norwegian concrete association

Publication no. 7

Sprayed Concrete for Rock Support

Appendix 1:
Informative note of September 2015
regarding practice and
interpretation of guidelines

August 2011
(Appendix 1, September 2015)

PREFACE

This edition of Publication No. 7 of the Norwegian Concrete Association, “Sprayed Concrete for Rock Support” replaces the 2003 edition. Since the last update in 2003, European standards concerning sprayed concrete have been published. These standards cover both the wet- and dry mix methods, for a wide range of applications: support and reinforcement of rock and soils, free-standing structures and also repairs and upgrading of existing structures. Consequently, the standards encompass compromises and rules that do not concern rock support. Those who are only interested in rock support (which can be characterized as a technological discipline of its own), have to assess and filter out the relevant information. Therefore, it was decided to update Publication No. 7 in the same manner as previous editions, but incorporating the relevant information from the new European standards.

This publication is meant as a supporting document and should be read alongside the current relevant standards, see chapter 1.1.1. This publication pertains only with what is relevant with respect to rock support, and elaborates on, clarifies and explains the standard’s requirements. With respect to the formulations presented in the current standards, this publication:

- gives limited options where this is desirable, based on the method of execution and/or the area of application,
- provides clarifications and explanations for adjustments to Norwegian traditions and practices. In certain cases these clarifications are in the form of supplements,
- contains other specifications than those in NS-EN. This mainly concerns test methods and the two-stage principle for inspection frequency.

This publication offers a concise compilation of the requirements concerning the use of wet mixed sprayed concrete for rock support; with explanatory text and illustrations provided. This publication is divided into 3 chapters; chapter 1 Product specification, chapter 2 Test methods and evaluation, and chapter 3 Guidelines. Chapter 1 and 2 can also be referred to in a contractual context.

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Oslo, August 2011

SEPTEMBER 2015:

In September 2015, an APPENDIX 1 was added to the Publication. The appendix contains an informative note from the Sprayed Concrete Committee. The note seeks to give some clarifications and recommendations, especially dealing with responsibility and documentation of energy absorption capacity of test panels. The note do not sketch out any changes to guidelines in the Publication.

Oslo, September 2015

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Informative note regarding practice and interpretation of guidelines formulated in the Norwegian Concrete Association's Publication no. 7: "Sprayed Concrete for Rock Support"

Introduction

After publishing the revised edition of the Norwegian Concrete Association's Publication no. 7 (denoted NB 7:2011 hereafter) in August 2011, it has become evident that the users of the Publication have had somewhat different interpretation of certain sections. There has for instance been some uncertainty regarding responsibility and the documentation of energy absorption capacity of test panels.

This informative note gives some clarifications and recommendations, which hopefully will contribute to unified practice and understanding.

Responsibility

The concrete producer is responsible for delivering the basic mix according to specifications, while the spraying contractor is responsible for installing the sprayed concrete. It is natural that the spraying contractor may have requests beyond what is specified by the project owner. For instance with respect to properties like the workability of the basic mix. As general rule, the concrete producer and the spraying contractor should come to an agreement concerning the concrete composition.

The project owner specify an energy absorption class, i.e. requirement to minimum energy absorption. The specification does normally not require the use of a specific fiber. The contractor choose a fiber and a fiber dosage that fulfill the specified energy absorption class. The responsibility of the concrete producer (when he has undertaken to add the fiber to the basic mix) is to add a specified amount of fibers and to ensure sufficient fiber distribution. Whoever adds the fiber is responsible for the documentation of fiber content and fiber distribution. When these requirements are met, it is the contractor's responsibility to document sufficient energy absorption.

It is recommended that the spraying contractor is been given the overall responsibility for ensuring sufficient energy absorption capacity and the accompanying documentation. This entails ensuring in cooperation with the concrete producer that the requirements for the basic mix are met, and in consultation with the fiber supplier choosing the fiber type and associated fiber content.

The fiber supplier typically holds most experience and documentation with regard to what fiber content is necessary to obtain the required energy absorption capacity, secondly the spraying contractor. The spraying contractor will naturally use his own experience and to the extent possible make use of the experience of the fiber supplier in choosing the correct fiber dosage.

