CALCULATION OF FACTORS FOR LONG-TERM LOAD COMBINATIONS IN ADAPT-BUILDER

Total deflection is calculated as:

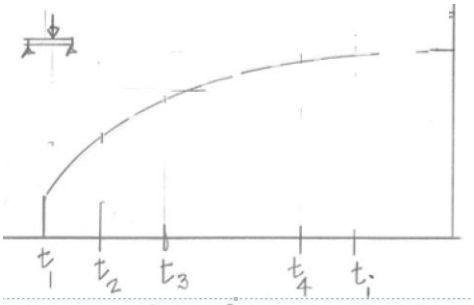
$d = d_t + d_l$

Where,

d_t = long term deflection at time t (all sustained loads)
d_l = immediate deflection due to additional live load (non-sustained portion of live load)

Calculation of long term deflection, d_t

When sustained loads are applied at the same time:



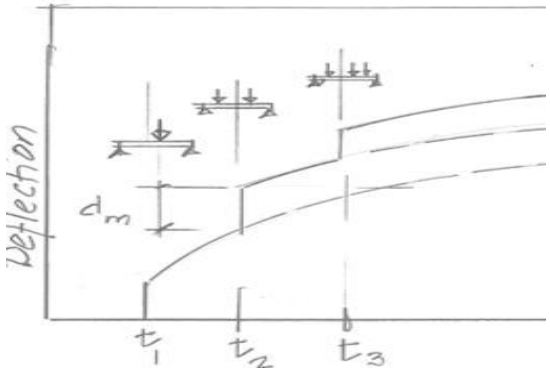
The long-term deflection is calculated as:

$d_t = d_m + C*d_m$

Where,

d_m = immediate deflection due to sustained load, or temperature for day 28
C = time dependent creep and shrinkage coefficient at day t

When sustained loads are applied in stages:



The long-term deflection is calculated as:

$$d_t = d_{m1} + C_1 * d_{m1} + d_{m2} + C_2 * d_{m2} + C_3 * d_{m3}$$

Where,

d_{mi} = instantaneous deflection due to added sustained load. It is calculated as the difference between deflections at Stage i+1 and Stage i. Deflections are calculated assuming cracked sections.

d_{mi} = (deflection at Stage i+1) - (deflection at Stage i)

C_i = time dependent creep and shrinkage coefficient at day t

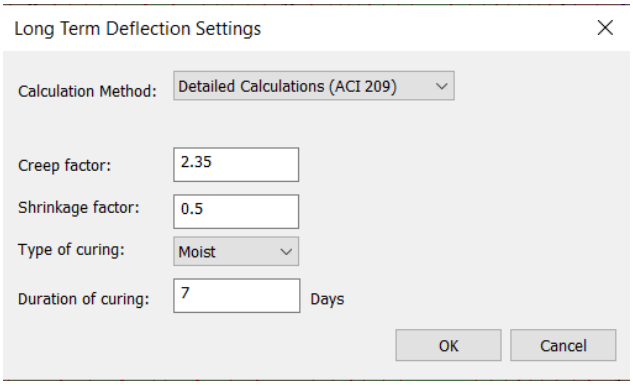
Computation of creep and shrinkage coefficient, C

For computation of the creep and shrinkage coefficient C, the following information from user input is used.

- Calculation method:
  - Detailed calculations based on ACI 209R-92, or
  - Multiplier method (ACI 318)
- Date of application of each load in days.
- Observation day. This is the day when the long-term deflection of the structure is sought.

Detailed calculations based on ACI 209R-92

User defined parameters:



The coefficients are calculated as follows:

C = C_r+Sr

Cr = Cru * $\frac{(t-t_0)^{0.6}}{10+(t-t_0)^{0.6}} * 1.25(t_0)^{-0.118}$ - moist curing

Cr = Cru * $\frac{(t-t_0)^{0.6}}{10+(t-t_0)^{0.6}} * 1.13(t_0)^{-0.094}$ - steam curing

Sr = Sru * $\frac{(t-t_c)}{35+(t-t_c)}$ - for moist curing

Sr = Sru * $\frac{(t-t_c)}{55+(t-t_c)}$ - for steam curing

Where,

C_r = Creep coefficient at age t

Sr = Shrinkage coefficient at age t

Cru = Creep factor - user defined ultimate creep factor

Sru = Shrinkage factor - user defined ultimate shrinkage warping deflection factor

