6.1.7 Shrinkage

6.1.7.1 *Basic shrinkage strain*

The basic shrinkage strain of concrete ($\varepsilon_{cs.b}$), may be:

(a) Normal-class concrete—

(i) determined from measurements on similar local concrete; or

(ii) taken as equal to 850×10^{-6}.

(b) Special-class concrete—

(i) determined from measurements on similar local concrete; or

(ii) determined by tests after eight weeks drying, in accordance with AS 1012.13.

6.1.7.2 *Design shrinkage strain*

The design shrinkage strain (ε_{cs}) shall be determined from the basic shrinkage strain ($\varepsilon_{cs.b}$) by any accepted mathematical model for shrinkage behaviour, calibrated such that $\varepsilon_{cs.b}$ is also predicted by the chosen model.

In the absence of more accurate methods, the design shrinkage strain at any time after commencement of drying shrinkage may be taken as—

$$k_1 \varepsilon_{cs.b}$$

where

k_1 is obtained from Figure 6.1.7.2

Based on a value of $\varepsilon_{cs.b}$ of 850×10^{-6}, this method gives the typical design shrinkage strains given in Table 6.1.7.2.

Consideration shall be given to the fact that ε_{cs} has a range of ±40%.

TABLE 6.1.7.2

TYPICAL DESIGN SHRINKAGE STRAINS AFTER 30 YEARS IN VARIOUS ENVIRONMENTS (FOR NORMAL-CLASS CONCRETE)

A1

Exposure environment	Final design shrinkage strain (ε_{cs}), 10^{-6}			
	Hypothetical thickness (t_h), mm			
	50	100	200	400
Arid	1 100	940	730	500
Interior environments	1 000	860	670	450
Temperate inland	900	760	590	410
Tropical and near-coastal	650	570	440	300

NOTE: For descriptions of exposure environments see Table 4.3 and Figure 4.3.

3.1.7 Shrinkage

3.1.7.1 *Calculation of design shrinkage strain*

The design shrinkage strain of concrete (ε_{cs}) shall be determined—

(a) from measurements on similar local concrete;

(b) by tests after eight weeks of drying modified for long-term value, in accordance with AS 1012.13; or

(c) by calculation in accordance with Clause 3.1.7.2.

3.1.7.2 *Design shrinkage strain*

When the design shrinkage strain of concrete (ε_{cs}) is to be calculated, it shall be determined as the sum of the chemical (autogenous) shrinkage strain (ε_{cse}) and the drying shrinkage strain (ε_{csd})—

$$\varepsilon_{cs} = \varepsilon_{cse} + \varepsilon_{csd} \quad \ldots 3.1.7.2(1)$$

The autogenous shrinkage strain shall be taken as—

$$\varepsilon_{cse} = \varepsilon^{*}_{cse} \times \left(1.0 - e^{-0.1t}\right) \quad \ldots 3.1.7.2(2)$$

where t is the time (in days) after setting and ε^{*}_{cse} is the final autogenous shrinkage strain given by—

$$\varepsilon^{*}_{cse} = \left(0.06 f'_c - 1.0\right) \times 50 \times 10^{-6} \quad \ldots 3.1.7.2(3)$$

At any time t (in days) after the commencement of drying, the drying shrinkage strain shall be taken as—

$$\varepsilon_{csd} = k_1 k_4 \varepsilon_{csd.b} \quad \ldots 3.1.7.2(4)$$

and k_1 is obtained from Figure 3.1.7.2 and k_4 is equal to 0.7 for an arid environment, 0.65 for an interior environment, 0.6 for a temperate inland environment and 0.5 for a tropical or near-coastal environment.

