# A Discussion on the Autogenous Shrinkage Interpretation from the Experimental Shrinkage Measurement Based on the Australian Testing Procedure AS1012.13

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**Abstract:** This paper discusses a suggested experimental procedure for performing an accurate assessment of the concrete shrinkage. The suggested experimental procedure is based on the Australian shrinkage assessment terms and concept, addressed in the current version of Australian Standard AS3600. Following the introduction of the current version of Australian Standard AS3600, it has been noted that there are difficulties in relating test data from concrete drying shrinkage tests carried out in accordance with the Australian Standard AS1012.13 to the design shrinkage strain calculated in AS3600. This issue arises as a result of AS3600 approach for conducting shrinkage calculation by separating the forms of shrinkage into autogenous and drying shrinkage components. This paper discusses these types of shrinkage and their relationship to shrinkage measured according to AS1012.13. It goes on to propose possible procedure of using such test results to assist prediction of the design shrinkage strain by the methods proposed in AS3600. In addition, the proposed test method for measuring the autogenous shrinkage provides a consistent experimental method, which reveals the portion of autogenous shrinkage out of the total shrinkage. Besides, the proposed test method is used for assessing the effectiveness of mitigation methods applied specifically for the reduction of autogenous shrinkage.

**Keywords:** Drying Shrinkage of Concrete, Autogenous Shrinkage, Design Shrinkage Strain

## 1. Introduction

The current version of AS3600 [1] Clause 3.1.7.1 deals with the concrete shrinkage by introducing a parameter termed design shrinkage strain ($\varepsilon_{cs}$) of concrete. The design shrinkage strain ($\varepsilon_{cs}$) of concrete is determined from measurements on local concrete. In a situation which the design shrinkage is predicted, it can be estimated by calculations provided by AS3600 Clause 3.1.7.2. This calculation addresses in AS3600 Clause 3.1.7.2 separates the sources of concrete shrinkage between autogenous shrinkage ($\varepsilon_{cse}$) and drying shrinkage ($\varepsilon_{csd}$) as demonstrated in Equation (1).

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

where, $\varepsilon_{cs}$ is the design shrinkage strain of concrete, $\varepsilon_{cse}$ is the autogenous shrinkage strain, and $\varepsilon_{csd}$ is the drying shrinkage strain

This change reflects the current European Codes EN1992-1-1 [2]. However, the two types of shrinkage noted in AS3600 Clause 3.1.7.2 now no longer have specific Australian Standard test methods from which the effect of intrinsic mix properties, such as concrete mix design values for these properties can be determined. The AS3600 code user is given the options of determining drying shrinkage "by tests after eight weeks of drying modified for long-term value, in accordance with the existing test method AS1012.13 [3], but the user is not advised as to how this data can be interpreted. In the previous version of AS 3600 [4] the value of basic shrinkage strain of concrete $\varepsilon_{cs.b}$ was either a default value of 850 micro-strains or directly assessed using the standard shrinkage test AS1012.13 value for drying shrinkage at 56 days as the value.

This problem arises from the fact that the Australian standard AS 1012.13 actually measures the entire shrinkage under the drying condition, which is different to just the drying shrinkage. The entire shrinkage under the drying condition includes both the drying shrinkage and autogenous shrinkage.

Autogenous shrinkage is considered to be a type of "drying" shrinkage that occurs when there is no loss of water from the concrete, but moisture is removed from the concrete pore structure through internal hydration of the binder rather than drying from the exposed surfaces of a concrete structure. The hydration reaction starts after water is mixed with cement. This reaction is time-dependent and involves only a portion of the mixed cement and water. It is observed that the resultant products of this reaction have less volume compared to the summation of the volume of reacted water and cement. Figure1 illustrates the difference between the volume of concrete resources and products resulted from cement reaction, when the ambient temperature is kept constant (the thermal expansion negligible). This form of chemical shrinkage has two major stages. The first one is named the plastic deformation, which includes concrete deformation in the plastic state and before the concrete initial setting time. The second stage is after initial concrete setting, when the hydrating cement has formed some structure that is capable of resisting stress and further chemical reaction in concrete results in the autogenous shrinkage. Accordingly, when a sufficient structure is formed to restrain chemical shrinkage following initial setting, the volume of the movement becomes “self-desiccation” shrinkage or “autogenous shrinkage” [5].