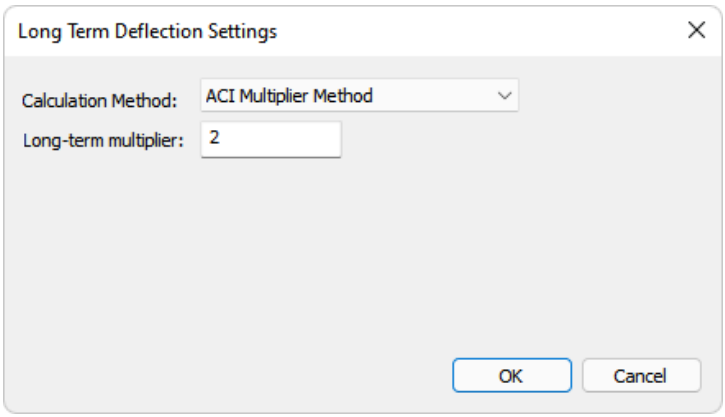
t = Observation day (t >= 7 for moist, >= 3 for steam curing)

t_0 = Age of concrete at loading

t_c = Duration of drying (t_c>=7 for moist, >=3 for steam curing)

Multiplier method (ACI 318)

User defined parameters:



The coefficients are calculator as follows:

C(t) = K*Ƶ'(td)

Where,

K = Used defined long-term multiplier. It represents ultimate creep and shrinkage coefficient adjusted for presence of compression steel.

Ȝ'(td) = Deflection multiplier for load duration td interpolated from the ACI 318 long term deflection multiplier curve and scaled for ultimate creep and shrinkage coefficient.

Calculation of live load deflection, dl

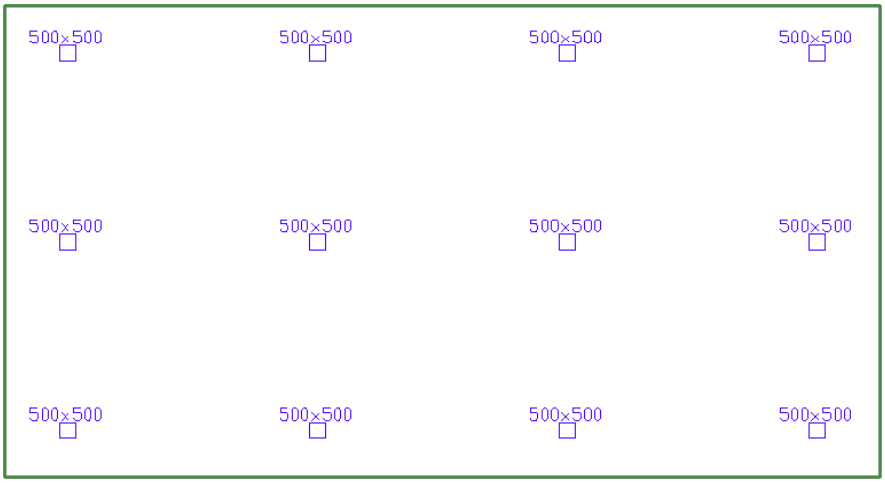
The immediate deflection due to any non-sustained portion of live load is calculated as follows:

dl = immediate total load deflection - immediate sustained load deflection

Example

This example demonstrates how to model load combinations where load is applied in stages and long-term factors are calculated automatically by the program.

Structure:



Loading:

- Selfweight
- Dead load = 1KN/m2
- Live load = 3 KN/m2

Load is applied in stages:

Stage 1: Formes removed 20 days after casting, t1=20 days.
Stage 2: Partitions and deflection-sensitive fixtures installed 40 days after casting, t2 = 40 days.
Stage 3: Live load placed on a slab 180 days after casting, t3= 180 days. Part of live load sustained on the structure (30%).

Calculate:

- Defections at 180, 360 and 5000 days after casting.

- Incremental deflection occurring after the installation of nonstructural elements likely to be damaged by large deflections.

Load Combination modeling steps

1. Create sustained load combinations for each loading stage and one total load combination. For each sustained load combination set:

    - Analysis/Design option to CRACKED DEFLECTION,
    - Deflection Load type to Sustained
    - Enter age at loading as shown below

    In this example 30% of live load is sustained and therefore the last stage includes factor 0.3 for live load.

