TN275_stress_redistribution_creep_composite_10
010308

STRESS REDISTRIBUTION IN COMPOSITE CONSTRUCTION DUE TO CREEP[1]

This Technical Note demonstrates the effect of concrete creep in re-distribution of stresses in composite members. The focus of the work is the condition, when fresh concrete is added to an existing base, such as topping slab in precast prestressed bridge girders (Fig. 1). Due to creep of both the topping layer and the existing concrete base, with time the stresses will change. The initial stresses in the base will drop, while the stresses in the topping slab will build up.

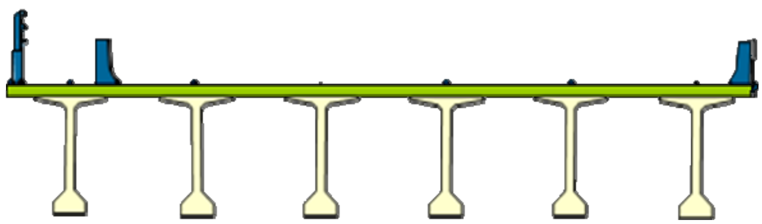

FIGURE 1 ILLUSTRATION OF A TYPICAL PRECAST-PRESTRESSED GIRDER WITH CONCRETE TOPPOING

The time-dependent software ADAPT-ABI [i] is used to illustrate the phenomenon, and also to verify the accuracy of the program in re-distribution of stresses due to creep. The time-dependent factors that affect the redistribution of stress are: creep, shrinkage, aging of concrete, and relaxation in prestressing steel. This Technical Note deals with the creep part of the time-dependent factors only.

Two stress conditions are considered, namely: (i) axial load only in the base member, and (ii) pure bending moment in the base member. For the first condition, the work demonstrates that the axial force will be re-distributed among the composite members, while its total value remains the unchanged. Likewise, for the condition of pure moment, with time the moment will be redistributed among the composite members, while the total value of the moment of the combined sections remains unchanged.

STRUCTURAL MODELS

The models selected each consist of a base member of rectangular cross-section, and two identical layers added on each side of it at a later date, to form a composite section.. The first model is a column consisting of an initial central core, with subsequently added concrete on its sides. The second model is a cantilever beam, with added layers of concrete at its top and bottom at a later date. The principal details of the models are:

Cross-section of each part:	100x100mm
Length of member:	1000 mm
Concrete strength:	30 MPa
Maximum creep coefficient	3

Other parameters of the models are given in the data file at the end of this Technical Note.

CREEP MODEL

Most building codes have material models for concrete that define the variation of creep with time. The creep curves depend on the age of the concrete, when the load is first applied. For ease of verification, creep tables for the loading ages considered in this Technical Note are extracted from AASHTO and reproduced below. These are for loading of concrete at the two ages 7 and 14 days. The strains in the tables are per unit of stress (MPa).

Loading Age=7 day

Age	Creep Strain
7	415.7E-8
9	484.5E-8
14	627.9E-8
28	933.9E-8
56	1383.8E-8
100	1896.0E-8
180	2520.7E-8
365	3308.2E-8
1825	4617.7E-8
3650	4918.6E-8
7300	5110.8E-8

Loading Age=14 day

Age	Creep Strain
14	368.7E-8
17	455.4E-8
28	690.2E-8
56	1095.6E-8
100	1534.9E-8
180	2060.8E-8
365	2717.6E-8
730	3278.1E-8
1825	3802.6E-8
3650	4050.9E-8
7300	4209.5E-8

CONSTRUCTION AND OBSERVATION DAYS

The following construction and observation sequence are used for both models

- Build the base layer on day 1
- Bring time forward to day 7
- Apply load (either axial or bending) on day 7
- Let the base layer cure and wait until day 14
- Cast the other layers on the sides of the existing layer on day 14
- Observe the re-distribution of the stress among the layers at days: 17, 19, 21, 23, 28, 42, 56, 70, and 100.

The input data generated for the models are given in the appendix of this Technical Note. The summary of the observed responses of the models are given in Table 1. In each instance, the model is once observed without the addition of the side layers, and once with the addition of the side layers.

RE-DISTRIBUTION OF AXIAL LOAD

Using the values of Table 1, the redistribution of stress due to an axial load of 60 kN placed on top of the base member is illustrated graphically in Figs. 2 and 3. The applied load is kept unchanged during the entire observation period.