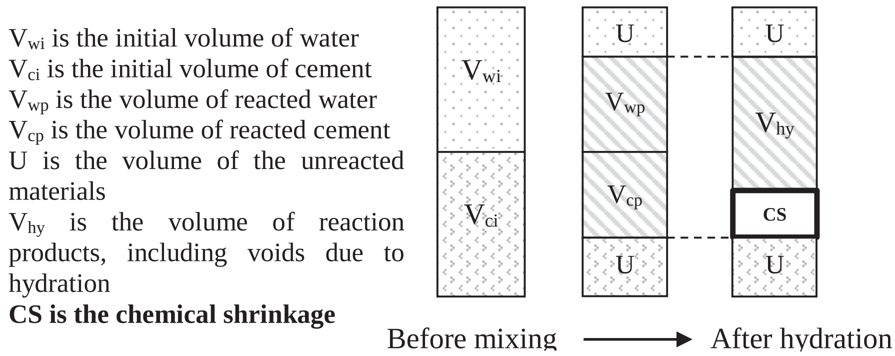


**Figure1: Volume of Cement, Water and Hydration Products [6]**

The autogenous shrinkage magnitude is largely an intrinsic characteristic and is independent of member size, and concrete ambient condition. In contrast, the drying shrinkage where the size and shape of member as well as the surrounding environment are significant factors in the rate of drying from exposed surfaces and so the rate of “drying shrinkage”. In contrast to the autogenous shrinkage, which is caused by chemical reaction, the drying shrinkage is the shrinkage resulting from the effects of the loss of moisture from the concrete surface and is partly reversible when the concrete is re-saturated.

As mentioned above, factors affecting the autogenous shrinkage are different from the factors influencing the drying shrinkage. Although the current version of AS3600 proposes a model for estimating $\varepsilon_{cse}$ and $\varepsilon_{csd}$ separately, unfortunately the Australian Standards provide no means of separately measuring these values in sampled concrete. For a concrete test specimen, the given standard test method for drying shrinkage will contain both of these components of shrinkage. These components are varying in proportion, and it is difficult to now interpret and relate standard test data to AS3600 design values without further guidance being given. In the following sections the authors will review literature relating to interpretation of the two forms of shrinkage, review selected test data and recommend a method for interpretation of test data that can be applied by users of AS3600.

## 2. Autogenous and Drying Shrinkage

A review of the literature on this property of concrete yields a significant number of papers detailing the proposed mechanisms and magnitude of this form of shrinkage [7–9]. The complexity of trying to relate this data to that of the standard concrete shrinkage test AS1012.13, is that the test data incorporates a number of different forms of volume change as a result of the various elements of the curing process that a specimen is subjected to and how this may, or may not, be related to concrete formed into a structure. Some of the forms of volume change that need to be considered are:

(a) Early Chemical Shrinkage

(b) Thermal expansion or shrinkage
(c) Autogenous Shrinkage
(d) Swelling on saturation
(e) Drying Shrinkage
(f) Carbonation Shrinkage

In Table 1 below the authors suggest the likely volume changes (as above) that will influence the unrestrained shrinkage of a standard test specimen used for a drying shrinkage test carried out in accordance with AS1012.13.

**Table 1: Typical Characteristics of Free Volume Change of Shrinkage Samples**

| Curing Period | Method of Curing | Likely Influences on Volume Change (from forms of volume change listed) |
|---|---|---|
| 0 hours to 24 hours | Field or Laboratory specimen "sealed" in form. | (a), (b), (c) and possibly (e) to some extent |
| 24 hours to 7 days | Specimen placed in lime saturated water at 23°C. | Possibly (c) to some extent and (d) |
| 7 days to 63$^{+}$ days | Specimen surface dried and maintained at 23°C and 50% Relative Humidity | (c), (e) and possibly (f) |

Other test methods such as ASTM 1698 [10] provide a method for assessing autogenous shrinkage and is only suitable for cement pastes and possibly mortars. Neither of these methods are suitable for assessing the autogenous shrinkage component of a standard shrinkage test but do have value in gaining a better understanding of the nature of and time dependency of autogenous shrinkage at early ages. It can be seen that autogenous shrinkage is likely to have an influence on the final cumulative shrinkage on most parts of the test specimen's combined curing periods with the probable exception of the period of wet curing where, depending on the concrete permeability, there will be a ready supply of water to replace chemically reacted water with the net impact being expansion or swelling.

