the top fiber will be in tension. Thus the moment to be resisted by concrete will have to be more than the externally applied moment, in order to compensate for the adverse residual stresses in steel.

FIGURE 1 TWO SPAN BEAM SHOWING THE NODE AND ELEMENT DESIGNATION

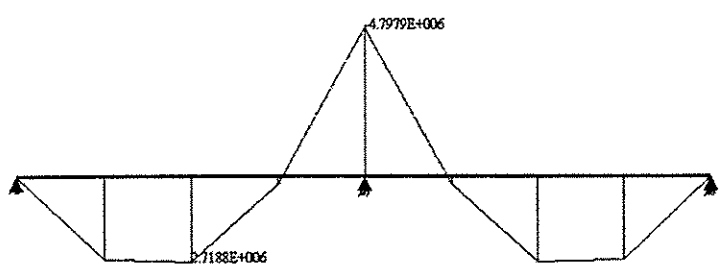

FIGURE 2 DISTRIBUTION OF MOMENT IN THE TWO-SPAN CONDITION

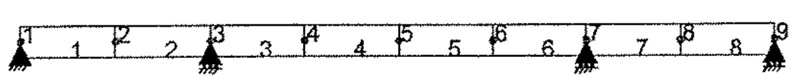

FIGURE 3 BEAM IN ITS THREE SPAN CONDITION

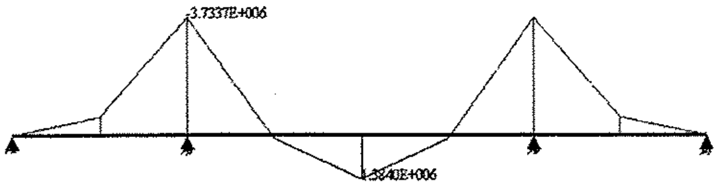

FIGURE 4 DISTRIBUTION OF MOMENT IN THREE SPAN CONDITION

INPUT DATA

```
;==========================================================================
;                              ADAPT-ABI
;      1733 Woodside Rd # 220, Redwood City, Ca 94061   www.adaptsoft.com
;==========================================================================
; Name of this file is: 17-2C    Date of last update: August 15, 2002

START
TITLE N=2
     Example of stress check for a member with steel, creep, shrinkage
     aging of concrete and change in position of supports


UNITS U=SI

CONCRETE PARAMETERS N=1
  1  M=ACI W=0.0000024

MESH INPUT
  NODES N=9
    1 X=0.00 Y=0.0
    2 X=500.00 Y=0.0
    3 X=1000     Y=0.00
    4 X=1500.00 Y=0.0
    5 X=2000.00 Y=0.0
    6 X=2500     Y=0.00
    7 X=3000.00 Y=0.0
    8 X=3500.00 Y=0.0
    9 X=4000     Y=0.00

  SECTION PROPERTIES N=1
    1 B=100 D=100

  CONCRETE PROPERTIES  N=1
    1 Fpc=30 Cr=3.0 Sh=0.0004 W=0.0000024 Ac=0.0

  PRESTRESSING STEEL N=1
    1  Ep=200000 Meu=0   K=0  Fpu=1860  Fpy=1700  R=0


 MILD STEEL PROPERTIES N=1
     1 Es=200000 P=0.05


  ELEMENTS N=8
    FRAME N=8
      1,1,2 C=1 X=1 Day=0 St=1
      2,2,3 C=1 X=1 DAY=0 ST=1
      3,3,4 C=1 X=1 Day=0 St=1
```

```
     4,4,5 C=1 X=1 DAY=0 ST=1
     5,5,6 C=1 X=1 Day=0 St=1
     6,6,7 C=1 X=1 DAY=0 ST=1
     7,7,8 C=1 X=1 Day=0 St=1
     8,8,9 C=1 X=1 DAY=0 ST=1

MESH COMPLETE

CHANGE STRUCTURE
  BUILD N=1,8,1
  RESTRAINTS
    1 R=1,1,0
    5 R=0,1,0
    9 R=0,1,0

CHANGE COMPLETE

SOLVE DAY=1

SOLVE DAY=3 ! OUTPUT

LOADING
   L=1,8,1 F=0,-10

SOLVE DAY=3

SOLVE Day=5      ! OUTPUT
SOLVE Day=7      ! OUTPUT
SOLVE Day=14     ! OUTPUT
SOLVE Day=28     ! OUTPUT
SOLVE Day=50     ! OUTPUT
SOLVE Day=100    ! OUTPUT rebar   ; prints rebar stresses

CHANGE STRUCTURE
  RESTRAINTS
     5 R=0,0,0    ;     Change position of supports
     3 R=0,2,0
     7 R=0,2,0

CHANGE COMPLETE

SOLVE Day=100     ! OUTPUT rebar   ; prints rebar stresses


STOP
```

RESULTS

The stresses at for each segment are reported in the output at three points, namely at top fiber of node I (at Ctop, point 1), top fiber of node J (at Ctop, point 3) and at the center of segment (point 5). These locations are shown in Fig. 5.