In Fig. 2, the curve marked 1 describes the shortening of the central core, if it were not provided with additional layers on its sides. The curve marked 2, shows the shortening of the combined layers. As anticipated the addition of the concrete layers will reduce the combined shortening.

The variation of the axial load in the central layer (marked 1) and the added layers (marked 2) are shown in Fig. 3. With passage of time, the force in the central layer is reduced, while the axial force in the added layers picks up. The sum of the axial force in all layers remains constant at 60 k (marked 1 and 2).

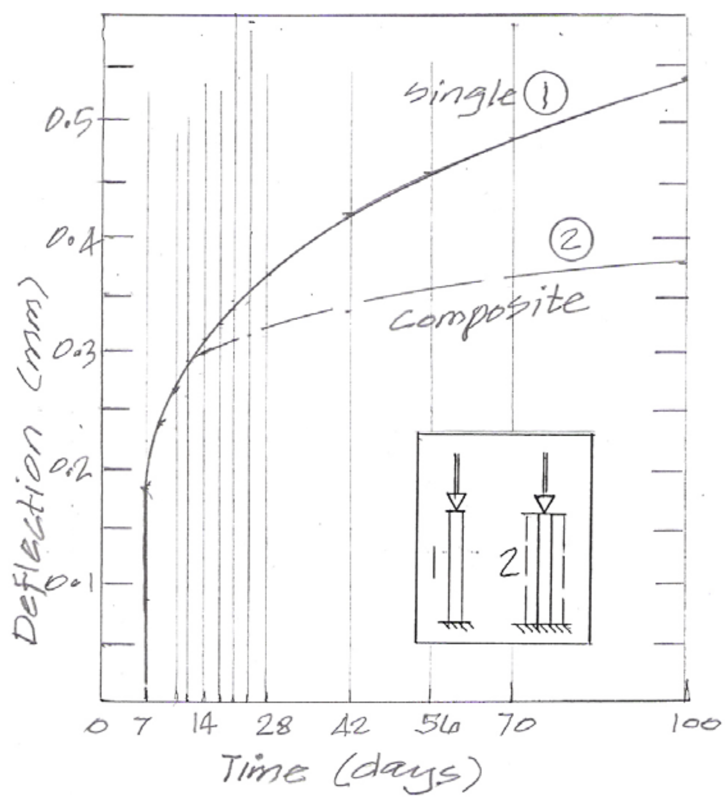

FIGURE 2 SHORTENING OF THE MEMBERS DUE TO AXIAL LOAD

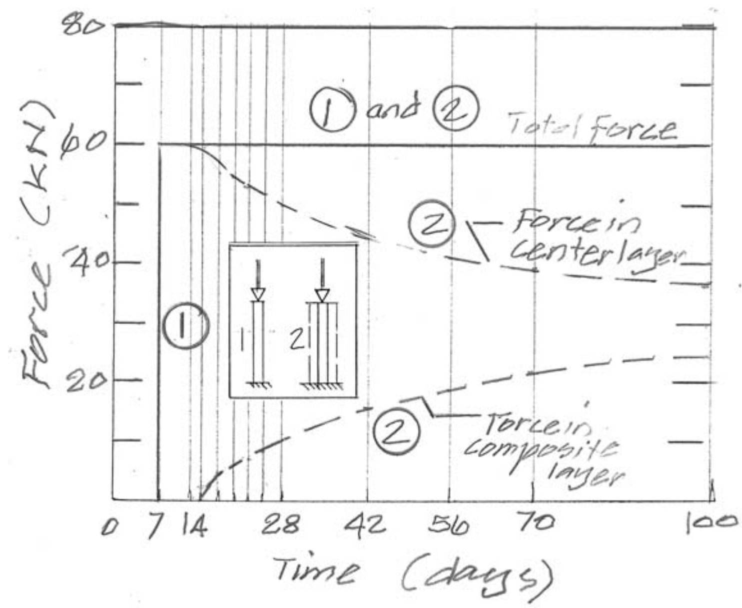

FIGURE 3 VALUES OF AXIAL LOAD IN DIFFERENT LAYERS AND THEIR SUM

REDISTRIBUTION OF MOMENT

The results of the cantilever beam example are shown in Figs. 4 and 5. The base cantilever (marked 1) is loaded with a concentrated force of 1 kN at its tip, causing a moment of 1 kNm at its support 1 m away. The deflection of the cantilever tip for the condition of the base layer (marked 1) and the composite combination are shown in Fig. 4, where the impact of creep deflection due to composite