In the case of a concrete structural element cast in a dry environment (i.e. not in water or subject to wet curing) the main influences on volume change will be (a), (b), (c) and to a lesser extent (e) until initial in form or other form of curing is complete and then (b), (c), (e) and (f) after curing is complete. In this case it can be seen that autogenous shrinkage will have a continuing influence on the members volume change from the time of hardening after placement.

A literature review discovered a number of methods for assessing a concrete mix autogenous shrinkage. Holt (2005) proposes three methods ranging from assessing plastic concrete chemical shrinkage using water displacement to casting a test slab in forms and assessing dimensional change after casting [9]. Further, using a mechanical measuring gauge [6], or laser sensors [11] were also suggested in the literature. Although there are different methods available to be applied for measuring autogenous shrinkage, the selected method should be consistent with the current method AS 1012.13 used for measuring shrinkage under the drying condition. The proposed model in AS3600 for estimating the autogenous shrinkage is provided in equation (2) below.

$$\varepsilon_{cse} = \varepsilon^{*}_{cse} \times \left(1 - e^{-0.1\times t}\right) = \left(0.06 f'_c - 1\right) \times \left(1 - e^{-0.1\times t}\right) \times 50 \times 10^{-6} \quad (2)$$

where, $t$ is time in days after initial setting of the concrete, $\varepsilon^{*}_{cse}$ is final autogenous shrinkage and $f'_c$ is the 28-day characteristic compressive strength of concrete in MPa.

Literature revealed that the autogenous shrinkage is dependent on the chemical composition of cement and concrete materials, and also the mix proportioning [6]. In order to assess the effectiveness of any selected mix design, and selected mitigation methods applied for producing concrete with lower autogenous shrinkage, it is required to have a method specifically measure the autogenous shrinkage. There are different methods addressed by literature for mitigating the autogenous shrinkage such as using low heat (LH) cement, introducing expansive additives, using shrinkage reducing agents (SRA's), adjusting water reducer dose, adjusting gypsum level in cement, replacing a portion of cement with fly ash and increasing the water to cement (W/C) ratio. All these methods can have effect in managing autogenous shrinkage and their level of effectiveness needs to be assessed by testing for any specific mix design.

In its defined form (from AS3600 [1] and EN 1992 [2]) drying shrinkage would be a combination of all shrinkage after taking account of autogenous shrinkage and any thermal shrinkage. To that extent it will contain some impact from carbonation shrinkage unless the measurement technique used seeks to avoid any availability of $CO_2$ or carbonation shrinkage is assessed separately removing the impact of carbonation removed from the over-all shrinkage measurement.

In its purest form “drying shrinkage” should be reversible. In other words, a concrete that has been dried for a period of time and the drying shrinkage component measured, with impacts of carbonation and autogenous shrinkage removed from the total shrinkage, may be re-saturated and the specimen should expand to the full amount of this drying shrinkage component. In reality the drying shrinkage is not fully reversible and literature suggests that the degree to which it is reversible will vary between 30% and 60% as a result of the introduction of additional links within the hydrating cement gel during the initial drying period [12].

Drying shrinkage occurs under drying conditions, which are not associated with chemical or autogenous self-desiccation of a concrete test specimen or a concrete structure, and takes place through the exposed surfaces of the concrete. The rate of drying is dependent on factors such as the concrete members’ size and shape as well as the exposed surface ambient conditions (temperature, air speed and relative humidity) and the permeability of the concrete. AS3600 and EN 1992 provide formulae for estimating the drying shrinkage component of a structure over time as impacted by environment (relative humidity) and member dimensions.

