ERMCO Guide to EN206:2013
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1. Introduction

This Guide has been prepared by ERMCO with the prime purpose of providing guidance to its members on the application of EN 206:2013; however, the information provided will be of interest to all users of EN 206. While ERMCO was actively involved in the revision of EN 206, the discussions, compromises and interpretation of particular clauses are known to those on the committees, but not to the wider ERMCO membership and users of EN 206. One objective of this Guide is to make this information more widely known and available to those who in the future will be revising EN 206.

This Guide is aimed at providing background information and guidance on the interpretation and application of selected clause changes to EN 206. In a few cases, it explains how a clause that was not changed should be interpreted.

Since first published in 2000, EN 206-1 [1] has had very few changes and these were mainly corrections, clarifications of the text and updated references to new European standards. This was the deliberate policy of CEN/TC104/SC1: Concrete - Specification, performance, production and conformity, (the European standardization committee responsible for EN 206) as they wanted a period of experience before introducing any significant changes. Consequently at the five-year review in 2005, it was considered that experience with the use of EN 206-1 was still very limited and so it was confirmed for a further five years. At the second five year review in 2010 it was agreed that a revision was now appropriate but the wish was to keep the changes to a minimum.

In 2010 a new Part of EN 206 (Part 9) [2] on self-compacting concrete was published, but prior to its publication CEN/TC104/SC1 had agreed that when EN 206-1 was revised, Part 9 would be combined with Part 1 into a new EN 206.

CEN/TC104/SC1 had also agreed that at sometime after publication of Part 9, the test methods for self-compacting concrete that are used in practice would be reviewed to see if the range of tests standardized at the European level needs extending and whether additional performance classes need to be introduced into a future revision of EN 206. It was felt premature to undertake this review for the 2013 revision of EN 206 and that this is a task to be undertaken before the next five-year review of EN 206. The transferred technical content of what was Part 9 is unchanged in the combined EN 206:2013 [3].

During the CEN edit phase a number of ‘Notes’ were moved from their clauses to a new Annex L: Further information regarding specific paragraphs. The reason given is that according to CEN drafting rules (see CEN/TC104/SC1- N807) ‘Notes’ shall not contain requirements, make recommendations nor give permissions. The alternative was to make these Notes part of the normative text. As this would significantly change their status and be likely to result in a negative vote, this
option was not followed. During the next revision, it would be sensible to consider each of these Notes and decide whether they can be moved to the normative text or left in Annex L.

Where clauses in EN 206 are cited they refer to clauses in EN 206:2013.

2. Scope of EN 206

There is no consensus on the exact scope of EN 206. There is consensus that EN 206 covers concrete for structures designed in accordance with EN 1992-1-1 and structural precast concrete. The lack of consensus is on how far it covers the other extreme of the concrete market, i.e. that for non-structural concrete. It is unrealistic to think that EN 206 (or any other standard) will be used for minor housing works where the concrete is produced on site using a shovel or in a small free-fall mixer.

EN 206 is the only European standard for the production of concrete, and many of its provisions should apply to any concrete production. EN 206, clause 1 (5) and (6) list some of the many applications of EN 206 where additional requirements may be appropriate and these lists could be extended to cover the production of hydraulically-bound materials conforming to EN 14227 [4] and cement-based screed materials conforming to EN 13813 [5].

The unclear ‘grey’ areas with respect to the scope of EN 206 are site-made concretes on small/medium-sized house building sites and non-structural precast products. Even the terms ‘structural’ and ‘non-structural’ are interpreted differently. Is a concrete masonry unit structural or non-structural? Some believe it is structural while others believe it is non-structural.

EN 206 is, and it should remain, the only European standard for the production of concrete. The technical rules for the production of concrete should be the same regardless of whether the concrete is ready-mixed, site-mixed or used in precast elements.

3. Provisions valid in the place of use, ETAs and national technical assessments

3.1 Provisions valid in the place of use

EN 206-1 had many clauses that referred to ‘provisions valid in the place of use’ or some other variation of this phase. The revision of EN 206 has added to the number of such provisions. CEN/TC104/SC1 decided that except where there is a specific need for a different wording, the phrasing ‘provisions valid in the place of use’ would be used consistently. A new Annex M, Guidance on provisions valid in the place of use lists all these provisions/permissions. In some cases it is essential to provide national provisions, e.g. for resistance against damaging ASR, but in other cases
each National Standards Body may just apply the requirement in EN 206 and not specify other requirements, e.g. on batching tolerances. National departures to the standard, other than where stated in Annex M, are not permitted. Aspects not covered by EN 206 may be covered by national provisions, e.g. transport times to site; resistance to alkali-carbonate reaction, provisions for sulfate resistance with mobile ground water.

‘Provisions valid in the place of use’ have been defined in EN 206 as ‘national provisions given in a National Foreword or National Annex to this Standard or in a complementary standard to EN 206 applicable in the place of use of the concrete’. The National Foreword does not have to provide the provisions, it simply has to identify where they are to be found.

3.2 Legal requirements

There are countries in Europe that have requirements for concrete given in regulations and other legal documents. Such regulations and legal requirements have a higher status than a European standard and it is not permitted for a CEN standard to state that you have to comply with the law; that is a given. Consequently the definition of ‘provisions valid in the place of use’ does not refer to regulations and legal requirements, but a producer is required to comply with them if they apply where the concrete is being placed on the market.

3.3 European and national technical assessments

Other omissions from the list of provisions valid in the place of use are European Technical Assessments (ETA) under the Construction Products Regulation [6] (formerly called European Technical Approvals under the Construction Products Directive) and national technical approvals/assessments. Within the European Union, an ETA has an equal status to a harmonised European standard; they are both European technical specifications that can support CE-marking of a construction product.

EN 206 requires constituents to have established suitability, and established suitability may come from conformity to a standard cited in EN 206, or from provisions valid in the place of use, or from an ETA or national technical approval that specifically refers to EN 206. The main difference is that an ETA is applicable anywhere in the European Union, and a national technical approval (NTA) is valid only in the country where it was developed and in other countries that have mutual recognition of national technical approvals. ETAs cover innovative products made by specific manufacturers outside the scope of standards. In the view of the European commission, ETAs have the same status as a European standard and they are used as the technical basis for CE-marking.

To be of any value, a technical approval, either an ETA or NTA, has to cover both requirements for the product and rules for use. Without rules for use within the technical approval there would be a
delay of several, if not many, years before the rules of use were provided in EN 206 or provisions valid in the place of use, and it is not the task of CEN or a National Standards Body to provide rules of use for a specific manufacturer’s product; concrete standards provide rules of use for generic constituents. There is, however, a problem.