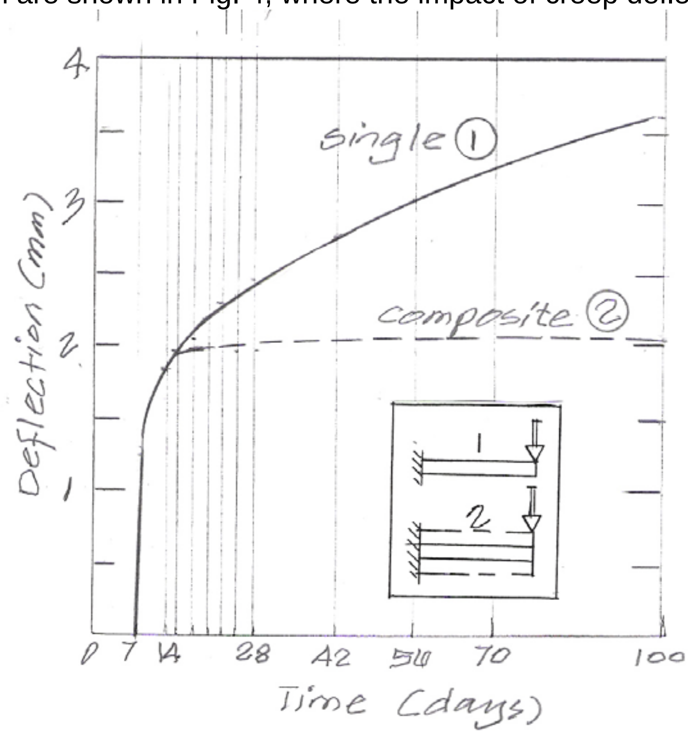

FIGURE 4 DEFLECTION AT CANTILEVER TIP DUE TO BENDING

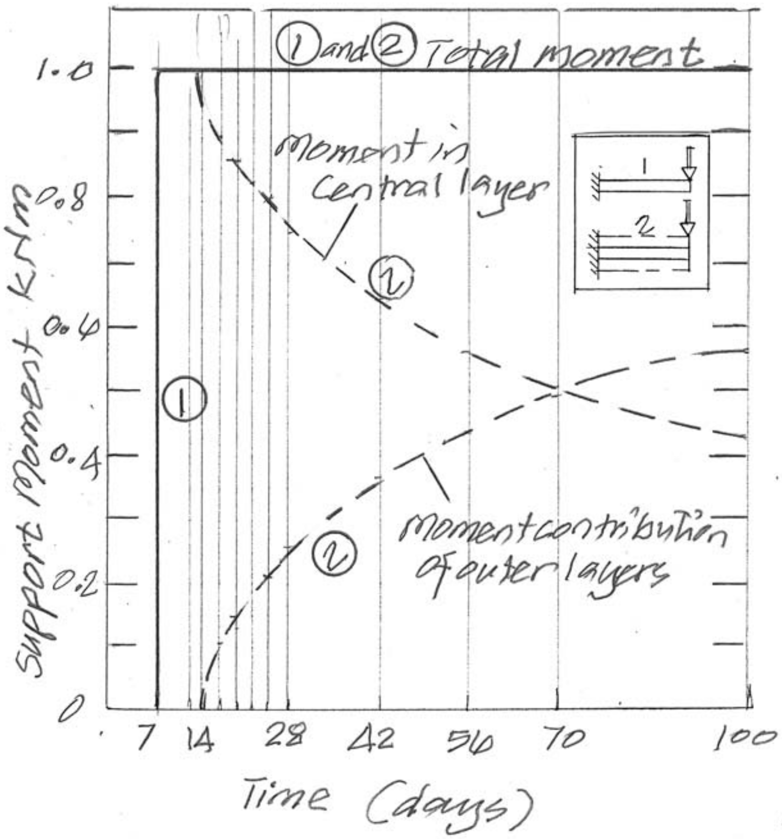

FIGURE 5 REDISTRIBUTION OF THE APPLIED MOMENT AMONG THE CONSTITUENT PARTS OF THE COMPOSITE SECTION

action is observed to be significant. Once new layers are added to the base layer, the moment carried by the base layer drops dramatically (Fig. 5). In this case the share of the distributed moment carried by freshly placed concrete exceeds the moment in the original later at about day 70 and beyond. It is important to note that, as indicated in Fig. 5, the total moment carried by the composite section remains unchanged.