The values of stresses and moments are reported in data block 111 of the output. For verification the top corner of segment 5 at node I is selected. From the program output, the stresses reported for this segment at day=100, just before the change in support condition and immediately afterwards are also extracted and reproduced herein.

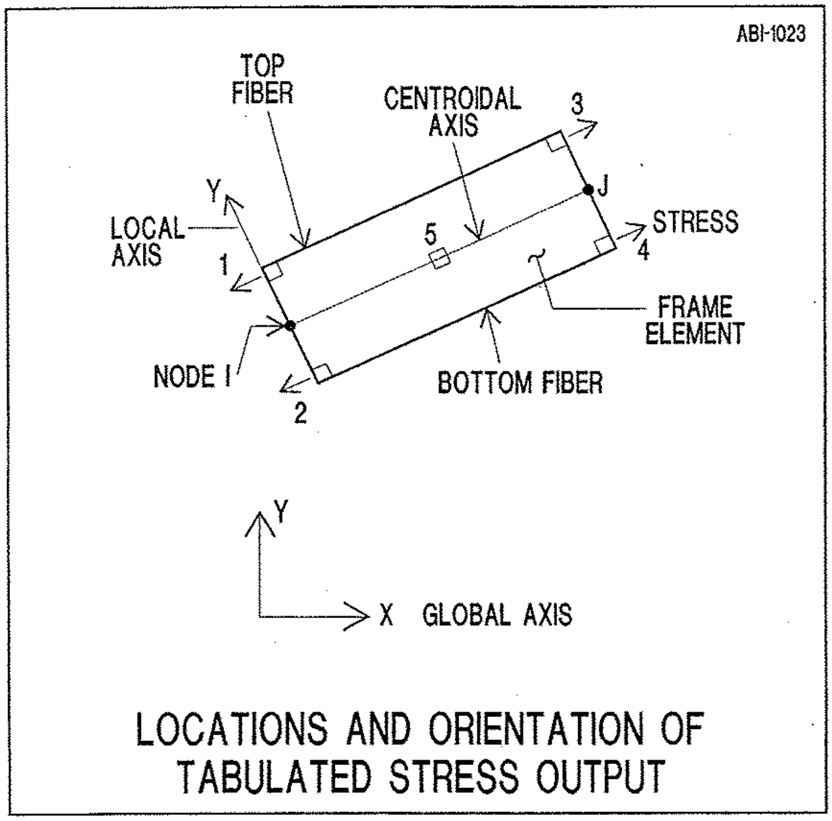

FIGURE 5 LOCATION OF STRESS REPORTS

TABLE 1 STRESSES AND ACTIONS IN SEGMENT 5 JUST BEFORE BEAM BEING CHANGED TO THREE SPANS (DAY=100)

111 - FRAME ELEMENT STRESSES

ELEM	MATERIAL COMPONENT	STRESSES AT POINTS		BENDING MOMENTS		SHEAR FORCES		AXIAL FORCES	
5	CONCRETE	**1**	**9.8720E+00**	I	-1.4093E+06	I	2.9595E+03	I	1.4163E+04
		3	9.9347E-01	J	7.0464E+04	J	2.9595E+03	J	1.4163E+04
		5	1.4163E+00						
	STEEL	**1**	**3.7830E+02**	I	-3.3886E+06	I	7.1160E+03	I	-1.4163E+04
		3	-4.8657E+01	J	1.6943E+05	J	7.1160E+03	J	-1.4163E+04
		5	-2.8325E+01						
	TOTAL			I	-4.7979E+06	I	1.0076E+04	I	1.8190E-12
				J	2.3989E+05	J	1.0076E+04	J	1.8190E-12
	STEEL PERCENT			I	70.6268	I	70.6268	I	.0000
				J	70.6268	J	70.6268	J	.0000

TABLE 2 STRESSES FOR ELEMENT 5 IMMEDIATELY AFTER CONVERSION TO THREE SPANS (DAY=100)