Part of any assessment of a ‘Product’ under an ETA is the impact on durability. EN 206 is not a harmonised standard, and the durability requirements are given in the provisions valid in the place of use, which differ from country to country. EN 206, clause 5.1.1 (2) NOTE 2 draws attention to this difficulty.

While it is relatively easy to establish general suitability of a constituent, this only means it is suitable for some concretes within the scope of EN 206; however, in practice, without specific suitability being established the product will not get used. A pragmatic solution to this issue is for the manufacturer to select the countries in which specific suitability is to be established, and as part of the technical assessment the national requirements there are taken into account by the Body issuing the ETA/NTA when determining specific suitability. For example with carbonation resistance, it is necessary to show that the ‘Product’ when used in concrete in a defined way gives rates of carbonation that fall within the envelope of concretes currently accepted. These envelopes of currently accepted performance are not the same in all EU members and consequently declarations of specific suitability may be qualified as applying in certain EU members only.

Concrete conforming to EN 206 may contain a constituent that is covered by an ETA or NTA and which is used in accordance with the rules of application given in the ETA/NTA, but this needs to be declared in the documentation, e.g. the concrete conforms to (NSB) EN 206 with constituent (xx) conforming to and used in accordance with ETA xxx. To be transparent, the planned use of a constituent conforming to an ETA/NTA should be made clear at the time of tender for the supply of concrete.

NOTE: Some CEN/TC104/SCI delegations wanted to limit ETA to the specification of the product and to use ‘provisions valid in the place of use’ to determine the rules of application. This approach is unacceptable to the European Commission and EOTA as it effectively stops or delays by years the use of constituents conforming to ETAs. The approach of determining specific suitability described above provides a fair balance between protecting the users of concrete and permitting innovation.

Each item in Annex M needs to be considered by the National Standards Body when drafting provisions valid in the place of use. For some items it is essential to provide national provisions, e.g. resistance to damaging alkali-silica reaction, while other options may only be taken up by one CEN Member State.
4. Aggregate size (Definitions of $D_{\text{upper}}$, $D_{\text{lower}}$ and $D_{\text{max}}$)

In the past life was relatively simple, the specifier specified the maximum aggregate size and, with rare exceptions, the concrete contained this size of aggregate. As the maximum aggregate size reduces, the paste volume increases, so it is generally in the producer’s interest to supply concrete with the maximum aggregate size specified. Nevertheless it is now common to supply concrete with a lower aggregate size than the maximum specified, particularly if it is self-compacting concrete, and such concretes may not provide adequate aggregate interlock to fulfil the design assumption with respect to shear resistance. This issue is addressed by revising and adding definitions of aggregate size.

The maximum aggregate size is controlled by the spacing between the reinforcement and the minimum section width. Depending on where you are in Europe, maximum aggregate sizes of 32mm or 22 to 20mm are typical. This is what is known as ‘dg’ in Eurocode EN 1992-1-1 [7], and in EN 206 is called ‘$D_{\text{upper}}$’, defined as ‘largest value of $D$ for the coarsest fraction of aggregates in the concrete permitted by the specification of concrete’, where $D$ is the upper sieve size.

In EN 1992-1-1, the shear model for normal-weight aggregates relies upon aggregate interlock and this is a function of aggregate size and aggregate strength. Even when shear links for reinforcement are provided, the model assumes that about 20% of the shear force is taken by aggregate interlock. Consequently EN 206 also requires the specification of ‘$D_{\text{lower}}$’, defined in EN 206 as ‘smallest value of $D$ for the coarsest fraction of aggregates in the concrete permitted by the specification of concrete’. At present there is no guidance in EN 1992-1-1 on what value ‘$D_{\text{lower}}$’ should be given.

There appears to be agreement that a value of ‘$D_{\text{lower}}$’ of 16mm will ensure aggregate interlock provided the aggregate is sufficiently strong as not to crush at the contact points; however, specifying such a value as $D_{\text{lower}}$ may cause considerable difficulties when supplying self-compacting concrete as it is frequently supplied with a $D_{\text{max}}$ of 8mm or 10mm. The effectiveness of these sizes in achieving the necessary aggregate interlock is still an open question. This is a topic that needs further research to justify any limitations on aggregate size or aggregate strength.

The shear rules for lightweight aggregate concrete take no account of aggregate interlock. The producer is free to select for the concrete $D_{\text{upper}}$, $D_{\text{lower}}$ or any size in between and declare this size on the delivery ticket as $D_{\text{max}}$ defined in EN 206 as ‘declared value of $D$ of the coarsest fraction of aggregates actually used in the concrete’. The terms $D_{\text{upper}}$ and $D_{\text{lower}}$ are for the sole use of the specifier and the term $D_{\text{max}}$ is for the sole use of the producer. If, as is likely in the short term after the adoption of EN 206 specifications continue to specify only ‘$D_{\text{max}}$’, this should be taken as meaning
‘$D_{upper}$’ and that the specifier has not specified a value for $D_{lower}$. The producer should declare $D_{max}$ as required by EN 206. An example is given in Figure 1.

EN 12620 [8] permits a proportion of oversize material of between 10% to 20% and therefore it should be expected and accepted that there will be aggregate particles in the concrete that are greater in size than the producer’s declared $D_{max}$.

Conformity to $D_{max}$ is based on production records showing that an aggregate defined as $d/D_{max}$ is included in the constituents being batched for the concrete. A procedure for identity testing is not defined nor is it normally necessary. In the rare situation where the user wants to undertake identity testing, any procedure should be based on wet sieving and take account of the permitted quantity of over-size.

![Figure 1: Example of relationships between different definitions of aggregate size](image)

5. Aggregate clauses
In 2012 a revision of EN 12620 was sent for voting by the Unique Acceptance Procedure (UAP) and it received a positive vote. A number of changes were made post the vote some of which were technical changes. This standard was published in May 2013. However, problems with some of the other aggregate standards led CEN to review all the published aggregate standards and it concluded that the published standards should be corrected back to the approved UAP versions with only editorial changes. If this were to be the case with EN 12620, technical errors would be introduced, as some of the technical changes were to correct errors. On reflection CEN has decided to withdraw the May 2013 version of EN 12620.
Due to these issues, the Commission has not cited the 2013 version of EN 12620 in the Official Journal and consequently CE-marking of aggregates continues to be based on the 2002 version of EN 12620, inclusive of the amendments to this version of the standard (2008). This will remain the situation until the Construction Products Regulation (CPR) compliant version of EN 12620 is published, probably in early 2015. Any concrete producer that is required to use CE-marked aggregates has to use the 2008 version of EN 12620 until the new version is published and cited in the Official Journal.