Panel tests (energy absorption capacity), general

The use of sprayed round and square test panels are equated, hence both geometries can be used. Traditionally round panels have dominated in Norway since they are considered to be easier to handle. Each test result is the average result from (minimum) 3 test panels. Some choose to produce 4 test panels during panel production as back-up in case of damage to one panel or other reasons that call for a spare panel. The fiber content and fiber distribution shall always be documented for the specific concrete batch used for panel production. For this to happen the concrete producer (that documents the fiber content and fiber distribution) and the spraying contractor (that produces the test panels) must coordinate their activities. To obtain proper screeding of the surface of the panels it is often necessary to reduce the accelerator dosage.

When reporting a test result, all 3 test panels shall make the basis for the average result independent of the failure mechanism (flexural failure, shear failure).

When using previously attained test result to document a given energy absorption class the required energy absorption must exceed the specified energy absorption with a margin (Table 3 in NB 7:2011).

When documentation is done within a project, no margin is required (Table 4 in NB 7:2011). Separate documentation is always required for the two concrete qualities M45 and M40 (w/b of 0.45 and 0.40, respectively). The project owner shall request and inspect previously attained documentation before the sprayed concrete works start.

The inspection frequency for the panel test (and for fiber content and fiber distribution) is linked to the sprayed concrete production volume. In principle, produced volume does not include "other concrete mixes" (such as sprayed concrete without fiber for reinforced arches, etc.). Including other concrete mixes is, however, voluntary since it simply leads to increased inspection frequency of the fiber reinforced sprayed concrete.

Scatter of results during panel tests

One energy absorption capacity test result is the average of at least 3 test panels, as mentioned. The panels shall be sprayed in the same location, the spraying shall be carried out successively and from the same concrete batch. Prior to the publication of NB 7:2011, The Sprayed Concrete Committee carried out several series of panel tests, see [1] and [2]. Those test series showed an average internal scatter (coefficient of variation) of 8.5% within a given laboratory. The scatter normally varied from a few % up to 15%, and sometimes a scatter of more than 20 % occur.

Round robin programs on panel tests have been carried out, both in Norway and internationally [3]. The experience from these programs is that the scatter of panel test results among different laboratories lies around 10-12 %, something that must be regarded as good considering the average 8,5% scatter for sets of three panels within one laboratory.

Hence, if aiming for a small or no margin to the requirement there will be a risk of obtaining results that are too low during project documentation, due to natural scatter. This is analogous to for instance compressive strength; one should always have a margin to the requirement to take the scatter into account.

Documentation of energy absorption capacity (section 1.2.6.1 in NB 7:2011)

Previously attained documentation – Alternative A (with a margin to the requirement): Documentation can be based on earlier results obtained from concrete mixes produced at other locations where the given fiber type and concrete quality were utilized. In such cases, the results must show a margin to the requirement when starting up spraying in a new project, see Table 3 in NB 7:2011.

The documentation can be based on two or more fiber dosage levels. This opens for the possibility to interpolate between the results (not extrapolation), and this way the fiber dosage can be determined before starting up the sprayed concrete works in a project. Figure 1 shows an example of the use of 2 fiber dosage levels, and 2 test series at each dosage level (i.e. a 15 % margin apply, see Table 3 in NB 7:2011). The two averages are interpolated and the necessary fiber dosage for the energy absorption class E700 (fiber dosage 1) and E1000 (fiber dosage 2) is found. In connection with the final decision on fiber dosage, some independent reflections could wisely be made regarding the choice; if for instance the variation is as shown for test result 1 and 2 for "high" fiber dosage in Figure 1.

Pretesting in the given project – Alternative B (with no margin to the requirement)
Pretesting as described in section 1.2.6.1 and Table 4 in NB 7:2011 is then valid (the same requirement also holds for quality control within the project, see section 1.2.6.2). A practice has developed where the interpolation method is used in projects during both pretesting (with the actual equipment and given concrete) and during ongoing quality control documentation. This is not described in NB 7:2011, but The Sprayed Concrete Committee considers the use of the interpolation method in projects to be sensible since it introduces robustness as it increases the test volume. Furthermore, it gives a basis for rapid adaption if there should be a need for changes in the fiber dosage. Even though a margin is not required, it is sensible to choose a somewhat higher fiber dosage to account for the natural scatter, as already discussed.