TABLE 1 DISPLACEMENT, FORCE AND MOMENTS FOR AXIAL AND BENDING MODELS

	Axial single		Axial - Composite			Bending single		Bending - Composite		
day	Deflection mm	Force kN	Deflection mm	Force KN center	Force kN sides	Deflection mm	Moment kNm	Deflection mm	Moment at center kNm	Moment at sides kNm
1	0	0	0	0	60	0	1	0	0	0
7	0	0	0	0	60	0	1	0	0	0
7	0.186	60	0.186	60	60	1.238	1	1.238	1	1
10	0.243	60	0.244	60	60	1.625	1	1.625	1	1
12	0.271	60	0.271	60	60	1.803	1	1.803	1	1
14	0.291	60	0.291	60	60	1.941	1	1.941	1	1
14	0.291	60	0.291	60	60	1.941	1	1.941	1	1
17	0.315	60	0.299	55.61	4.39	2.009	1	1.948	0.896	0.896
19	0.327	60	0.303	53.72	6.28	2.183	1	1.951	0.853	0.853
21	0.339	60	0.307	52.32	7.68	2.256	1	1.954	0.821	0.821
23	0.341	60	0.31	51.21	8.79	2.308	1	1.956	0.794	0.794
28	0.369	60	0.317	48.96	11.04	2.461	1	1.962	0.742	0.742
42	0.416	60	0.333	44.45	15.55	2.771	1	1.975	0.637	0.637
56	0.453	60	0.345	41.31	18.69	3.021	1	1.984	0.565	0.565
70	0.484	60	0.355	39.04	20.96	3.229	1	1.993	0.511	0.511
100	0.537	60	0.373	35.66	24.34	3.581	1	2.007	0.432	0.432