One of the difficulties in preparing EN 206 was that the revision of the aggregate standards was being undertaken at the same time. A concern was that the ‘aggregates for concrete’ standard includes an enlarged range of materials, where any level or set of characteristics may or may not be declared, and that these would be an aggregate conforming to EN 12620 [8]. But, such a declared category may not be suitable for use in any type of concrete in accordance with EN 206. The reason for this is that CEN/TC154 (the European committee responsible for standards for aggregates) wanted a single standard for aggregates for any/all uses. As this was not acceptable to CEN it was decided to adopt a base text to cover all aggregates, and for each application (e.g. concrete) identify in grey those classes deemed inappropriate. From the specifiers viewpoint it is somewhat confusing where a standard called ‘Aggregates for concrete’ contains categories that are not suitable for concrete. However, as this version of the standard has been withdrawn, this is no longer an issue.

But knowledgeable specifiers who look at the existing version of EN 12620 will recognise that this standard covers aggregates for use in all concretes and for their specific situation it may not be enough to specify ‘aggregates shall conform to EN 12620’ and they will want to introduce into their specifications restrictions on the categories and materials that may be used in their concrete. As these will vary from specifier to specifier, this is an administrative and logistical problem for concrete producers particularly if the specifier always wants what they consider ‘the best’. To avoid such confusion, the provisions in the place of use should define the aggregate categories that are suitable for normal reinforced and prestressed construction.

A new Annex E provides guidance on suitable categories for natural aggregates, air-cooled blastfurnace slag aggregates, lightweight aggregates and coarse recycled aggregates. It also contains recommendations for the use of recycled aggregates in concrete.

6. Use of more than one cement in a concrete

EN 206, clause 5.2.2 Selection of cement was not changed, but some guidance on its application is appropriate. It starts with the words ‘Cement shall be selected .....’. In English this may be taken to
mean a single cement or more than one cement. When translated into some other languages, e.g. French, it is only singular; ‘a cement shall be selected ....’. During the public comment stage there were requests to clarify that a concrete may contain more than one cement. It was quickly established that mixing cements in the same concrete is practised in many CEN Members States. The combination of cements that may be included in a concrete varies and it was clear that simply permitting the procedure without controls on unwanted outcomes is not technically sound. At this late stage in the revision of EN 206, there was not time to establish what should be permitted and what should not be permitted, and to find a compromise that was likely to get a positive vote.

Consequently the text at the start of EN 206, 5.2.2 is unchanged, but it is accepted by CEN/TC104/SC1 that concrete conforming to EN 206 may contain more than one cement provided this combination of cements conforms to provisions valid in the place of use.

Combining two cements in one concrete is not a variation of the equivalent performance of combinations concept where, now, two cements are used instead of a cement and an addition, as there is no additional testing of the concrete or of the combination of the two cements. The delivery ticket and other documentation must be transparent and report the relative proportions of the two cements, e.g. 40% CEM I and 60% CEM III/B.

7. Use of additions

Some of the most significant changes between EN 206-1:2010 and EN 206 are in the provisions for the use of additions. The main changes are:

- the k-value concept has been defined;
- the k-value concept has been extended to cover the use of ggbs;
- rules of application for the k-value concept have been extended from CEM I to include the use with CEM II/A cements;
- the principles for two performance approaches to the use of additions have been included.

The performance concepts and how they are being applied in practice is described in CEN/TR 16563 [10]. The impacts of these changes are described in the following sections.

7.1 The k-value concept in EN206

The k-value is specified for durability only and it has nothing to do with achieving the specified strength of the concrete, as this is dealt with directly via the compressive strength requirement.
The k-value concept as described in EN 206 is based on attempting to reproduce the durability performance of a concrete containing only a nominated ‘Cement A’, which is normally a CEM I cement. Such an approach does not reflect the fact that most national specifications permit a wide range of cement types, all with the same requirements for maximum w/c ratio and minimum cement content [9]. Nowadays, in practice, specifiers will expect a concrete containing an addition (fly ash or ggbs) to perform similarly in durability terms to one containing a cement incorporating that same material (fly ash or ggbs), and not to one containing only ‘Cement A’.

It has to be recognised that using an addition will enhance some aspects of the durability performance of ‘Cement A’ but reduce others. This relative performance is taken into account in the given rule of application for silica fume (clause 5.2.5.2.3), but not for the other additions.

The given principle for the k-value concept is logical if the provisions valid in the place of use permitted only ‘Cement A’ within a given set of limiting values; however, CEN Technical Report 15868 [9] shows that CEN Member States usually permit a wide range of cement types within that same range of limiting values. A consequence of this approach is best illustrated by an example. In exposure class XS3 a typical requirement is a maximum w/c ratio of 0.45 and a minimum cement content of 340 kg/m³. Assume admixtures are used and the required consistence is obtained at these limiting values.

With CEM I, the resulting free water content is 153 litres (0.45 x 340). If it is decided to improve the chloride resistance by replacing CEM I with 50% ggbs at the mixer, under the k-value concept and using the recommended k-value of 0.6, the binder content becomes:

\[
0.45 = \frac{153}{(\text{mass cement} + 0.6 \text{ mass ggbs})}
\]

\[
\text{mass CEM I} + 0.6 \text{ mass ggbs} = 340 \text{ kg/m}^3
\]

At 50% ggbs, the masses of cement and ggbs are the same so the mix will contain 212.5 kg of CEM I (340/1.6) and 212.5 kg of ggbs giving a total binder content of 425 kg/m³, which is an increase of 85 kg/m³. If instead of adding ggbs at the mixer CEM III/A cement is used (the same binder constituents), the limiting values revert to 0.45 and 340.

This is a consequence of the application of the k-value concept with a k-value of 0.6 for ggbs. The increased risk of early-age thermal cracking in large sections and cost means that k-value concept with a value of 0.6 for ggbs is unlikely to be used in practice.

There is a further complication for the few CEN Member States that vary the limiting values depending upon the cement type. They need to define whether the limiting values for ‘Cement A’ apply, or some other limiting values. The recommendation in CEN/TR 16563 [10] is when part of
Cement “A” is replaced by an addition, the limiting values that have to be applied are those that would apply for Cement “A”. Such an approach attributes no benefit to using additions over that of ‘Cement A’.