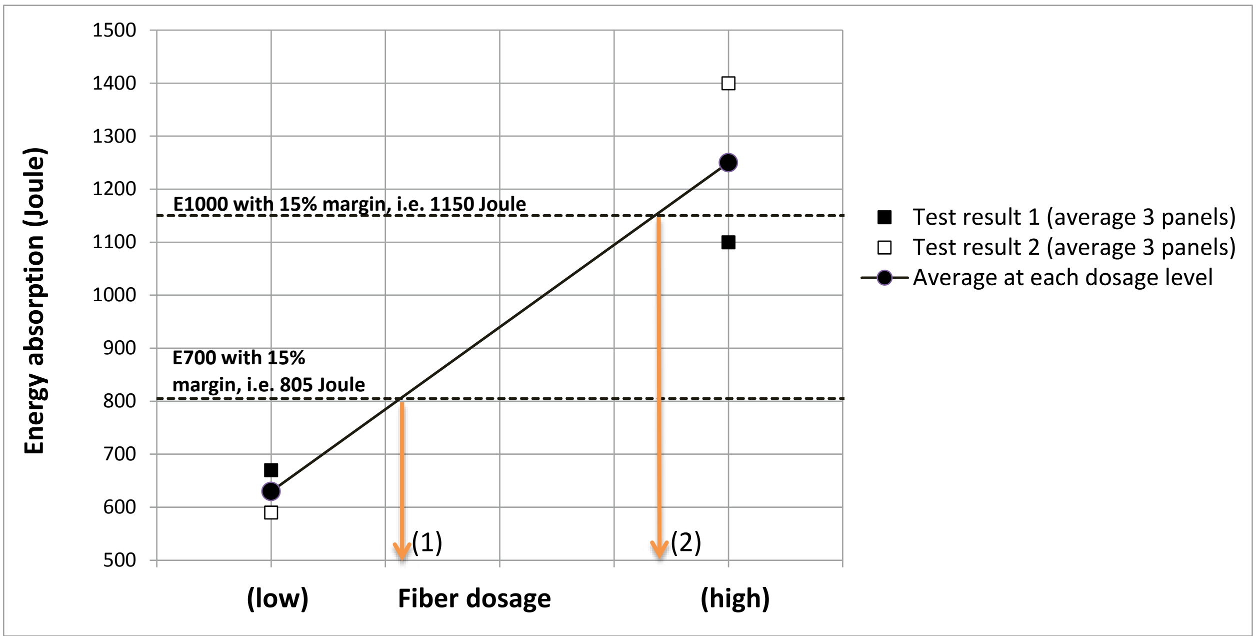

Figure 1 Illustration of "alternative A" documentation of energy absorption capacity with the use of 2 fiber dosage levels and 2 test results at each level, something that means a 15 % margin to the energy absorption class according to Table 3 in NB 7:2011.

When using the interpolation method in a project, one or more sets of panels must be produced with sprayed concrete containing less fiber than what is used in the daily sprayed concrete production. After production of these panels, the remaining concrete in the batch may be installed after consulting with the project owner. There are examples that acceptance of use of such single loads has been given (for instance on areas with good rock quality). Alternatively, other sensible use has been found nearby. It is an advantage to integrate approved procedures in the quality inspection plan of the project.

Documentation of fiber content and fiber distribution

The tendency of fiber balling has declined after introducing the requirement for documentation of fiber content and fiber distribution. Too high slump (risk of segregation) has, however, shown to give a risk of poor fiber distribution.

Inspection frequency

The inspection frequency for fiber content, fiber distribution and energy absorption capacity is given in Table 6 and Table 7 in NB 7:2011, respectively.

References

[1] Bjøntegaard Ø. and Myren S.A. (2011) The accuracy of FRS concrete panel tests. Tunneling Journal, Oct/Nov 2011, pp. 44-50
[2] Bjøntegaard Ø. and Myren S.A. (2011) Fibre Reinforced Sprayed Concrete Panel Tests: Main results from a methodology study performed by the Norwegian sprayed concrete committee. Sixth International Symposium on Sprayed Concrete, 12.-15. September 2011, Tromsø, Norway
[3] Bjøntegaard Ø., Myren S.A. and Skjølsvold O. (2013) Round Robin Test program on Energy Absorption Capacity of Round Panels according to Norwegian Concrete Association's Publication no 7:2011. COIN Project report 48 – 2013, SINTEF Building and Infrastructure, ISSN 1891–1978 (online), ISBN 978-82-536-1349-9 (pdf), p.52

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