The basic drying shrinkage strain ($\varepsilon_{csd.b}$) is given by—

$$\varepsilon_{csd.b} = \left(1.0 - 0.008 f'_c\right) \times \varepsilon^{*}_{csd.b} \quad \ldots 3.1.7.2(5)$$

where the final drying basic shrinkage strain ($\varepsilon^{*}_{csd.b}$) depends on the quality of the local aggregates and shall be taken as 800×10^{-6} for Sydney and Brisbane, 900×10^{-6} for Melbourne and 1000×10^{-6} elsewhere.

Based on a value of $\varepsilon^{*}_{csd.b} = 1000 \times 10^{-6}$, this method gives the typical design shrinkage strains shown in Table 3.1.7.2.

NOTE: Concrete exposed to early drying undergoes shrinkage due to capillary suction. This can result in cracking and poor service performance, particularly of exposed slabs. The amount of shrinkage from suction depends on the ambient conditions and the concrete mix, and can exceed the combined shrinkage from other causes. Therefore, it is important to prevent excessive drying of concrete between the commencement of casting and the application of curing at the completion of finishing.

Consideration shall be given to the fact that ε_{cs} has a range of ±30%.

TABLE 3.1.7.2

TYPICAL FINAL DESIGN SHRINKAGE STRAINS AFTER 30 YEARS

f'_c (MPa)	Final design shrinkage strain ε^*_{cs} $(\times 10^{-6})$															
	Arid environment				Interior environment				Temperate inland environment				Tropical, near-coastal and coastal environment			
	t_h (mm)				t_h (mm)				t_h (mm)				t_h (mm)			
	50	100	200	400	50	100	200	400	50	100	200	400	50	100	200	400
25	990	870	710	550	920	810	660	510	850	750	610	470	720	630	510	400
32	950	840	680	530	880	780	640	500	820	720	590	460	690	610	500	390
40	890	790	650	510	830	740	610	480	780	690	570	450	660	590	490	390
50	830	740	610	490	770	690	580	460	720	650	540	440	620	550	470	380
65	730	650	560	460	680	620	530	440	640	580	500	410	560	510	440	370
80	630	570	500	420	590	540	480	410	560	520	450	390	500	460	410	360
100	490	460	420	380	480	450	410	370	460	430	400	360	420	400	370	340

EXCEL MACROS

```
Function DesShrinkStrain(t, th, RH, basic_shrinkage_strain)

'AS3600-2001

't=time (in days)

'th=hypothetical thickness (in mm)...th=(2*Ag/ue) where ue is the exposed
surface area plus half the perimeter of any closed voids contained therein

'RH=Average humidity (%)

'consideration should be given to the fact that this value can vary by +/-30%

'Arid RH=40%; Semi-Arid RH=50%; Temperate Inland RH=60%; Tropical RH=70%;

ks4 = 0.62 + 1.5 * Exp(-0.005 * th)

ks5 = (4 - 0.04 * RH) / 3

ks6 = 0.15 * th
```

```
ks1 = (ks4 * ks5 * t ^ 0.7) / (t ^ 0.7 + ks6)

DesShrinkStrain = ks1 * basic_shrinkage_strain

End Function



Function escd(fc, t, strain, th, environment)

'AS3600-2009

'environment must equal arid, interior, temperate inland or tropical

'final drying shrinkage strains are 800E-6 for Brisbane and Sydney, 900E-6
for Melbourne and 1000E-6 elsewhere

ks109 = (0.8 + 1.2 * Exp(-0.005 * th)) * t ^ 0.8 / (t ^ 0.8 + 0.15 * th)

If environment = "arid" Then

ks409 = 0.7

ElseIf environment = "interior" Then

ks409 = 0.65

ElseIf environment = "temperate inland" Then

ks409 = 0.6

ElseIf environment = "tropical" Then

ks409 = 0.5

End If

escdb = (1 - 0.008 * fc) * strain

escd = ks109 * ks409 * escdb

End Function


Function esce(fc, t)

'AS3600-2009

esce = (0.06 * fc - 1) * 50 * 10 ^ -6 * (1 - Exp(-0.1 * t))

End Function
```