7.2 Other k-value concepts

EN 206 does not describe principles for other k-value concepts. Currently Austria and Finland both use a k-value concept based on the similarity in performance to concrete with an addition to that of concrete with cement that includes as a main constituent the same addition.

It is a moot point as to whether other k-value concepts are permitted within the scope of EN 206. Clause 5.2.5.1 (4) permits the use of different rules of application, but not different k-value concepts (i.e. different principles). As some of these other k-value concepts have a solid technical basis, National Standards Bodies (NSB) that use such a k-value concept should be encouraged to continue with their use within its provisions valid in the place of use. A NSB is permitted in 5.2.5.1 (4) to define k-values other than the values given for fly ash and silica fume, or recommended for ggbs, and it is unlikely that their choice of k-values will be questioned by the European Standardization Committee CEN/TC104/SC1 even if their choice of k-values is based on a different k-value concept.

7.3 Application of the performance concepts

The principles of the performance approach to the use of additions have been introduced into EN 206, but not the rules of application. Further guidance on the use of these concepts and examples of current practice are given in CEN/TR 16563 [10]. Some rules of application had been proposed to CEN/TC104/SC1/TG5: Use of additions but these were not accepted. The requirements for the use of equivalent performance concepts are set out in EN 206, clause 5.2.5.1 (5) and this is ‘where suitability has been established’. This is followed by a NOTE referring to Annex L which recommends that suitability should be established from provisions valid in the place of use.

While using provisions valid in the place of use is likely to be the most common way of establishing suitability, it is not the only way. For example, an ETA for a product may also establish specific suitability (see Section 3). It can also be argued that a rule of application that has been standardized in another CEN Member and has a proven track record of use in practice, already has ‘established suitability’. Consequently rather than invent new rules of application, a National Standards Body or a concrete producer could simply adopt one or more of the current rules of application. While a National Standards Body has the freedom to modify an existing rule of application to create a new rule of application, a concrete producer does not have this freedom, nor the freedom to use a mix of current rules of application as such ‘hybrids’ do not have established suitability. If an existing rule of application is adopted by a concrete producer as the means showing ‘establishing suitability’, it has to be taken in full, including any requirements for certification.
The principles for the performance concepts set out in EN 206 encompass the existing rules of application (as the principles in EN 206 were specifically drafted with the objective of including the existing rules of application) and these rules of application may continue to be used without modification. CEN/TR 16563 [10] provides details of these rules of application.

There are two different performance concepts.

7.3.1 Equivalent concrete performance concept
The Equivalent Concrete Performance Concept (ECPC) (EN 206, clause 5.2.5.3) requires the rule of application to include durability testing of the candidate concrete and the reference concrete to determine equivalence. With the ECPC the limiting proportions, e.g. maximum w/c ratio, may vary if justified by the testing. The Netherlands is the only country with a well-developed and used ECPC.

7.3.2 Equivalent performance of combinations concept
The philosophy behind the EPCC is the acceptance that any concrete made with cement conforming to a cement standard, and fulfilling the durability requirements given in the provisions valid in the place of use will have adequate durability. If the criteria for a combination fulfil similar requirements, the resulting concrete will also have adequate durability if it fulfils the equivalent criteria for the concrete given in the provisions valid in the place of use for the identified cement type., i.e. maximum W/C ratio becomes maximum W/(C + A) ratio, and minimum cement content becomes minimum (C + A) content where ‘C’ is cement and ‘A’ is addition. In this case the reference is not a specific source of cement, but a set of criteria that are similar to those used to define a cement.

The rules of application for the Equivalent Performance of Combinations Concept (EPCC) (EN 206, clause 5.2.5.4), on the other hand, require the combination of cement and addition to achieve given criteria and the concrete to achieve specified strength requirements. Please note that this combination of cement and addition does not exist as a separate product and is not ‘cement’, as cement conforming to its European standard is a product that is placed on the market. The components of a combination - the cement and addition - are products that are placed separately on the market, and covered by CE-marking; but the combination of these materials is not a product as defined by the Construction Products Regulation. The application of the EPCC does not permit the limiting values given in provisions valid in the place of use to be varied.

7.3.3 New rules of application
If a National Standard Body wishes to develop its own rules of application, it would be sensible to base these on one of the existing procedures, as these have a well-proven track record of working in practice. CEN/TR 16563 [10] provides some more detailed information on the national approaches.
countries, Ireland, Portugal and the United Kingdom, have different rules of application for the EPCC. The rule of application used in the UK has been incorporated in British standards for over 30 years and it has widespread use within the UK and a very successful track record. The more recent rules of application used in Ireland and Portugal have developed further than this original rule of application and both rules of application have successful track records.

8. Mix adjustments after the main mixing process

EN 206, clause 7.5 permits in special cases, admixtures, pigments, fibres or water to be added where:
— this is under the responsibility of the producer;
— the consistence and the limiting values of the concrete continue to conform to the specified values;
— there is a procedure for undertaking this process in a safe manner documented within the factory production control; and
— if water is added, a conformity control has to be carried out on a sample of the final product.

In all cases the quantity of admixture, pigment, fibres or water added at the truck mixer has to be recorded on the delivery ticket. What comprises the ‘conformity control’ after the re-mixing is not defined. A consistence test to show that the batch is within specification may be considered as appropriate.

These provisions recognise that under these controlled conditions it is not bad practice to add water on site. Where there are very tight tolerances on consistence and the time to travel to site is variable, e.g. due to varying traffic, such a procedure is essential in achieving the required performance at delivery.

The aim of the documented procedure is to freely permit:

● effective water held back from the main mixing process to be added at site;

● batches that are below the lower limit of the consistence class/value to be brought into specification provided this low consistence is not the result of excessive delays on site or during transport to site;

● the replacement of water absorbed by the aggregate or lost by evaporation up to the time when the cement/combination starts to set.

By limiting the procedure to adjustments within the agreed waiting time that restore the specified slump class, the producer remains fully responsible for the concrete achieving the specified compressive strength class and the maximum w/c ratio.

Any procedure should comprise the following elements:
- procedure for safe access to the mixer to add water or admixture;
- a clear written statement of the permitted maximum addition of water or admixture to respect the specified maximum w/c ratio;
- proven compatibility of any admixture added to the concrete;
- a clear written statement of the maximum time after the cement is first added to the aggregates for adjusting the consistence (or, if the aggregates are dry, the maximum time after water is added to the cement);
- a clear written statement of the minimum time for re-mixing;
- a clear written statement of target consistence after re-mixing;
- a clear written statement of maximum consistence after re-mixing.