As shown in Equations (3), (4) and (5) from AS3600, at any time “*t*” after the commencement of drying, the drying shrinkage strain shall be taken as:

$$\varepsilon_{csd} = k_1 \times k_4 \times \left(1 - 0.008 \times f_c^{'}\right) \times \varepsilon_{csd.b}^{*} \tag{3}$$

where, $k_1$ is the time after the commencement of drying in days, the value of the factors $k_4$ for the test prism is approximately 0.65 (drying room in AS1012.13 test environment is equivalent to an “interior environment” in AS3600), $f'_c$ is the 28-day characteristic compressive strength of concrete in MPa, and $\varepsilon^*_{csd.b}$ is the final basic drying shrinkage strain, which is taken as $800\times10^{-6}$ for Sydney and Brisbane, $900\times10^{-6}$ for Melbourne and $1000\times10^{-6}$ elsewhere.

$$k_1 = \frac{\left(0.8 + 1.2e^{-0.005t_h}\right) \times t^{0.8}}{t^{0.8} + 0.15t_h} \tag{4}$$

where, $t$ is the time after the commencement of drying in days, $t_h$ is hypothetical thickness of a member in mm calculated using Equation (5)

$$t_h = \frac{2A_g}{u_e} \tag{5}$$

where, $A_g$ is gross cross-sectional area of a member in mm² and $U_e$ is exposed perimeter of a member cross-section plus half the perimeter of any closed voids contained therein in mm.

Finally, consideration should be given to the fact that the design shrinkage strains ($\varepsilon_{cs}$) provided by Clause 3.1.7.2 of AS3600 has a range of ±30% error. The test method for assessing concrete shrinkage, AS1012.13, uses a concrete prism of approximate dimensions 75mm×75mm×280mm. Accordingly, the calculation for the above AS3600 parameters based on the AS1012.13 sample size are tabulated in Table 2.

**Table 2: The calculated Drying Shrinkage parameters for Test Specimen based on AS 3600 Model**

| $f'c$ [MPa] | $t_h$ | $k_1$*(1-0.008*f'c) | | | | | $k_4$ | $\varepsilon^*_{csd.b}$ |
|---|---|---|---|---|---|---|---|---|
| | | 0-Day | 7-Day | 14-Day | 56-Day | 1000-Day | | |
| 20 | 37.5 | 0.000 | 0.690 | 0.897 | 1.231 | 1.475 | 0.65 | 800 |
| 50 | 37.5 | 0.000 | 0.493 | 0.641 | 0.879 | 1.053 | 0.65 | 800 |
| 100 | 37.5 | 0.000 | 0.164 | 0.214 | 0.293 | 0.351 | 0.65 | 800 |

[1] days after placing under drying condition (7 days from casting)

The above parameters (using $\varepsilon^*_{csd.b}$ = 800 micro-strain) are further converted to estimated drying shrinkage values in Table 3 below.

**Table 3: The calculated Drying Shrinkage for Test Specimen based on AS 3600 Model**

| $f'c$ [MPa] | Drying Shrinkage (Microstrain) | | | | |
|---|---|---|---|---|---|
| | 0-Day | 7-Day | 14-Day | 56-Day | 1000-Day |
| 20 | 0 | 359 | 466 | 640 | 767 |
| 50 | 0 | 256 | 333 | 457 | 548 |
| 100 | 0 | 85 | 111 | 152 | 183 |

[1] days after placing under drying condition (7 days from casting)

## 3. Estimate Concrete Shrinkage Using Numerical Models

The drying shrinkage test method used in Australia is AS1012.13. The test method assesses the total drying shrinkage of a concrete prism of approximate dimensions 75mm×75mm×280mm that has been cured for 7 days, 1 day at ambient temperature in moulds and 6 days in lime saturated water set at 23°C. Following this initial curing the specimen is placed in a drying environment kept at a temperature of 23°C and relative humidity of 50% for a further period (usually a further 56 days) with regular measurements of total shrinkage taken up to the end of the testing period.