    For Total Load combination set Deflection Load Type to Total. Note that age at loading is not available here.

Label	Analysis/Design opti...	Deflection Loa...	Age at Loa...	Observat...	Selfweight	Dead load	Live load
Stage1	CRACKED DEFLECTION	Sustained	20		1		
Stage2	CRACKED DEFLECTION	Sustained	40		1	1	
Stage3	CRACKED DEFLECTION	Sustained	180		1	1	0.3
Total Load	CRACKED DEFLECTION	Total			1	1	1

2. Create long-term load combinations as shown below. For each “auto” long-term load combination set:

    - Analysis/Design option to Long-term Deflection
    - Deflection Load Type to Auto
    - Enter Observation day
    - Enter factors equal to 1 in columns of applicable sustained load combinations

    For example, for the long-term load combo with observation day = 40, Stage 1 and Stage 2 load combinations apply and are included by entering factors 1 in Stage 1 and Stage 2 columns. Note that in this example Long_term_40 is required to calculate incremental long term deflection after installation of partitions.

    The incremental deflection is calculated as the difference between deflections at age 5000 and age 40.

    To model incremental deflection set:

    - Analysis/Design option to Long-term Deflection
    - Deflection Load Type to User
    - Enter applicable factors as shown below for Incre_defl_40_5000 combination

Label	Analysis/Design opt...	Deflecti...	Age at L...	Observation day	Stage1	Stage2	Stage3	Total Load	Long_term_defl_40	Total_defl_5000
Long_term_defl_40	Long-Term Deflection	Auto		40	1	1				
Long_Term_defl_180	Long-Term Deflection	Auto		180	1	1	1			
Total_defl_360	Long-Term Deflection	Auto		360	1	1	1	1		
Total_defl_5000	Long-Term Deflection	Auto		5000	1	1	1	1		
Incre_defl_40_5000	Long-Term Deflection	User							-1	1

3. Click Calculate Long-Term Factor button.The program calculates factors for all “auto” long-term load combinations. The factors for the “user” long-term load combination will not be changed.

Label	Analysis/Design opti...	Deflection ...	Age at ...	Obser...	Selfweight	Dead lo...	Live lo...	Stage1	Stage2	Stage3	Total Load	Long_term_defl_40	Total_defl_5000
Stage1	CRACKED DEFLECTION	Sustained	20		1								
Stage2	CRACKED DEFLECTION	Sustained	40		1	1							
Stage3	CRACKED DEFLECTION	Sustained	180		1	1	0.3						
Total Load	CRACKED DEFLECTION	Total			1	1	1						
Long_term_defl_40	Long-Term Deflection	Auto		40				1.019	1				
Long_Term_defl_180	Long-Term Deflection	Auto		180				0.143	1.67	1			
Total_defl_360	Long-Term Deflection	Auto		360				0.137	0.344	1.558	1		
Total_defl_5000	Long-Term Deflection	Auto		5000				0.153	0.293	1.996	1		
Incre_defl_40_5000	Long-Term Deflection	User										-1	1

Validation

Method: Detailed Calculations (ACI 209)

Creep factor, C_{ru} = 2.35

Shrinkage factor, S_{ru} = 0.5

Type of curing = Moist

Duration of curing, t_c = 7 days

Long-term_defl_40

t = 40 days

Stage 1	t_0 = 20 days	C_r = 0.776, S_r = 0.243, C_1 = 1.019
Stage 2	t_0 = 40 days	C_r = 0, S_r = 0, C_2 = 0

Long_term_defl_40 = Stage1 + C_1*Stage1 + (Stage2 - Stage1) + C_2*(Stage2 - Stage1)

= C_1*Stage1 + Stage2

= 1.019*Stage1 + Stage2 (OK)

