# Cracked-section analysis

## How are cracked sections analyzed in SAFE?

**Answer:** Two types of **cracked-section analysis** are available, including:

- Immediate cracked deflection
- Long-term cracked deflection accounting for creep and shrinkage

**Cracked-section analysis** is run in SAFE using either of the following two methods:

1. All load patterns are applied in a single load case which uses either immediate or long-term cracked deflection, discussed as follows:

   **Immediate cracked deflection**, in which all loads (DEAD + SDEAD + LIVE) are applied in a single load pattern, then analysis is run with the Crack Analysis option.

   **Long-term cracked deflection**, in which analysis is divided into the following two categories:

   - **Non-sustained portion**, in which cracked-section analysis considers only the non-sustained portion of LIVE load, solving for incremental deflection.
   - **Sustained portion**, in which long-term cracked analysis considers the sustained loading from DEAD, SDEAD, and a portion of the LIVE load. Creep and shrinkage are included only in this sustained portion of analysis because these effects are only applicable under sustained loading.

     **NOTE:** Short-term concrete modulus = Elastic concrete modulus Ec(to)
     **NOTE:** Long-term concrete modulus = Age-adjusted concrete modulus Ec(t,to), given as:

     $$\overline{E}_C(t, t_0) = \frac{E_C(t_0)}{1 + X\varphi(t, t_0)}$$

     For example, assume that 25% of the LIVE load is sustained. Analysis proceeds as follows:

     - Case 1: Cracked analysis for short-term load with short-term concrete modulus is given as DEAD + SDEAD + $_{s}$LIVE, in which $_{s}$ = 1.0
     - Case 2: Cracked analysis for permanent load with short-term concrete modulus is given as DEAD + SDEAD + $_{L}$LIVE, in which $_{L}$ = 0.25 ($_{L}$ = 0 if 100% of the LIVE load is non-sustained)
     - Case 3: Long-term cracked analysis (with creep and shrinkage) for permanent load with long-term concrete modulus is given as DEAD + SDEAD + $_{L}$LIVE, in which $_{L}$ = 0.25

       The value of total long-term deflection is then the combination of Case 3 + (Case 1- Case 2). The difference between Case 1 and Case 2 represents the incremental deflection (without creep and shrinkage) due to non-sustained loading on a cracked structure.

       The procedure indicated above results on total long term deflection over time. Most engineers simply check this values against ACI 318 Table 9.5(b), since this will always result in safe and conservative design. In order to remove portion of dead load deflection occurring before attachment of nonstructural elements, the following procedure can also be used:

       Case 4= Cracked analysis for permanent load with short-term concrete modulus is given as DEAD + $_{D}$SDEAD, in which $_{D}$ = percentage of super imposed dead load present before attachment of non structural elements

       Or Case 4= Cracked analysis for permanent load with long-term concrete modulus creep and shrinkage is given as DEAD + $_{D}$S DEAD, in which $_{D}$ = percentage of super imposed dead load present before attachment of non structural elements, and say using a creep factor for 3 months.

       The value of total long term deflection to occur after attachment of nonstructural elements is then the combination of Case 3 + (Case 1- Case 2)- Case 4.

       We recommend this method, though an alternative is available, described as follows:

2. A single load pattern is applied in a load case, then another case is set to continue From State at End of Nonlinear Case.

For example:

- Add a DEAD load case using the Nonlinear (Cracked) option, starting with a Zero Initial Condition.
- Add a SDEAD load case using the Nonlinear (Cracked) option, starting From State at End of Nonlinear Case DEAD.
- Add a LIVE load case using the Nonlinear (Cracked) option, starting From State at End of Nonlinear Case SDEAD.

  The DEAD load case predicts cracking from a zero initial condition, in which no load is present, then computes cracking due to DEAD load-pattern application. Adding SDEAD then uses the stiffness at the end of DEAD load case, and contributes additional deflection. Deflection reports the total deflection from both DEAD and SDEAD cases, however, the increase in DEAD load deflection due to additional cracking from SDEAD load application is not recognized, therefore we do not recommend this method.

## Cracked-slab deflection

SAFE can use user-defined reinforcement to compute cracked-slab deflection. For this option, select Run > Reinforcing Option for Cracking Analysis, then select User Specified Rebars in Reinforcement Source. Select Draw Slab Rebar from the vertical menu on the left. Note that rebar must be added in both the tension and compression regions for the entire slab since the software will only use the user-defined reinforcement, and not use the reinforcement desig
.

## References

### Refer to watch and learn video: Cracked section analysis

During nonlinear cracked-section analysis, SAFE estimates deflection using a moment-rotation curve as described in the reference which follows:


- Ghali, A., Favre, R., Elbadry, M. (2002). (3rd ed.). London, England: Spon Press.
- SAFE verification example 16 by going to Help > Documentation > verification> Analysis > Example 16-Cracked Slab Analysis. Example 16.pdf


## See Also

- Cracking article
- Soil-structure interaction section
- Modeling cracked-section properties article
- Cracking FAQ article