As noted in Section 2 the "total shrinkage" measured by the test method AS 1012.13 is the total shrinkage under drying conditions, which contains components of "drying shrinkage", autogenous shrinkage and possibly carbonation shrinkage. Based on information provided by Neville [12] the authors have estimated that it is probable that carbonation shrinkage of a concrete test specimen over 56 days drying is relatively low. The carbonation shrinkage is estimated by the authors as being in the likely range of 2 to 15 microstrains at most [12]. On this basis, the authors believe that it is reasonable to include any carbonation shrinkage as part of the overall drying shrinkage and not assessed separately [5].

Based on this, the shrinkage of concrete test specimens will be composed of a combination of residual autogenous shrinkage combined with drying shrinkage. On the assumption that the amount of remaining autogenous shrinkage between 7 days from casting to 63 days from casting (56 days of drying) can be estimated from a member  with dimensions of the test specimen noted above and will have an estimated value taken from AS3600. Estimates from AS3600 in Table 4 below can provide an approximate comparison in the relative proportions of drying and autogenous shrinkage in three different concrete grades. Field test results to AS1012.13 on S50 grade concrete typically present values of shrinkage of approximately 650 microstrains at 56 days drying for sample S50, which is slightly higher than the total shrinkage of S50 grade concrete, calculate using AS3600 and EN 1992-1-1 models (refer to Table 4 & 5).

The autogenous shrinkage for different ages is calculated and presented in Tables 4 & 5. It should be taken into account that the presented autogenous shrinkage values are adjusted by subtracting the value of autogenous shrinkage at the start of drying condition (after 7 days of curing). This subtraction provides a similar reference point for measuring both autogenous and drying shrinkage.

Table 4 & 5 data ignore any potential differences in the impact of water saturation curing used from day 2 to day 7 in the test method on the value of the remaining autogenous shrinkage from 7 days to

63 days. This arises from the assumption that autogenous shrinkage is related to binder hydration and pore size. The autogenous shrinkage mechanism is more significant for higher strength, low W/C ratio concrete with a dense matrix with low porosity. Accordingly, concrete held at a constant temperature for the 6 days of saturation curing may have a relatively minor impact on these factors compared to a specimen which has no drying from the surface but no added water from curing and held at the same temperature for 6 days (stated for autogenous shrinkage only).

**Table 4: The Estimated Drying and Autogenous Shrinkage by AS 3600 Model**

| Shrinkage Type | Applied Model | Concrete Grade | Estimated Shrinkage by Type [Microstrain] | | | | |
|---|---|---|---|---|---|---|---|
| | | [MPa] | 0-Day[1] | 7-Day | 14-Day | 56-Day | 1000-Day |
| Autogenous | | | 0 | 2 | 4 | 5 | 5 |
| Drying | AS3600 | 20 | 0 | 359 | 466 | 640 | 767 |
| **Total** | | | **0** | **361** | **470** | **645** | **772** |
| Autogenous | | | 0 | 25 | 37 | 49 | 50 |
| Drying | AS3600 | 50 | 0 | 256 | 333 | 457 | 548 |
| **Total** | | | **0** | **281** | **371** | **507** | **597** |
| Autogenous | | | 0 | 62 | 94 | 124 | 124 |
| Drying | AS3600 | 100 | 0 | 85 | 111 | 152 | 183 |
| **Total** | | | **0** | **148** | **205** | **276** | **307** |

[1] days after placing under drying condition (7 days from casting)

Table 4 above is can be repeated for the test specimen using the formulae provided in European Standard EN1992-1-1as set out in Table 5 below.

**Table 5: The Estimated Drying and Autogenous Shrinkage by EN1992-1-1 Model**

| Shrinkage Type | Applied Model | Concrete Grade | Estimated Shrinkage by Type [Microstrain] | | | | |
|---|---|---|---|---|---|---|---|
| | | [MPa] | 0-Day[1] | 7-Day | 14-Day | 56-Day | 1000-Day |
| Autogenous | | | 0 | 3 | 5 | 10 | 15 |
| Drying | EN1992-1-1 | 20 | 0 | 255 | 355 | 506 | 583 |
| **Total** | | | **0** | **258** | **360** | **516** | **598** |
| Autogenous | | | 0 | 12 | 19 | 38 | 59 |
| Drying | EN1992-1-1 | 50 | 0 | 178 | 249 | 354 | 409 |
| **Total** | | | **0** | **190** | **268** | **392** | **468** |
| Autogenous | | | 0 | 26 | 43 | 87 | 132 |
| Drying | EN1992-1-1 | 100 | 0 | 95 | 133 | 189 | 218 |
| **Total** | | | **0** | **121** | **176** | **276** | **350** |