Total_defl_5000

t = 5000 days

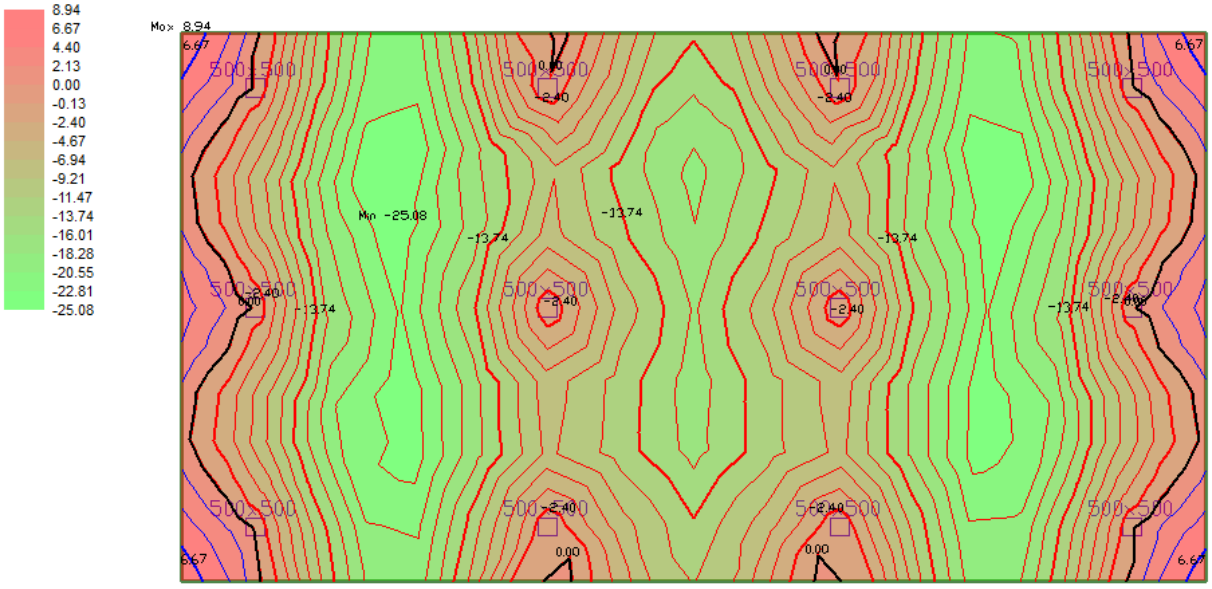
Stage 1	t_0 = 20 days	C_r = 1.945, S_r = 0.497, C_1 = 2.442
Stage 2	t_0 = 40 days	C_r = 1.792, S_r = 0.497, C_2 = 2.289
Stage 3	t_0 = 180 days	C_r = 1.499, S_r = 0.497, C_3 = 1.996

Long_term_5000 = Stage1 + 2.442*Stage1+ (Stage2 - Stage1) + 2.289*(Stage2 - Stage1) + (Stage3 - Stage2) + 1.996*(Stage3 - Stage2) + (Total Load - Stage3)

= 0.153*Stage1 + 0.293*Stage2 + 1.996*Stage3 + Total Load (OK)

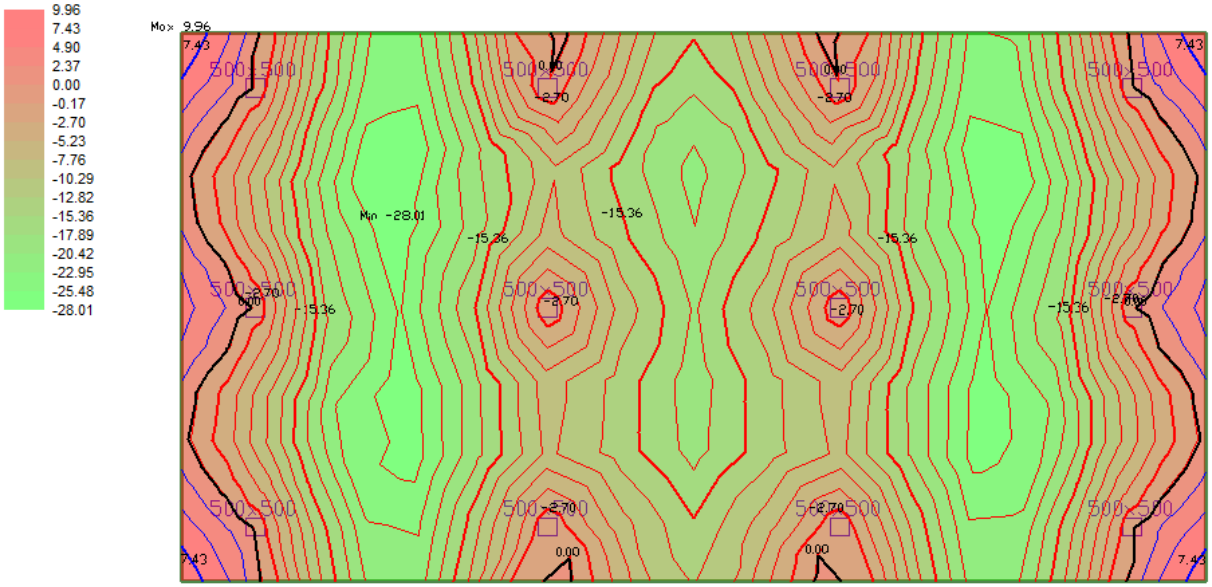
Deflection at 360 days:

