REVISION OF CONCRETE PRODUCTION STANDARD NZS 3104

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SUMMARY

The concrete production standard NZS 3104 was last updated in 2003 and is currently under review in 2018. This revision is important to update the standard and ensure that productivity in concrete construction improves without compromising the quality of concrete supplied in NZ. The concrete production standard and plant audit scheme of the Readymix sector of Concrete NZ provide a comprehensive quality assurance system unique to New Zealand. Issues to be considered in this revision include using statistical data when setting or reviewing target mean strengths, including 7-day testing, reviewing workability/consistence classes, clarification of issues to do with mixer evaluations, within test coefficient of variation, professional scale checks and mobile batching vehicles.

INTRODUCTION

The concrete production standard NZS 3104 forms the basis of supply for readymix concrete companies and is supported by the Plant Audit Scheme of the Readymix Sector of Concrete NZ. The standard is simple to follow and provides a safe and practical means of ensuring quality of concrete supplied around New Zealand. The current revision (P3104) is an update and will consider the following aspects that are currently either not explicit or are not considered in the standard:

- Target mean strengths are currently fixed and statistical data is only used negatively as a means of showing testing control whereas in countries like Australia a test series has target strengths set based directly on standard deviation data such that low variability would allow lower targets to be set
- 7-day strengths are not mentioned in the standard with the only reference being to 28-day strengths despite most readymix suppliers undertaking 7-day testing and it being mandatory now in the plant audit scheme
- The requirement to test three rather than two cylinders at 28 days is based on within test coefficient of variation data and the revision would clarify how this is analysed for test series and concrete plants
- Clarification of the sample numbers used when undertaking a mixer evaluation test that measures uniformity of concrete properties
- Review of whether using workability/consistence classes would be beneficial since slump targets are not mentioned in the standard and are the subject of debate during construction
- Clarification of how to undertake mixer evaluations on central mixers, better guidance for operators of mobile batching vehicles and requirements for companies providing professional scale check services.
This review will be undertaken by a standards committee comprising a cross-section of the construction industry and the engineering profession. None of the above items can be assumed to be included in the revision as each will be carefully considered by the committee.

AREAS OF REVIEW FOR P3104

Any review of a New Zealand standard needs to have a clear set of objectives and are well motivated and researched. The standards committee is likely to be formed in August 2018 and will consider the following issues with the intention to complete its work before the end of the year.

Statistical approach for setting and/or reviewing target mean strengths

Currently target strengths are set in NZS 3104 without any allowance for statistical factors such as standard deviation. The approach is quite different to similar international standards in that target strengths are set and maximum standard deviation and coefficient of variations set to ensure adequate control of testing. Review of several international concrete standards shows that target strengths are set based on probability and in the case of small series confidence intervals also used. Other materials standards such as NZS 4671 adopt a more rigorous statistical approach in which target strength is set based on a 90% confidence interval at a 95% probability of passing the specified strength. This significantly increases the margin for smaller series of less than 100 tests.

Some parties would argue that the current approach is unduly conservative and that there is no incentive for improving the quality of testing at concrete plants. Analysis of this issue can support the argument or dispute it based on what testing data is considered and how this is analysed. A simple analysis based on probability can be used to illustrate this point and is shown below and illustrated in general terms in Figure 1:

- Grade 30 MPa concrete has a mean strength of 36 MPa for a test series of 30 test results
- Standard deviation was found to be 3.6 MPa with a coefficient of variation of 10.0%
- Target strength based on simple probability of 95% passing is 36.0 MPa
- Target strength based on 90% confidence of 95% passing is 37.5 MPa.

![Figure 1: Confidence intervals and probability distribution functions used for strength data](image)
While it is possible to suggest that target strength could be lowered when variation in strength data is low (i.e. COV< 10%), higher variability would produce more than 5% risk of failure based on larger test series. Smaller test series of 12 or more results are often reported and confidence intervals can be used to provide a more rational risk assessment of failure in these cases as is applied by AS 1379 and ACI 318.

Strength data collected by the plant audit committee indicates that failure rates for concrete (i.e. strength results less than the grade strength) are below 1.0% rather than nominal 5% assumed based on probability. Several factors may contribute to this lower than assumed failure rate but the most likely factor is that target strengths given in NZS 3104 are seen by plant engineers less as a target but as a limit. This means action is taken before strengths fall below target since penalties can be applied. Typically mean strengths reported for test series are 1-3 MPa above target and this reduces failure from 5% to 1%.

**Testing compressive strength of concrete at 7-days as well as 28-days**

NZS 3104 does not refer to any testing age except 28-days but in practice most concrete supply companies provide an early assessment of strength based on 7-day testing. The plant audit scheme of the Readymix sector of Concrete NZ has revised the plant audit handbook to make 7-day strength testing mandatory for audited plants. It would therefore seem appropriate that the standard be revised accordingly.

Testing at 7-days provides an early assessment of the 28-day strength since this is typically between 70-80% of the strength at 28 days (see Figure 2). The typical strength development of concrete is shown in Figure 2 and shows that 7-day strength is usually close to the grade strength when the 28-day strength is at target levels. Resistance to changing the standard in this regard is mostly to do with logistical issues for smaller concrete plants that need to transport test cylinders to laboratories for testing.