Delays on site do occur and contractors may wish to use the procedure described above to cover delays that were caused by their actions. As the procedure requires the producer to remain responsible for the quality of the concrete, and as there may be contractual issues, e.g. additional charges for vehicles held on site, the use of this procedure for this purpose can only be by agreement.

EN 206, clause 7.5 does not permit the addition of fibres under the responsibility of the user. All the above relates only to fibres added by concrete producers under their responsibility. Where the user has fibre added at site under his responsibility, the concrete producer is responsible for the quality of the concrete prior to the addition of fibres. Some concrete producers do not permit the user to add fibres on site for health and safety reasons. Where fibres, or any other constituent, are added under the responsibility of the user, the specifier should require routine identity testing of the concrete as the producer will establish conformity of the concrete prior to the site addition of a constituent under the responsibility of the user. It is recommended that the concrete producer undertakes conformity testing of the batches subjected to identity testing prior to the addition of fibre on site so that in the case of dispute over the quality, proper responsibility can be assigned.

If admixtures, pigments, fibres or water are added to the concrete in a truck mixer on site without approval/supervision of the producer’s quality management personnel the concrete batch or load is “non-conforming” and the customer is responsible for the consequences. If more water is added than is permitted by the adjustment on site procedure, the load is “non-conforming”. Whilst the addition of water under the instruction of the specifier may be regarded as a change to the specification, it is often the cause of concrete with sub-standard performance and consequential claims and it is not permitted by EN206.
9. Conformity and production control

9.1 Conformity of consistence

The ERMCO position is that a batch of concrete is accepted or rejected with respect to its consistence at the time of delivery, and therefore all that is required are the simple limits for classes or tolerances on a target value. In EN 206-1:2000 there were class limits given in Tables 3 to 6 and further deviations on these class limits given in Table 18. The complexity of this approach frequently led to discussions over what was permitted by EN 206-1. CEN/TC104/SC1 did not accept the proposal to combine these values into single limits as this was likely to be regarded as changing the class limits and so the class limits and deviations on the class limits have been kept separate.

9.1.1 Tolerances of consistence specified by class

The class limits are unchanged, but there have been some changes to the permitted deviations on the class limits (EN 206, Table 21: Conformity assessment for consistence classes, SCC properties, air content and homogeneity of fibre distribution of fresh concrete at the point of delivery). The upper limits for the slump and degree of compactability classes have been reduced; and with the flow classes both the lower and upper limits have been reduced. This reduction in the combined limits has to be set against the fact that these now apply to every batch. Previously only 15% of the results could be outside the class limits. There are no deviations permitted on the slump-flow class limits. Table 1 summarizes the conformity limits for consistence specified by class and taken from the initial discharge.

9.1.2 Tolerances on consistence specified by target value

The more significant changes to the tolerances on consistence are those that apply when consistence is specified by a target value. A view was expressed that target values were specified in special cases and where a tighter tolerance is needed. It was, and still is, permitted to specify tighter tolerances than those given in EN 206 for these very special cases and it is up to the producer to decide if they can accept a contract with such limits. Nevertheless EN 206 now has tolerances on target values (EN 206, Table 23) that are tighter than those on class limits.

While some of the tolerances given in EN 206, Table 23: Conformity criteria for target values of consistence and viscosity, are different to those that were given in EN 206-1:2000, Table 11, the main difference is that deviation on these tolerances is no longer permitted. The net result is that some of the tolerances on target values are smaller than the precision obtainable with the test procedure!

Example: Flow table test. For a target flow value of 555mm the flow table test (EN 12350-5) gives a repeatability (r) value of 69mm and a reproducibility (R) value of 91mm. This compares with a tolerance of ± 40mm in EN 206, Table 23 and ± 30mm in EN 206, D.3.4 (3). Clearly such tolerances...
are not achievable in normal production. EN 206, Table 23 and clause D.3.4 (3) do not state whether these tolerances apply to a representative sample or to a spot sample taken from the initial discharge. The provisions valid in the place of use should clarify whether these tolerances apply to representative samples and if so, define the additional deviations that are permitted when the test is based on a spot sample taken from the initial discharge.

EN 206, Table 23 permits provisions valid in the place of use to define different tolerances. Consideration should be given to using this permission to increase the tolerances on the flow table test to values that reflect the precision of the test.
**Table 1: Limits on consistence classes based on testing a spot sample taken from the initial discharge**

<table>
<thead>
<tr>
<th>Consistence class&lt;sup&gt;a)&lt;/sup&gt;</th>
<th>Conformity criteria based on testing the initial discharge (former EN 206-1:2000 limits shown in brackets)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower limit</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Slump classes tested in accordance with EN 12350-2</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Slump class S1</td>
<td>0 mm (0)</td>
</tr>
<tr>
<td>Slump class S2</td>
<td>30 mm (30)</td>
</tr>
<tr>
<td>Slump class S3</td>
<td>80 mm (80)</td>
</tr>
<tr>
<td>Slump class S4</td>
<td>140 mm (140)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Slump-flow classes tested in accordance with EN 12350-8</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Slump-flow class SF1</td>
<td>550 mm (550)</td>
</tr>
<tr>
<td>Slump-flow class SF2</td>
<td>660 mm (660)</td>
</tr>
<tr>
<td>Slump-flow class SF3</td>
<td>760 mm (760)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Flow table classes tested in accordance with EN 12350-5</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow class F2</td>
<td>330 mm (320)</td>
</tr>
<tr>
<td>Flow class F3</td>
<td>400 mm (390)</td>
</tr>
<tr>
<td>Flow class F4</td>
<td>470 mm (460)</td>
</tr>
<tr>
<td>Flow class F5</td>
<td>540 mm (530)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Compaction classes tested in accordance with EN 12350-4</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Compaction class C1</td>
<td>1.22 (1.21)</td>
</tr>
<tr>
<td>Compaction class C2</td>
<td>1.07 (1.06)</td>
</tr>
<tr>
<td>Compaction class C3</td>
<td>1.00 (0.99)</td>
</tr>
<tr>
<td>Compaction class C4&lt;sup&gt;b)&lt;/sup&gt;</td>
<td>&lt; 1.00 (&lt; 0.99)</td>
</tr>
</tbody>
</table>

<sup>a)</sup> Classes outside the recommended range for the test (see EN 206, 5.4.1) are not given.

<sup>b)</sup> Only applies to lightweight concrete.