Slab, Deformation, Z-Translation (mm)
Load Combination: cracked_Total_defl_360
Max 8.94@(0.00, 15.00, 3.00)
Min -25.08@(5.80, 9.84, 3.00)



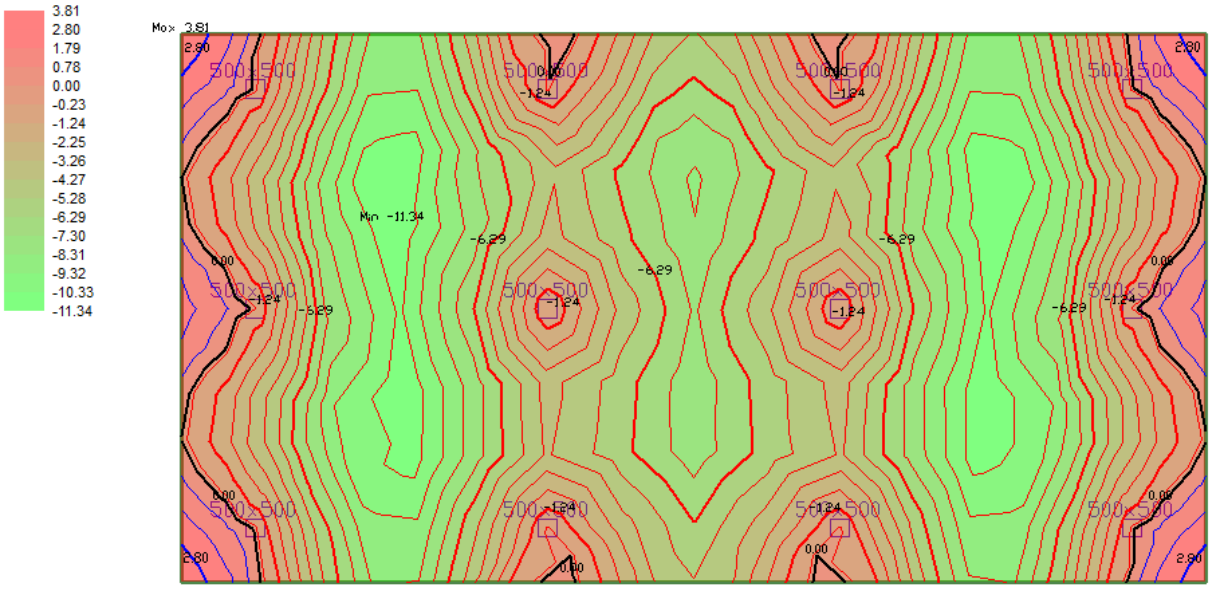
Deflection at 5000 days:

Slab, Deformation, Z-Translation (mm)
Load Combination: cracked_Total_defl_5000
Max 9.96@(0.00, 15.00, 3.00)
Min -28.01@(5.80, 9.84, 3.00)



Deflection at 40 days:

Slab, Deformation, Z-Translation (mm)
Load Combination: cracked_Long_term_defl_40
Max 3.81@(0.00, 15.00, 3.00)
Min -11.34@(5.80, 9.84, 3.00)



Incremental deflection after installation of partitions, from day 4 - 5000:

Slab, Deformation, Z-Translation (mm)
Load Combination: cracked_Incre_defl_40_5000
Max 6.16@(0.00, 15.00, 3.00)
Min -16.68@(5.80, 9.84, 3.00)