[1] days after placing under drying condition (7 days from casting)

As can be seen from the data presented in Table 4 & 5 the two standards have slightly differing estimates on the amount of autogenous shrinkage that occurs between 7 days from casting and 63 days from casting and drying shrinkage over the period from start of drying to 56 days drying. For example grade S50 concrete will have an autogenous shrinkage portion from 7 days to 63 days (56 days drying) estimated as 49 micro-strains while it is estimated as 38 micro-strains using EN1992-1-1 model. The differences in total shrinkage estimated for shrinkage test specimens between the two standards are generally within the ±30% suggested by both standards. It is evident that the estimate of total shrinkage for test specimens is significantly lower than is seen in these grades of concrete in practice (and as reflected in the 2001 and previous versions of AS3600 where typical 56-day drying shrinkage test data was used to estimate total shrinkage).

Considering reported data from literature, autogenous shrinkage can vary significantly for a concrete of the same characteristic strength based on constituents such as binder composition and admixtures (Holt [5]). In view of this the authors recommend that a test method for assessing the autogenous shrinkage component of the standard concrete shrinkage test is developed so that the “basic drying shrinkage” as defined in AS3600 may be better estimated from testing.

## 4. Applying AS3600 Model for Concrete Shrinkage Estimation

The process of estimating the design shrinkage strain given in AS3600 is outlined by Gilbert (2002) [8] in his earlier proposal to Australian Standards. In essence the standard provides three ways to estimate this value. The first (default) method is to estimate the total shrinkage based on the Standard's formulae and a basic drying shrinkage strain value given for different regions. The second requires knowledge of typical drying shrinkage test values for given mixes available in a particular project location. The third method requires a test of the specific concrete mix in accordance with Australian Standard AS1012.13 to determine the shrinkage (typically after 63 days from casting or 56 days drying after the initial 7 days curing). In Standard AS3600 the total member shrinkage is given as being a combination of drying shrinkage ($\varepsilon_{csd}$) plus the autogenous shrinkage ($\varepsilon_{cse}$) at any given time ($t$). Unfortunately the AS1012.13 test, as noted in previous sections, provides data that contains both drying shrinkage and autogenous shrinkage and these need to be separated out so that the test value can be useful in estimating the value of drying shrinkage component in either of the second or third methods noted above.

The problem here is one of timing and its impact on the test method used. Autogenous shrinkage effectively starts from when the concrete reached initial setting (normally within 4 to 12 hours of mixing the concrete) whereas drying shrinkage only starts after ceasing moist curing (in the case of the test method after 7 days). It would seem that in order to interpret the standard test results then the component of autogenous shrinkage in the test drying period needs to be estimated and removed from the result so as to report a final drying shrinkage value for the test prism of the standard dimensions. One way to achieve this is to use the AS3600 equation for the autogenous shrinkage from 7 days to 63 days (test specimen drying period) to determine the correction value to the 56 days drying test value so as to estimate the actual drying shrinkage component. This autogenous shrinkage component is dependent on characteristic compressive strength in the standard and the authors have calculated the relevant values in Table 4 above based on the AS3600 equations. The influence of time and curing on shrinkage based on AS1012.13 can be considered by the estimation of the autogenous shrinkage using equation (2) derived from AS3600 above. For example for the S50 concrete, the autogenous shrinkage is calculated from this formula to be 50 microstrain at the initial time of starting drying of the shrinkage test specimen (7 days). This value can then be subtracted from the estimated autogenous shrinkage from this equation at later ages and the net differential autogenous shrinkage deducted from AS1012.13 test results at these ages to estimate the drying shrinkage component.

The above method is an approximation and may be sufficient for estimation but the problem with the above analysis is that the actual value of the autogenous shrinkage test has been shown to vary significantly for the same concrete strength and needs to be assessed by testing of the same concrete rather than estimated in this way.