**9.2 Production day**

The term ‘production day’ is used in EN 206, Table 17: Minimum rate of sampling for assessing conformity. It was not possible to agree a definition of production day. While there was some consensus within the ERMCO membership, there was insufficient consensus within CEN/TC104/SC1 to include a definition. Part of the problem is that EN 206 covers such a wide range of types of production facilities. What is possible on a large site with its own full-time technician is not possible where one technician is serving several ready-mixed concrete plants.
Provisions valid in the place of use should define the meaning of ‘production day’. ERMCO recommend that the following definition be adopted:

‘Day on which 25 m$^3$ or more from a concrete family, and/or designed concrete outside the family, has been produced. Where the production on single days has been less than 25 m$^3$, a production day is:

- either, the day within a period in which a cumulative 25 m$^3$ or more from a concrete family, and/or designed concrete outside the family, has been produced since the last production day or since the commencement of production;

or if it is shorter in time,

- where the total production of a family or designed concrete over a 30 day period has been less than 25 m$^3$, the day on which this family or designed concrete is next produced.’

9.3 Confirmation criterion for family members

With both Method B and Method C for verifying conformity, the relationship between family members has to be established during the initial testing of the concrete family.

EN 206, Table 18: Confirmation criterion for family members, has been extended to cover a higher number of test results for a single concrete within a family. If there are 15 or more test results for a family member, the membership of the family has to be checked by applying the mean strength conformity criterion for an individual concrete ($f_{cm} \geq f_{ck} + 1,48\sigma$). The problem is when you operate a concrete family the known estimated standard deviation is that of the family, which is usually higher than that for the single concrete being checked by applying the criterion in EN 206, Table 18. The value of ‘$\sigma$’ being referred to in EN 206, Table 18 is that of the individual concrete. It was agreed by CEN/TC104/SC1 that it is permissible to use either the estimated standard deviation of the family, or to estimate the standard deviation of this individual concrete as being that of the sample standard deviation, $s_n$ based on the 15 or more results.

The application of the criterion for membership of a concrete family is only applicable when Method B is used to verify conformity. When Method C is applied, incorrect relationships between family members will be shown by the production being out of control and large standard deviations.

9.4 Method C

One of the most significant changes to EN 206 is the introduction of the use of control charts as an alternative method of assessment of conformity, ‘Method C’. CUSUM charts have been used successfully in ready-mixed concrete production and Shewhart charts in the precast industry for over thirty years. The Construction Products Regulation requires product standards to have a procedure for
the assessment and verification of the constancy of performance (AVCP) and Method C is a better way of achieving the control of concrete. Control charts detect real changes from the normal variability in time for the producer to make small changes to the mix proportions long before the concrete is non-conforming with respect to mean strength. When the control system is set up and operated correctly, there is an almost non-existent risk of the concrete not achieving conformity of mean strength and with CUSUM the risk of non-conformity of individual batches is limited to loads that are about three standard deviations below the mean value.

EN 206, clause 8.3 sets out the principles that have to be applied when using this method of conformity and EN 206, Annex H sets out some rules of application. The CUSUM rule of application is based on the UK procedure that has been in use in ready-mixed concrete production for over thirty years. Provisions valid in the place of use are permitted to provide additional rules of application, but these rules have to fulfil the principles set out in EN 206, clause 8.3. Any producer is free to use the rules of application given in EN 206, Annex H or the rule of application given in the national provision.

The use of Method C is based on the concept that the producer may make small changes to the mix proportions should the control system indicate that the target values are not being achieved. The specification of a designed concrete requires the specification of the compressive strength class and limiting mix proportions, e.g. maximum w/c ratio and minimum cement content. Therefore there should be no barrier to a producer making such changes provided the changed concrete mix proportions still conforms to the specified requirements. ERMCO is aware of local specifications that do not permit the mix proportions to be changed once agreed. Such a procedure stops or, at the very least, delays taking timely action to prevent non-conformity of compressive strength.

The use of Method C will be new to many and (the same) guidance on use is provided by ERMCO [11] and by CEN [12]. Over time the benefits of using Method C to both users of concrete and producers of concrete will be appreciated. Non-conformity of concrete is not in the interest of users or producers (perhaps testing companies benefit!). Controlling the production of concrete to ensure conformity of mean strength should be the objective of every concrete producer and EN 206 now provides the tools by which this can be achieved.

**9.5 Conformity of fibre concrete including specification by performance**

Another change to EN 206 is the introduction of conformity criteria for fibre concrete where the type and content of fibres are specified. When fibre concrete is specified in this way the minimum content of fibre is specified. Most batches are required to have at least this minimum value but a limited number of results are permitted to have up to and including 5% fewer steel fibres, and up to and
including 10% fewer polymer fibres (see EN 206, Table 22: Conformity assessment for fibre content, density, maximum water/cement ratio and minimum cement content). Any batch with a lower quantity of fibre is non-conforming. The number of batches that are permitted to be below the specified minimum but within the permitted deviation is given in EN 206, Table 24: Acceptance numbers for conformity criteria given in Table 22. As with EN 206-1 when this approach was applied to consistence, it is unlikely that a producer will declare non-conformity for all the supplied concrete if the number of batches exceeds that given by the acceptance number. In these circumstances what the producer should be expected to do is increase the target fibre content so that future production meets the acceptance number.

Table 22 refers to clause 5.4.4, which states that assessment is on the basis of production records, and by implication, not on any required test.

EN 206, Table 21: Conformity assessment for consistence classes, SCC properties, air content and homogeneity of fibre distribution of fresh concrete at the point of delivery, also has a requirement for the homogeneity of mixing, but only when mixing of the fibres is in the truck. When fibres are added in a central mixer, the initial testing is enough to prove that the mixing process achieves homogeneity of mixing, and further testing of homogeneity is not required.

EN 206 makes reference to performance classes of fibre reinforced concrete, but it does not define these classes or the associated test methods. It simply says that in the case of performance classes, the classes, the test methods and the conformity criteria shall be specified.

The revision of Eurocode 2 [7], which has recently started, intends to include provisions for the design of fibre concrete where the fibres are acting structurally. It is likely that this will lead to the definition of performance classes for fibre concrete. As soon as the direction in which they are going is fixed, CEN/TC104/SC1 needs to be informed so that they can standardize test methods and develop conformity criteria for these performance classes.

9.6 Batching tolerances

EN 206, clause 9.7 gives the batching tolerances for batches of 1 m$^3$ or more. A change has been introduced to permit provisions valid in the place of use to replace the tolerances given in EN 206, Table 27. It should be noted that any changes to the batching tolerances in the production control do not over-ride the conformity requirements for minimum cement content and maximum w/c ratio.

