nts for deflection are to be checked at specified load levels includ

ete members depend on a large number of factors including the degr load levels, cracking due to construction loads, creep and shrinka ncrete, modulus of elasticity, and support conditions. Because of th of factors affecting deformations, relatively simple procedures, as give nay be used in deflection computations; however, undue reliance shou ed results.

re available for control of deflections in one-way and two-way non . In the first approach, deflection requirements are considered to b ircumstances, by providing a member thickness equal to or exceeding pan length. In the second approach, deflections must be calculated and maximum permissible values. Situations not covered by the specified lues must be considered on an individual basis.

ation SP 203 comparing Code Provisions for Deflection Control i des additional information.

Control by Span to Depth Ratios

onstruction (Non-prestressed)

iction *not* supporting or attached to partitions or other construction likely deflections, deflections need not be computed if the member thickness value given in Table 6.1 (Table 9.1 of CSA Standard A23.3). If the attached to non-structural elements likely to be damaged by large iinimum thicknesses does not apply and deflections must be computed isfy maximum permissible values.

onstruction (Non-prestressed)

iction, if the slab thickness equals or exceeds the minimum thickness 3.3.3 to 13.3.5, deflections need not be computed. These minimum iether or not the slab is supporting partitions or other construction likely eflections.

is specifying minimum thickness for two-way construction are given in

s of two-way slabs present a serious serviceability problem not easily r installation of non-structural elements and mechanical services. It is r on the side of thicker rather than thinner slabs.

Limits

is must not exceed the limits given in Table 6.3 (Table 9.2 of CSA d as fractions of the clear span length, ℓ_n.

sidered are,

due to specified live load, L

non-structural elements likely to be damaged by large deflections.

Other deflection criteria may have to be considered by the designer. For example, where excessive deflection may result in either aesthetic or functional problems, such as objectionable visual sagging, ponding of water, vibration, or improper operation of sliding doors, total deflection should be considered. Guidance on deflection limits for a range of design situations is given in Ref. 1.

6.4 Deflection Computations

6.4.1 Computation of Immediate Deflections for Beams and One-way Slabs (Non-prestressed)

For uniformly loaded members, immediate deflections can be computed using the expression:

$$\Delta = K\left(\frac{5}{48}\right)\frac{M\,\ell^2}{E_c\,I_e} \tag{6.1}$$

where M = support moment for cantilever, midspan moment for simple and continuous beams

ℓ = span length

E_c = modulus of elasticity of concrete

$(3300\sqrt{f'_c} + 6900)\,(\gamma_c/2300)^{1.5}$

$(1500 \le \gamma_c \le 2500\ kg/m^3)$

$= 4500\sqrt{f'_c}$ for normal density concrete

I_e = effective moment of inertia

K = coefficient as follows

	K
Cantilevers (fixed end)*	2.400
Simple spans	1.0
Fixed-Hinged Beams	
–Midspan deflection	0.800
–Max deflection (when using max. moment)	0.738
Fixed-Fixed Beams	0.600
Continuous Spans	$1.20 - 0.20M_o/M_m$

where $M_o = w\ell^2/8$ and M_m is the net midspan moment.

*In the case of cantilevers, the deflection due to the rotation at the support must also be included.

For loading other than uniformly distributed, the formulae given in Chapter 1 of this Handbook can be used.

The effective moment of inertia, I_e, is given by

$$I_e = \left(\frac{M_{cr}}{M_a}\right)^3 I_g + \left[1 - \left(\frac{M_{cr}}{M_a}\right)^3\right] I_{cr} \qquad (6.2)$$

where $M_{cr} = \dfrac{f_r I_g}{y_t}$ (6.3)

$f_r = 0.6\lambda\sqrt{f'_c}$ (6.4)

λ = *1.00* for normal density concrete

λ = *0.85* for structural semi-low density concrete

λ = *0.75* for structural low density concrete

M_a = moment at load level under consideration

The quantities I_g, I_{cr}, and y_t can be calculated for rectangular and T-sections using the equations and charts given in Tables 6-4 to 6-9. Use of the Design Aids is illustrated in the Design Examples. I_e should be evaluated based on moment at the support for cantilevers, and midspan moment for simply supported beams. For continuous beams average values of I_e based on support moments and midspan moments should be used. CSA A23.3 states that I_e may be taken as a weighted average as given by the following expressions:

One end continuous:

$$I_{e\,(avg)} = 0.85\, I_{e\,(pos)} + 0.15\, I_{e\,(neg)} \qquad (6.5)$$

Both ends continuous:

$$I_{e\,(avg)} = 0.70\, I_{e\,(pos)} + 0.30\, \frac{I_e(neg)_{left} + I_e(neg)_{right}}{2} \qquad (6.6)$$

For column supported end spans where partial fixity is provided by the exterior column the following expression could be considered:

$$I_{e\,(avg)} = 0.75\, I_{e\,(pos)} + 0.25\, I_{e\,(neg)} \qquad (6.7)$$

I_e should normally be calculated based on the load level under consideration. For example, dead load deflection should be calculated with I_e based on the dead load moment. Deflection under combined dead plus live load should be calculated with I_e based on total load moment. Live load deflection would then be taken as the difference between total load deflection and dead load deflection. The use of I_e based on total load moments to compute all terms would tend to overestimate the dead load deflections and underestimate the live load deflections.

When construction procedures are likely to result in high loads at early age, such as in multi story floor construction, I_e for all cases should be based on the construction load level as discussed in Section 6.4.3.

6.4.2 Computation of Long-Time Deflection for Beams and One-Way Slabs (Non-prestressed)

Having calculated the immediate deflection Δ_i corresponding to the sustained load level, the additional long-time deflection, Δ_t, due to creep and shrinkage may be calculated using Eq. 6.8.

S

The variation of S with time is shown graphically in Fig. 6.1. The us[e] for both creep and shrinkage effects is sufficiently accurate for most situat[ions] ... creep is stress-dependent while shrinkage is not, it may be desirable in so[me] ... the two effects separately. For example, in lightly loaded slabs reinforce[d] ... may be necessary to consider the effect of shrinkage warping separ[ately] ... deflection due to sustained load. To calculate the long-time deflection cor[...] and shrinkage separately, the following equations may be used.

$\Delta_t = \Delta_{cp} + \Delta_{sh}$

The creep deflection is given by

$\Delta_{cp} = k_r\, C_t\, \Delta_i$

where $k_r = \dfrac{0.85}{1 + 50\rho'}$

The ultimate value of C_t may be taken as *1.6* for average conditi[ons] ... times,

$C_t = \dfrac{1.6}{2.0} S$

The shrinkage deflection is given by:

$\Delta_{sh} = K_{sh}\, \phi_{sh}\, \ell^2$

$\phi_{sh} = \dfrac{A_{sh}\, \varepsilon_{sh}}{h}$

For this purpose, the ultimate value of ε_{sh} may be taken as 400×10^{-6} ... For intermediate times

$\varepsilon_{sh} = \dfrac{S}{2.0} 400 \times 10^{-6}$

The term A_{sh} is obtained from Table 6.10. The steel percentages ... refer to the support section of cantilevers and the midspan section of ... spans. For T-beams, use $\rho = 100\,(\rho + \rho_w)/2$ in determining A_{sh}, where ρ_w ...

The following values of K_{sh} can be used in Eq. 6.12.

Cantilevers
Simple beams
Beams continuous at one end only
Beams continuous at both ends

Design Example 6.1

Required: Calculate midspan deflections for exterior span of Tee B[eam] ... calculated deflections with CSA Standard A23.3 Maximum Permissible V[alues] ...

1. Loads

Dead Load