![Figure 2: Typical strength development of 30 MPa concrete using GP cement](image-url)

**Clarification of measurement of within test coefficient of variation (WTCOV)**

Within test coefficient of variation (WTCOV) is measured to assess the reliability of strength data used to calculate the mean strength at 28 days. WTCOV is measured by multiplying the range between strength results (absolute difference between highest and lowest strength) by
the Z-factor (0.89 for two and 0.59 for three cylinders) and dividing by the mean strength. Typically, the difference in strength between 28-day results is less than 2.0 MPa when sampling, compaction, curing and testing are done in accordance with NZS 3112. Currently NZS 3104 clause 2.15.5.2 states that when a test series exceeds 20 and the WTCOV is less than 4.0%, the number of cylinders can be reduced from three to two (see Figure 3). This clause if applied as stated could result in some series using three cylinders and others having two cylinders depending on WTCOV values. In recent years, the application of WTCOV has been based on all test results such that all series are tested using either two or three cylinders depending on within test variability data. This is a more practical approach as within test variations are not intrinsic or materially related but are caused by extrinsic, testing-related factors.

![Two Cylinder Testing](image1)

![Three Cylinder Testing](image2)

**Figure 3**: Within test coefficient of variation versus strength ranges (high minus low strength)

**Clarification of mixer evaluation testing**

Currently NZS 3104 Table 2.7 mentions sample sizes of either 2 or 5 cylinders when checking the performance requirements of uniformity of concrete for stationary and truck mixers. The plant audit committee of PAS has recently decided to revise this to three samples, which would simplify testing and assessment of mixer evaluations. Uniformity testing of central and truck mixers would therefore be simplified both in terms of testing and reporting as the current approach allows a dual approach with either limited test samples with tighter within test controls or more test samples with less within test controls. The criteria for assessing uniformity will remain the same and is shown in Table 1.

<table>
<thead>
<tr>
<th>Test method property</th>
<th>Maximum permissible difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic density of concrete</td>
<td>30 kg/m³</td>
</tr>
<tr>
<td>Slump</td>
<td>30 mm</td>
</tr>
<tr>
<td>Air content</td>
<td>1.0%</td>
</tr>
<tr>
<td>Mean compressive strength at 28 days *</td>
<td>Greater of 10% f, or 3.0 MPa</td>
</tr>
</tbody>
</table>

*Where the number of test specimens to be reported is three
This simplification is procedure would be beneficial as currently there is some uncertainty on whether the mixer evaluation is acceptable. The simplification would also make it easier to assess compliance when entering data into the PAS online database.

**Workability/consistence classes for fresh concrete**

Currently NZS 3104 does not mention slump apart from tolerances for snatch and representative sampling given in Table 2.7. There is sometimes a misunderstanding in structural specifications that NZS 3104 gives recommendations about slump targets as happens in some international concrete standards such as EN 206-1. At the same time, some specifiers have sought to keep slump targets lower than practical to try “improve concrete quality”. It has been suggested that having workability/consistence classes in NZS 3104 may provide better guidance to designers and provide suppliers some flexibility. The comparison in approach is shown in Figure 4.

![Slump tolerances given in NZS 3104 vs BS 8500-1:2006 Slump classes](image)

**Figure 4: Slump tolerances for snatch sampling (NZS 3104) and slump classes (BS 8500)**

Specified slump classes are used in BS 8500 with five broad classes used and defined as S1 to S5 with details shown in Figure 4. This allows a range of values to be selected with the difference between low and high limits typically been from 60-80mm and similar or higher tolerances compared to those used in NZS 3104. The advantage of such an approach is that the concrete can be specified in a broad slump class such as S3 (90-170mm) rather specifying a target slump of 100mm with a tolerance of 30mm. A possible unintended consequence of this approach is that designers who would have previously specified a target slump of 100mm will select slump class S2 with a slump range of 40-110mm. This is the risk of introducing a new approach into the standard and may result if specifiers have a poor understanding of workability of concrete.

**Clarification of other minor matters**

Other matters that will be considered during the review of the concrete production standard include the following:
- Update definitions at the front of the document to include new organisation names
- Revision of the provisions for low volume production plants to better characterise these smaller operations
- Better description of the requirements of independent scale system specialists that are required to check weigh scales every two years
- Better guidance for operators of mobile batching vehicles that provide concrete by continuous batching (reference to ASTM and ACI documents)

None of the above are likely to controversial and in all cases the additional information will provide better guidance to improve performance.

CONCLUSIONS

The above topics represents what the standards committee will discuss and it is unlikely that all of the above will be included after consideration. It is also possible that other matters will be considered in the review. The standards committee for NZS 3104 will have representatives from Concrete NZ, BRANZ, SESOC, readymix concrete companies and consulting engineers to ensure a balanced review. It is hoped that this review will be complete before the end of 2018 so that the revision is ready to be implemented by the start of 2019. The revised standard will attempt to improve productivity of concrete without compromising the quality of concrete supplied in New Zealand.

ACKNOWLEDGEMENTS

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REFERENCES

ACI 318-08, Building code requirement for structural concrete, American Concrete Institute, 2008.