There are no requirements for batching less than 1 m$^3$ and the provisions valid in the place of use should introduce requirements. If the provisions valid in the place of use do not introduce requirements, concrete producers are free to apply whatever tolerances they wish. An alternative to
introducing tolerances for small batches is to introduce a minimum load size as a proportion of the mixer capacity.

**Table 2: Tolerances for the batching process of constituents**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Tolerance per load&lt;sup&gt;b)&lt;/sup&gt;, whichever is the greater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement &amp; additions used at &gt; 5% by mass of cement</td>
<td>± 3% or (−5 kg + 20 kg)</td>
</tr>
<tr>
<td>Total aggregates</td>
<td>± 3% or (±50 kg)</td>
</tr>
<tr>
<td>Water and additions in the form of a slurry</td>
<td>± 3% or (−5 kg + 3 kg)</td>
</tr>
<tr>
<td>Admixtures and additions used at ≤ 5% by mass of cement</td>
<td>± 5% or ±0.01 kg</td>
</tr>
<tr>
<td>Metallic fibre</td>
<td>± 3% or ±1 kg</td>
</tr>
<tr>
<td>Polymer fibres</td>
<td>± 5% or ±0.5 kg</td>
</tr>
</tbody>
</table>

<sup>a)</sup> The minimum load size shall be 0.5 m<sup>3</sup>.<br>
<sup>b)</sup> By applying these tolerances to the load, the producer can correct batching errors when the load comprises more than one batch.

The proposals given in Table 2, which is a compromise between existing national requirements, are recommended if tolerances are to be applied. Table 2 adopts the percentage limits in EN 206, Table 27 and adds numerical limits to cover small loads. A minimum load size of 0.5 cubic metres is also introduced. The technical justification for these tolerances is given in Annex A.

The alternative to Table 2 would be to have a minimum batch size as a proportion of the mixer capacity, say 50%. The simplicity of this approach has merit and it is applicable to mixers of all sizes.

### 10. Identity testing

The range of identity tests given in EN 206, Annex B has been extended from that given in EN 206-1 to reflect practice in many places.

**Consistence and air content:** Identity test criteria are provided for with the same limits as for conformity testing.

**Viscosity, passing ability and segregation resistance:** It was also intended to include identity testing for these properties, but requirements did not appear in the published draft. Where identity testing is undertaken for viscosity, passing ability and segregation resistance specified by a class, the limits given in EN 206, Tables 7 to 11 apply. No deviation is permitted on these tolerances (see EN 206, Table 21: *Conformity assessment for consistence classes, SCC properties, air content and homogeneity of fibre distribution of fresh concrete at the point of delivery*. If viscosity is specified as a
target value, the tolerances in EN 206, Table 23: Conformity criteria for target values of consistence and viscosity, apply, but note the issue of whether these tolerances apply to a representative sample or spot sample is also relevant (see 9.1.2 of this Guide).

Homogeneity of fibre concrete: Another introduction is identity testing criteria for the homogeneity of fibre concrete. This test is intended mainly for fibre concrete that has been truck mixed. European test procedures are available for steel-fibre concrete and class II polymer-fibre concrete, but there is no European test for class 1a and 1b polymer-fibre concrete. A review of existing test methods by CEN/TC104/SC1/TG8 indicated that there is little chance of reaching agreement in the near future on a European procedure that is suitable for fresh concrete. With such fibre types, the problem of specifying the method to apply has been passed to ‘provisions valid in the place of use’.

11. Annex D
Annex D on additional requirements for concrete to be used in certain geotechnical applications (bored piles, diaphragm walls, cast-in-place displacement piles and micro piles) is completely new. The objective was to take existing requirements for concrete from standards under CEN/TC288 and have them included in EN 206. The requirements may seem very conservative, but these elements are underground and cannot be easily inspected. This Annex is also different in that it is, and will remain, a joint text from CEN/TC104 and CEN/TC288.

Most of the clauses in this Annex contain requirements/information on what needs to be specified to the concrete producer under clause 6 of EN 206.

11.1 Cement types
EN 206, clause D.2.1 list cements that have established suitability for use in the geotechnical applications covered by Annex D. In the provisions valid in the place of use, this list may be supplemented by additional cements that have established suitability for these applications. If the specification does not list specific cement types, and it should not unless this is absolutely essential, the concrete producer is free to select any of the cements listed in EN 206, D.2.1 or the provisions valid in the place of use provided they also are permitted in the provisions valid in the place of use for the specified exposure classes. For example in exposure class XA3, the cements have to be sulfate-resisting and this requirement means that some of the cement listed in EN 206, D.2.1 would not conform to the specified requirements.

11.2 Aggregates
As with all concrete, both a $D_{upper}$ and $D_{lower}$ have to be specified and EN 206, D.2.2 contains requirements for the specifier related to the selection and then specification of $D_{upper}$. As the minimum
cement content and minimum fines contents are related to aggregate size, it is essential to specify a
\( D_{\text{lower}} \). EN 12620 is not the most helpful of standards as three sets of sieve sizes are permitted.
Fortunately, sizes 8mm, 16mm and 32mm are common for the three sets of sieve sizes but in one set
20mm is a size and in another set it is 22mm. For practical and economic reasons \( D_{\text{upper}} \) and \( D_{\text{lower}} \)
should be aggregate sizes stocked by the concrete producer. In this specific application, it may be
necessary to make \( D_{\text{upper}} \) and \( D_{\text{lower}} \) the same value if a specific size is required in the concrete. If a
range between \( D_{\text{upper}} \) and \( D_{\text{lower}} \) is given for a diaphragm wall and the minimum cement content is also
specified, the producer should check with Table D.2 to see if the specified minimum cement content
aligns with, or is greater than, that given in the table for the producer’s selected value of \( D_{\text{max}} \). If it is
less than this value, the producer would be prudent to check whether the specifier wants conformity to
the specified minimum value or to the value in Table D.2.

EN 206, D.2.2 (1) contains the following: ‘In order to minimize segregation, aggregates should be
continuously graded, and round aggregates are preferred.’ This is a preference and not a requirement
on the producer. As excessively flaky aggregates are unlikely to be suitable for these applications, it
would be appropriate to specify a limit on the flakiness of the aggregates using one of the Flakiness
Index categories or Shape Index categories given in EN 12620 [8]; however, this is not at present a
requirement of EN 206, Annex D.