APPENDIX

Input data for the single axial model. The data for other cases is similar (see the end of this data entry).

```
;=================================================================
;                                  ADAPT-ABI
;         1733 Woodside Road, Suite #220, Redwood City, CA 94061
;      4E Park Plaza, 71 Park Street, Kolkata - 700016, INDIA
;                             www.adaptsoft.com
;=================================================================
; Name of this file  creep_1.inp
;
; One or more concrete prisms are used to illustrate impact of creep

START

TITLE N=1
      Laboratory time dependent model, early age loading

UNITS U=SI

COMPOSITE ANALYSIS

CONCRETE PARAMETERS N=1 T=8,11 ; MaxShrinkageReadings=0

  LoadingAge=1 Eci=32314       ;Eci=14622
  ObservationAge CreepStrain
       1          8982.7E-8
       3         10505.1E-8
       5         11869.2E-8
       7         13112.8E-8
      14         16961.7E-8
      28         23256.5E-8
     100         44707.7E-8
     365         77123.7E-8
     730         92738.5E-8
    3650        114422.1E-8
    7300        118888.9E-8

  LoadingAge=3 Eci=32314       ;Eci=21791
  ObservationAge CreepStrain
       3           542.7E-8
```

```
     5          633.9E-8
     7          715.4E-8
    14          957.1E-8
    28         1341.1E-8
    56         1933.3E-8
   100         2620.9E-8
   365         4537.9E-8
   730         5459.2E-8
  3650         6737.3E-8
  7300         7000.4E-8

LoadingAge=5 Eci=32314       ;Eci=25066
ObservationAge CreepStrain
     5          455.2E-8
     7          531.1E-8
     9          598.8E-8
    14          745.8E-8
    28         1073.1E-8
    56         1567.2E-8
   100         2135.6E-8
   365         3711.5E-8
   730         4467.2E-8
  3650         5514.3E-8
  7300         5729.8E-8

LoadingAge=7 Eci=32314       ;Eci=27008
ObservationAge CreepStrain
     7          415.7E-8
     9          484.5E-8
    14          627.9E-8
    28          933.9E-8
    56         1383.8E-8
   100         1896.0E-8
   180         2520.7E-8
   365         3308.2E-8
  1825         4617.7E-8
  3650         4918.6E-8
  7300         5110.8E-8

LoadingAge=14 Eci=32314      ;Eci=30214
ObservationAge CreepStrain
    14          368.7E-8
    17          455.4E-8
    28          690.2E-8
    56         1095.6E-8
   100         1534.9E-8
   180         2060.8E-8
   365         2717.6E-8
   730         3278.1E-8
  1825         3802.6E-8
  3650         4050.9E-8
  7300         4209.5E-8


LoadingAge=28 Eci=32314      ;Eci=32314
ObservationAge CreepStrain
    28         358.1E-8
    31         439.4E-8
    40         619.7E-8
    56         847.5E-8
   100        1269.7E-8
   180        1747.0E-8
   365        2328.7E-8
   730        2819.0E-8
  1825        3274.8E-8
  3650        3489.7E-8
  7300        3626.7E-8

LoadingAge=56 Eci=32314      ;Eci=33531
ObservationAge CreepStrain
    56         376.1E-8
    60         481.6E-8
    65         582.2E-8
    75         734.7E-8
   100         998.5E-8
   180        1491.4E-8
   365        2043.1E-8
   730        2493.3E-8
  1825        2905.3E-8
```

```
    3650        3097.9E-8
    7300        3220.2E-8

  LoadingAge=100 Eci=32314     ;Eci=34131
  ObservationAge CreepStrain
     100         406.1E-8
     103         491.7E-8
     107         580.7E-8
     114         699.9E-8
     128         871.3E-8
     180        1245.5E-8
     365        1832.8E-8
     730        2272.1E-8
    1825        2661.4E-8
    3650        2840.8E-8
    7300        2953.9E-8


MESH INPUT
  NODES N=6
  1 X=100.0 Y=0.0 ! 6 X=100 Y=1000 G=1,6             ; Fixed base column


  CONCRETE PROPERTIES N=1
  1 FPC=30.0 CR=3.0 SH=0.0 W=0 M=1               ; Laboratory model

  SECTION PROPERTIES N=1
  1 D=100 B=100                                 ; 100X100 Section

  OFFSET DATA  N=2
  1 OI=-100.0,0.0  OJ=-100.0,0.0
  2 OI=100.0,0.0  OJ=100.0,0.0

  MILD STEEL PROPERTIES N=1                      ; No midl steel
  1 Es=200000 P=0.0

   ELEMENTS N=15
    FRAME N=15
    1,1,2 C=1 X=1 ST=1 Day=0 G=1,5,1,1,1       ; Laboratory model
    6,1,2 C=1 X=1 ST=1 Day=0 OFF=1 G=6,10,1,1,1
    11,1,2 C=1 X=1 ST=1 Day=0 OFF=2 G=11,15,1,1,1

MESH COMPLETE

CHANGE STRUCTURE
  BUILD N=1,5                                    ; Install column
  RESTRAINTS                                     ; and Base support
    1 R=1,1,1

CHANGE COMPLETE

SOLVE Day=1    ! OUTPUT
SOLVE DAY=3     ! OUTPUT
SOLVE DAY=5     ! OUTPUT
SOLVE Day=7    ! OUTPUT

LOADING
  N=6 F=0, -6.0E4,0

SOLVE Day=7   ! OUTPUT
SOLVE DAY=10    ! OUTPUT
SOLVE DAY=12    ! OUTPUT
SOLVE Day=14   ! OUTPUT

;CHANGE STRUCTURE
;  BUILD N=6,15
;
;CHANGE COMPLETE

SOLVE DAY=14   ! OUTPUT
SOLVE DAY=17   ! OUTPUT
SOLVE DAY=19   ! OUTPUT
SOLVE DAY=21   ! OUTPUT
SOLVE DAY=23   ! OUTPUT
SOLVE DAY=28   ! OUTPUT
SOLVE DAY=42   ! OUTPUT
SOLVE DAY=56   ! OUTPUT
SOLVE DAY=70   ! OUTPUT
SOLVE DAY=100  ! OUTPUT
```

```
STOP
```

For the bending condition, the following two lines in the input data apply

```
LOADING
  N=6 F=1000,0,0
```

---

[i] ADAPT ABI version 4.xx