ReforceTech
Basalt Fiber Reinforcement Technology

Introduction to guidelines for

ReforceTech BFRP reinforcement bars in concrete structures

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DNV Technical Report 2009-0316
Qualification of Basalt Fibre Reinforced Polymer (BFRP) Bars for Application in Reinforced Concrete Structures
Rev. 0, 2010-02-01

For ReforceTech AS

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Foreword

ReforceTech AS develops a new technology for efficient production of basalt fibre reinforced polymer (BFRP) bars for reinforcement of concrete structures. DNV was contracted to qualify this technology for reliable and safe use in load-bearing concrete structures according to DNVs procedures documented in DNV-RP-A203 and DNV-OSS-401. DNV has

1) managed technology qualification,
2) executed qualification activities in collaboration with the technology owner and others, to document with confidence the bar's performance as reinforcement in concrete structures and
3) developed Guidelines for these bars.

The Guidelines are provided in this document.

The ReforceTech BFRP bars are considered fit for service as reinforcement in concrete structures if produced

1) in accordance with the specification provided in Section 3.1 of DNV Technical Report 2009-0316 "Qualification of Basalt Fibre Reinforced Polymer (BFRP) Bars for Application in Reinforced Concrete Structures" Rev. 0 dated 2010-01-29,
2) under strict quality assurance and control in accordance with these Guidelines.

BFRP bars deliveries are considered fit for service as reinforcement in concrete structures when the actual delivery has been verified to have been produced in accordance with the above.

Separate verification shall be performed to ensure that concrete structures reinforced with these BFRP bars are designed, constructed and maintained in compliance with these Guidelines.

Structures for service in areas with own regulations for design and construction need approval by the applicable regulatory authority.

Text that applies specifically to the ReforceTech product is shown shaded and in frames and is not applicable to other products.

These Guidelines shall be used together with DNV-OS-C502 Offshore Concrete Structures. All requirements of that standard apply unless expressly stated otherwise herein.

Introduction

Refer to DNV-OS-C502 for A100 – A500.

Objective

107 The objective of these guidelines is to provide guidance on the design, construction and in-service inspection of concrete structures reinforced with BFRP bars instead of or in combination with steel reinforcement bars such that, when these guidelines are used in conjunction with an applicable national or international standard, a structure that is fit for service is obtained.

Scope, limitations and application

202 These guidelines are applicable to design, construction and inspection of concrete structures that are covered by the object standard applied in conjunction with these guidelines.

Provided that this is agreed between the parties, acceptable within the applicable jurisdiction and accepted by the responsible approval authority, these guidelines can serve as a contractual reference document between the parties and form the basis for approval (certification or classification).

In case of ambiguity in interpretation of the provisions herein, the basis documented in DNV-TR-2009-0316 and the documents referenced therein should be considered. If this does not resolve the ambiguity, the issue can be resolved by a dedicated technology qualification exercise according to DNV-RP-A203.

A 600 Users of the Guidelines

601 The client is understood to be the party ultimately responsible for the system as installed and its intended use in accordance with the prevailing laws, statutory rules and regulations.

602 The authorities are the national or international regulatory bodies.

603 The contractor is understood to be the party contracted by the client to perform all or part of the necessary work needed to bring the system to an installed and operable condition.

604 Subcontractors are contracted by the contractor to perform of the work needed to bring the system to an installed and operable condition. The designer is understood to be the party contracted to fulfil all or part of the activities associated with the design. Manufacturers are understood to be the party contracted to manufacture all or part of the system being responsible for its deliveries. They include the manufacturer of the bars and the party constructing the concrete structure.

605 The third party verifier is an independent neutral party that verifies the design of a structure or component.

A700 Guidelines for BFRP bars

701 These guidelines are the result of a structured technology qualification process carried out according to DNV-OSS-401 and DNV-RP-A203. The guidelines provide principles, technical requirements and guidelines for the design, construction and in-service inspection of concrete structures. Compliance of a specific structural design and construction with these guidelines implies that the structure is fit for the specified service if the QA/QC ensures that the bars used are according to specifications and that design, construction and in-service inspection meets the criteria of these guidelines.

702 All aspects of concrete structures not covered herein should be in compliance with recognized international or national standards.

703 These Guidelines are so structured as to provide particularly user-friendly application together with DNV-OS-C502 Offshore Concrete Structures.

704 Furthermore, the Guidelines address specifically how the structural design prescriptions of NS 3473, developed for steel reinforcement bars, can be modified to account for the particular properties of BFRP reinforcement bars.
705 It shall be noted that NS3473 covers only Section 6 of this Guideline; hence the provisions of Sections 1, 2, 3, 4, 5, 7 and 8 shall still apply when using NS3473 together with Appendix H as the basis for detailed design.

706 Appendix H "Guidelines for design of BFRP reinforced concrete member together with NS3473" is not approved by Norsk Standard and shall be considered as recommendations only.