11.3 Concrete mix design

ERMCO has noted that between CEN/TC104/SC1 N761, the NOTE in 5.2.1 (2) has in version N808
and subsequent versions become 5.2.1 (3). The wording is unchanged as:

(3) The concrete should be designed so as to minimise segregation and bleeding of the fresh concrete
unless specified otherwise.

The word ‘should’ indicates that this is still informative and not a requirement, but in some cases it is
being taken incorrectly as being a requirement. ERMCO strongly objects to requirements and
recommendations that are subjective and such requirements/guidance have no part in a performance-
based standard. In the few situations where it is necessary to go beyond the norm, it is possible to
specify directly requirements for bleeding and segregation in terms of limits and test methods. In the
view of ERMCO this informative clause should be replaced with a clear requirement such as:

‘(3) Where there is a specific need to limit bleeding and segregation, these should be taken into
account in the concrete specification either indirectly in terms of specifying appropriate limiting
values or directly in terms of limits and test methods.’

Such a change would align this recommendation with EN 206, clause D.3.

EN 206, clause D.3 requires the specification to take into account:

— the need for a high resistance against segregation;
the need for adequate plasticity and good cohesiveness;

— the need for flowing well;

— the need to be able to compact adequately by gravity;

— the need for sufficient workability for the duration of the placement procedure, including the removal of any temporary casings.

It is unacceptable for the specifier to simply transfer these unclear requirements to the concrete producer. Some of these factors are subjective, and it is ERMCO policy not to accept specifications that contain subjective requirements. Some of these characteristics can be, and should be, specified in a quantitative way. For example, the need to ‘flow well’ should be covered by the specified consistence class. The need for sufficient workability for the duration of the placement, can be specified by consistence after a specified number of hours after batching. Viscosity, segregation resistance and passing ability could be specified using the categories given in EN 206 for self-compacting concrete.

Nevertheless there are still subjective requirements and the solution in EN 206, D.3.1 (2) is to have the mix approved prior to production. The Annex does not specify how the mix is to be approved. The procedure used to approve a mix might be based on previous successful use of the proposed mix design, observation of laboratory trial mixes, full scale trial mixes/placement or a detailed review of the mix proportions.

Acceptance of the mix design then means acceptance of the non-quantitive (subjective) requirements placed on the concrete. The quantitive requirements, consistence, compressive strength etc. are verified during production using the conformity criteria given in EN 206.

11.4 Maximum water-cement ratio

The maximum w/c ratio is the lower of the one required by provisions valid in the place of use for the specified exposure classes, or 0.60. The value of 0.6 seems high for concretes that have to take into account the characteristics described in EN 206, D.3.1.

11.5 Fresh concrete

EN 206, D.3.4 requires the consistence to be specified as a target value. Recommended values are given for flow and slump but not for slump-flow. Taking into consideration the flow requirements for these concretes, specifying consistence by slump-flow is a good approach, but when EN 206, Annex D was being drafted there was no consensus on what target values should be recommended. ERMCO should collect information on what slump-flow values are being specified in practice (and
where known, whether they were successful) with the objective of introducing recommended values into the next revision of EN 206.

It should be noted that the tolerance for flow on the target value is even lower than that given in EN 206, Table 23: Conformity criteria for target values of consistence and viscosity, and significantly less than the precision of the test. The issues associated with such tolerances are described in section 9.1.2 of this Guide.

12. References

Annex A: Justification for the tolerances given in Table 2

A.1 Introduction

The technical justification for these tolerances is based on the following reasoning. The target w/c ratio is 0.02 below the specified maximum w/c ratio and the combined worse case tolerances should not lead to an increase in w/c ratio greater than 0.04. The combined worse case is when:

- the aggregate quantity is on the maximum positive limit;
- the cement and addition is on the maximum negative tolerance;
- the water is on the maximum positive tolerance;
- the batch size is at its minimum.

To test whether the criterion of not increasing the w/c ratio by more than 0.04 a structural concrete near the lower end of the range has been selected. This comprises:

- Cement 300 kg/m$^3$ (relative density 3.12)
- Free water 180 kg/m$^3$ (relative density 1.0)
- Aggregates 1940 kg/m$^3$ (relative density 2.7)

These yield a volume of 995 litres the remaining 5 litres comprising entrapped air giving a yield of one cubic metre.

A.2 Impact on w/c ratio of existing limits in EN 206 Table 27

A volume of one cubic metre is selected. The adverse deviations will lead to the following changes in yield:

- +3% of aggregates will increase yield by 21.6 l;
- -3% cement will reduce yield by 2.9 l;
- +3% water will increase yield by 5.4 l.

The total yield of these mix proportions is 1024 litres.

Applying these adverse tolerances gives a cement content of 291 kg and a water content of 185.4 kg in a volume of 1.024 cubic metres giving a w/c ratio of 0.64. This calculation shows that the tolerances in EN 206, Table 27 are unlikely to lead to an increase in w/c ratio greater than 0.04.

The percentage limits in EN 206 Table 27 have been included in Table 2 and at a volume of one cubic metre they are the controlling limits in Table 2 and so Table 2 introduces for batch sizes of one cubic metre or more no changes from the existing EN 206, Table 27.

In this calculation the cement content has been reduced to 284 kg/m$^3$ but it is the w/c ratio that is the more important parameter.

A.3 Impact of the numerical limits in Table 2

Between one cubic metre and 0.5 cubic metre, which is the limit on load size, the controlling tolerances change from the percentage figures to the numerical values. The worse case will be when load size is 0.5 m$^3$ and the tolerances given as numerical values apply.

The tolerances given in table 2 will lead to the following changes in yield:

- +50 kg of aggregate (at a relative density of 2.7) will increase the yield by about 18.5 l;
- -5 kg of cement will reduce the yield by about 1.6 l;
+ 3 kg of water will increase the yield by 3l.

The total yield of these mix proportions is 520litres (target batch size is 0.5 m$^3$).

The mix proportions for a 0.5 m$^3$ load are a cement content of 150 kg and a water content of 90 kg. Applying the adverse tolerances leads to a cement content of 145 kg and a water content of 93 kg in a volume of 0.52 cubic metres giving a w/c ratio of 0.64.

These tolerances satisfy the criteria of not increasing the w/c ratio by more than 0.04 and the worse case impact on w/c ratio is the same as that given in EN 206, Table 27.

There is a slightly worse impact on cement content as this reduces to 279 kg/m$^3$, but the impact on w/c ratio is much more important for durability and this is the same as that given by the tolerances in EN 206, Table 27.