The authors propose a means of being able to carry out this testing is to cast duplicate specimens the same concrete used to cast test specimens for assessment of "drying shrinkage" to AS1012.13. These duplicate specimens need to be "sealed" after the initial 7-day curing cycle of the AS1012.13 method to prevent water ingress or surface drying and their shrinkage measured in the same curing temperature to that of AS1012.13 with the resultant shrinkage of theses duplicate specimens measured being attributed to the autogenous shrinkage component of the same concrete over this curing period.

## 5. Proposed Methods of Relating Shrinkage Test Data

As autogenous shrinkage is defined as the shrinkage that occurs through self-desiccation after setting of plastic concrete then the author's believe that it is feasible to assess the impact of this on a standard shrinkage test carried out in accordance with AS1012.13 by using duplicate samples of the same concrete as cast for the standard "drying shrinkage" testing that are subject to the same curing up to 7 days from casting as the standard "drying shrinkage" specimens as noted above.

The author's note that following the curing procedure for the proposed method is going to omit the significant proportion of autogenous shrinkage during the first 7 days after setting. Selection of the autogenous reference point for the samples cured 7 days results in neglecting almost 50% of the total autogenous shrinkage if using formula (2) above as a guide. This method is purely recommended for "correcting" the AS1012.13 method for the component of autogenous shrinkage over the period of the test and not as an estimate of the concrete total autogenous shrinkage including the period from setting to 7 days. The authors recommend that a separate test method for autogenous shrinkage from setting to 7 day's is developed along similar lines to those proposed by Holt [6].

Accordingly, after the standard curing regimes noted in AS1012.13 up to 7 days from casting the test specimens the "autogenous shrinkage" specimens are removed from moist curing and measured, in the same way as detailed in AS1012.13 for the specimens used for the current "drying shrinkage" test. The additional process of "towelling" the specimens is applied to dry to a saturated surface dry condition except that the authors recommend that each specimen mass is then measured to ± 0.1 gram accuracy (including the standard "drying shrinkage" specimens). After finishing each measurement, the autogenous shrinkage specimens are quickly returned to a storage that prevents loss of moisture through evaporation from the concrete surface. This storage will be maintained at 23°C ±2°C and may be storage in a sealed container suspended over water on a rack or by sealing the surface of the concrete specimens to prevent moisture loss. These specimens are measured for shrinkage or expansion at the same storage ages (maturity) as the 'drying shrinkage" test specimens and each specimen mass recorded at the time of measurement as noted earlier. The "autogenous shrinkage" test specimen measurements will be accepted provided mass loss or gain does not exceed 0.2 gram over the measurement period. The results of autogenous shrinkage from 7 days to the time of measurement ($\varepsilon_{cset}$) can then be used to assess the drying shrinkage of the concrete by deducting $\varepsilon_{cset}$ from the standard total shrinkage value assessed by the method of AS1012.13.

It is the authors' opinion that this test method needs significant assessment to validate. The test method outlined here should be trialled to assess the drying shrinkage on a number of concrete mixtures ranging in grade strength from 20MPa to 100MPa as common grades used in construction. The method for storing the test specimens to prevent absorption or loss of water is varied to obtain "sealed specimen" behaviour with no loss or gain of moisture. The aim of the proposed test program will be to provide recommendations on suitable methods to prevent loss of moisture from the autogenous shrinkage specimens so that this may be adopted as a standard method in Australia and assist with aligning the resulting net drying shrinkage test data with the relevant provisions of AS3600.

## 6. Conclusions

This paper discusses the design and application of a test method, which may provide more accurate estimates of the actual drying shrinkage of concrete, specifically. A new method based on the Australian shrinkage test method AS1012.13 is proposed subject to a review of methods to be used in curing autogenous shrinkage test specimens. The suggested method follows mirrors the required procedure which is described in the current AS1012.13. The proposed method provides a means to interpret the characteristics of concrete based on experimental results and not just on the AS3600 model and assumed values, which only considers strength grade of concrete and has 30% error margin in prediction.

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