707 For structures other than offshore structures, the proper use of these Guidelines results in reliable structural designs if the load combinations specified in EN1990 and quoted in Sec. 5 C114 are accounted for. These Guidelines are not approved by Comité Européen de Normalisation (CEN) and such use of the Guidelines shall be considered as recommendations only.

708 In using BFRP reinforcement in reinforced concrete structures, the following advantages and disadvantages should be noted. The success in applying the material in an cost effective manner will depend on taking necessary account of these advantages and disadvantages.

Advantages:

- Low weight. The bars has a density which is 1/4 of steel reinforcement.
- Concrete dimensions and weight will be less due to reduced need for concrete cover.
- BFRP does not corrode and can be positioned close to the surface. The size of cover is only dependent on specifying sufficient cover to transfer bond.
- Meshes of BFRP bars with small diameter may be placed at low cover to considerably improve the SLS performance (crackwidth) of BFRP reinforced members.
- As the BFRP reinforcement is not sensitive to corrosion, larger cracks may be accepted for BFRP reinforced structural members than what is acceptable for steel reinforced concrete members in cases where crackwidth control is not controlled by visual appearance.
- BFRP reinforcement has a higher initial tensile strength than steel reinforcement.
- BFRP reinforcement can be prestressed to a relative low values and still retain its prestressing level when considering losses due to its low E modulus.
- BFRP reinforced concrete members are more flexible than steel reinforced concrete members and may be very useful where high flexibility is important.
- BFRP reinforced concrete members undergo large deflections prior to failure. The failure deflection is larger than normal for steel reinforced members. Also, the deflection increase with a steadily increasing load, while steel reinforced members only experience a small load carrying increase following yield of the reinforcement.

- BFRP reinforcement can be used together with other steel reinforcement or steel tendons. The likely application of BFRP bars in this case is for surface reinforcement. In cases with mixed application of steel and BFRP, the critieria for crack width control and concrete cover to steel reinforcement and tendons apply.

Disadvantages:

- The E modulus of BFRP is much lower than steel reinforcement. This has impact on strength (position of neutral axis), shear strength (contribution from longitudinal bars and shear reinforcement), minimum reinforcement, deflection and crack widths.
- The material has to be applied differently than in traditional steel reinforced concrete structures to become cost effective.
- The BFRP material has a strength which is dependent on the time of load exposure. This is named the sustained load effect. Special load combinations with different material factors for BFRP are assigned for each load combination to account for this effect.
- BFRP reinforcement are relative light, but shall also be handled relatively carefully at the construction site in order not to damage the bars.
- The BFRP reinforcement has to follow a tight production control system and relevant properties of the BFRP has to be provided on data sheet to the designer and also as part of the construction control.

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Table of Contents in the DNV guideline

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References

Refer to DNV-OS-C502 for B100.

References for use of BFRP bars

201 The recognised reports, codes, guidelines and standards in Table 1 are referenced in these guidelines.

Table 1: Other references

Reference	*Title*
DNV-TR-2009-0316	Qualification of Basalt Fibre Reinforced Polymer (BFRP) Bars for Application in Reinforced Concrete Structures. DNV Technical Report 2009-0316.
ACI 440.1R-06	Guide for the design and construction of structural concrete reinforced with FRP bars. American Concrete Institute. February 10, 2006
ACI 440.3R-04	Guide test methods for fiber-reinforced polymers (FRPs) for reinforcing or strengthening concrete structures. American Concrete Institute. June 28, 2004.
ACI 440R-07	Report on fiber-reinforced polymer (FRP) reinforcement for concrete structures. American Concrete Institute. September 2007
CSA 806-02	Design and Construction of Building Components with Fibre-Reinforced Polymers. Canadian Standards Association. November 2005
ISO 10406-1	Fibre-reinforced polymer (FRP) reinforcement of concrete – Test methods – Part 1 FRP bars and grids. ISO, 2008-12-15
SINTEF	Eurocrete. Modification to NS3473 when using fiber reinforced (FRP) reinforcement, Cement and Concrete 1998-04-8.
ACI 440-4R – 04	Prestressing Concrete Structures with FRP Tendons. September 21, 2004

List of reports

Waagaard et al. Qualification of Basalt Fibre Reinforced Polymer (BFRP) Bars for Application in Reinforced Concrete Structures. DNV Technical Report 2009-0316. Rev.0, 2010-02-01.

McGeorge D et al. Tests report on large scale beams and slabs with BFRP bar reinforcement. Det Norske Veritas AS. Technical Report 2009-3141, Rev.0, 2010-01-29.

McGeorge D et al. Tensile strength properties of BFRP bars in the long and short term, DNV Technical Report 2009-3140, Rev.0, 2010-01-17.

McGeorge D et al. Elongation properties of BFRP bars: E-modulus, creep and thermal expansion, DNV Technical Report 2009-3142, Rev.0, 2010-01-17

McGeorge D et al. Bond and bend strength of BFRP bars, DNV Technical Report 2009-3139, Rev.0, 2010-01-18.