111 - FRAME ELEMENT STRESSES

ELEM	MATERIAL COMPONENT	STRESSES AT POINTS	BENDING MOMENTS	SHEAR FORCES	AXIAL FORCES
5	CONCRETE	**1 -1.7751E+01**	I 3.1946E+06	I -6.4499E+03	I 1.4165E+04
		3 1.5984E+00	J -3.0305E+04	J -6.4499E+03	J 1.4165E+04
		5 1.4165E+00			
	STEEL	**1 1.8894E+02**	I -1.8106E+06	I 3.8910E+03	I -1.4165E+04
		3 -4.4519E+01	J 1.3490E+05	J 3.8910E+03	J -1.4165E+04
		5 -2.8331E+01			
	TOTAL		I 1.3840E+06	I -2.5589E+03	I 1.8190E-12
			J 1.0459E+05	J -2.5589E+03	J 1.8190E-12
	STEEL PERCENT		I -130.8225	I -152.0607	I .0000
			J 128.9747	J -152.0607	J .0000

In the above tables, the contribution of moment from concrete is listed under "CONCRETE." Likewise, the contribution of momnet due to steel is listed under "STEEL." Evidently, the two contributions add up to the sum of the moments taken by concrete and steel, as listed under "TOTAL."

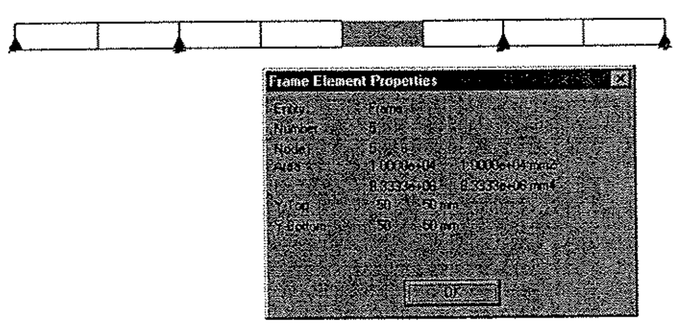

FIGURE 6 PROPERTIES OF SEGMENT 5
(100x100 mm square section)

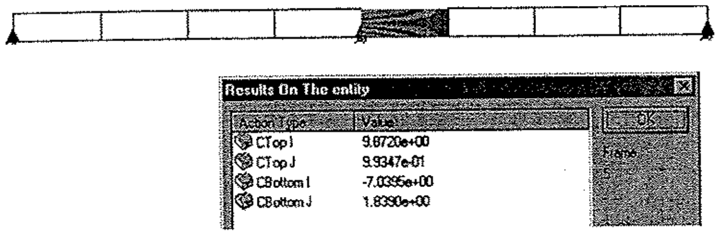

FIGURE 7 STRESS IN CONCRETE IN SEGMENT 5 WHEN BEAM IS TWO SPAN; DAY=100 (9.872 MPa tension)

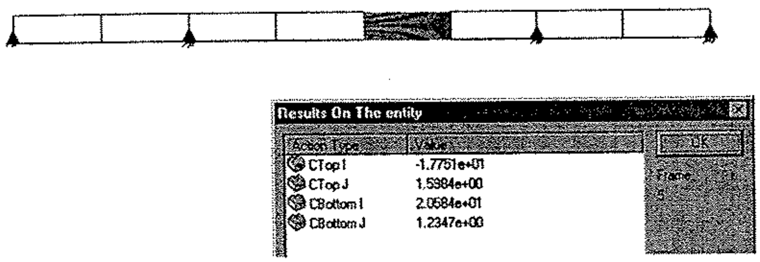

FIGURE 8 STRESS IN CONCRETE IN SEGMENT 5 WHEN BEAM IS MADE INTO THREE SPAN; DAY=100(17.751 MPa compression)

STRESS VERIFICATION (day=100; three span condition)

Stress will be verified for segment 5 node I top fiber.

Total moment at mid-span (Table 2 and Fig. 4) 1.3840 E6 Nmm
Moment taken by steel -1.8106 E6 Nmm

Hence, moment to be resisted by concrete is:
1.3840E6 - (-1.8106E6) = 3.1946 E6 Nmm (agrees with report)

Stress in concrete from bending:
= M*Ctop/I = 3.1946E6*50/8.333E6 = -19.1683 MPa

Stress in concrete due to axial forces:
= 1.4165E4 (tension)/10000 (area) = 1.4165 MPa

Total stress = -19.1683 + 1.4165 = 17.7518 MPa (same as reported by ADAPT in Fig. 8 and tabular output).

Several observations are noteworthy.

(i) Steel stress at the top fiber is in tension, where moment is negative. This contrary to common intuition, but is correct.

(ii) The moment that is resisted by concrete alone is larger than the externally applied moment. That is to say, in this case, the presence of steel has aggravated the stresses in concrete.

(iii) The application of simple beam theory to the geometry of the cross-section and the total actions at the section would not yield the correct value of stresses.