MasterFlow 9500
Durable Grouted Connections in the Offshore Oil and Gas Industry
Master Builders Solutions from BASF

Building on partnership. Our Master Builders Solutions experts find innovative and sustainable solutions to meet your specific construction needs. Our global experience and network help you to be successful – today and tomorrow.

MasterFlow 9500
Durable Grouted Connections in the Offshore Oil and Gas industry

More Than a Group: BASF for Sustainable Offshore Structures

BASF is the world’s leading chemical company: The Chemical Company. Our portfolio ranges from chemicals, plastics and performance products to agricultural products, fine chemicals, oilfield chemicals, oil and gas. As a reliable partner, BASF helps customers to be more successful in virtually all industries. With high value products and intelligent solutions, we play an important role in finding answers to global challenges such as climate protection, energy efficiency, nutrition and mobility.

BASF is the leading supplier of chemical systems and formulations for the construction industry. Continuous innovation and tailor-made solutions ensure that our customers stay at the forefront of technology.

The BASF Admixture Systems division specifically helps customers in the ready-mix, precast and other concrete industry products. The use of BASF’s admixtures can be tailored to achieve the best concrete mix for the foundation design and geotechnical conditions, whilst minimizing the CO₂ footprint of the concrete. Our range of superplasticizers, curing agents, release agents, air entraining agents, accelerators and corrosion-inhibiting admixtures provide the flexibility for material innovation to address these challenges whilst increasing productivity and delivering whole-life cost benefits, thus saving our customers time and money.

For the construction of modern, giant oil and gas platforms we offer high-performance MasterFlow Exagrou materials. Whether having to absorb the enormous vibrations, wave actions, torque and axial loads, whatever the type of grouted connection in the offshore installations: BASF’s special new MasterFlow Exagrous masters all challenges during the entire lifetime of the offshore platforms. We offer special new MasterFlow Exagrous that are able to absorb the enormous vibrations, wave actions, torque and axial loads during the entire lifetime of the offshore platforms.

Based on our long-term technological experience and our innovative power, we strive continuously to develop new products to meet our customers’ ever increasing requirements.

With BASF’s global presence and technical expert network, we can guarantee our customers solid support in all regions of the world.

The comprehensive portfolio under the Master Builders Solutions brand encompasses concrete admixtures, cement additives, chemical solutions for underground construction, waterproofing solutions, sealants, concrete repair and protection solutions, performance grouts, performance flooring solutions.
MasterFlow 9500
Durable Grouted Connections in the Offshore Oil and Gas Industry

Specialists for Construction Products

Innovative products for specific applications

The latest technical developments in the offshore oil and gas industry allow for more exploitation of these energy sources. New installations are being built with higher demands on the structures, while offshore platforms that have already reached their design life are being repaired and maintained to ensure longer oil and gas exploitation. The foundations of the offshore platforms need to meet ever higher quality requirements and at the same time the construction or maintenance period needs to be reduced.

Offshore structure loads

Offshore oil and gas structures are massive structures that are dynamically exposed to high wave loads and other service stresses. The interaction of the oil and gas production with the durability of the fixed structure, e.g. a piled jacket construction, is of utmost importance for the long term exploitation of these energy sources. More specifically, the load transferring components of the installation – platform, foundation and seabed anchors – require therefore special attention in the design of the offshore structure.

The most important loads acting on an offshore foundation structure are:

- Axial load
- Wave load
- Vibration
- Impact

All these loads need to be transferred/absorbed by the grout used in the grouted connections. A careful design and selection of the grouting material is therefore of utmost importance. Safe and durable installation of offshore oil and gas structures, or the repair and maintenance thereof, largely depend on high performance building materials which connect the foundation to the seabed or strengthen the sub-structure. Products used in grouted connections must exhibit minimum product requirements:

- Fatigue resistance:
  - Ultra-high final strengths
  - Excellent long term durability

- Application in wider weather windows:
  - Material applicable down to 0 °C
  - Rapid strength development, even at cold temperatures

- Validation by Det Norske Veritas:
  - For grouted connections in all offshore installations

- Improved risk management:
  - Products installed by licensed contractors

- Cost effective installations:
  - Considerable reduction of the overall installation time

- Faster return on investment:
  - Ensuring project completion on time
  - Earlier exploitation possible

BASF’s specially developed ultra-high performance material – MasterFlow 9500 Exagrout – meets all these requirements and has faster and more durable installation times in offshore foundation structures.
DET NORSKE VERITAS

TYPE APPROVAL CERTIFICATE

CERTIFICATE NO. K-5944
This is to certify that the
Structural Cementitious Grout
with type designation
MasterFlow 9500
Issued by
BASF A/S
DK-6230 Redskro, Denmark
has been assessed with respect to

Application
For use in load carrying grouted connections

Further details, including properties and operational limitations, are given overleaf.

This Certificate is valid until 2019-06-09.
Issued at Havik on 2014-06-09
DNV local station: Havik, Norway
Approval Engineer: Andreas Lervik
Hege Berg Thomann
Head of Section
Exagrount for Offshore Oil and Gas Structures

In newly built offshore structures, jacket foundations are provided by open-ended tubular steel sleeves and piles are driven through the sleeves into the seabed. A high-performance grout is installed in the cavity between pile and sleeve, the so-called grouted connection. Due to fatigue, collision damage or planned changes that increase topside loads, repairs and strengthening measures for the offshore structures might be required. Grouted connections are most suited to repair damaged structures, while filling a member with grout offers the advantage of not increasing member diameter or wave loading. MasterFlow 9500 is a new generation of ultra-high-strength, high-modulus, fatigue-resistant, cement-based Exagrount for installation in all offshore grouted connections. The material has been especially formulated for large scale pump applications:

- Grouting of oil and gas installations where excellent fatigue resistance is required, e.g. in jacket type foundations.
- Grouting under very harsh conditions, e.g. offshore applications or below water grouting, at temperatures as low as 0 °C.
- All void filling where high strength and fatigue resistance is important, e.g. grouted clamps or member filling.

MasterFlow 9500 exhibits long-term durability and guarantees a fast, secure and cost-effective installation. Offshore oil and gas structures are special – their safe and durable installation largely depends on the correct design and interaction of all components – and may require a high-performance MasterFlow Exagrount to guarantee long-term operation of all components – high performance MasterFlow Exagrount guarantees long-term operation.

The Master Builders Solutions experts from BASF help the offshore industry to be more successful by better understanding the needs of our partners and reducing the risks involved in the construction and exploitation of offshore platforms. For us, managing risks means amongst others:

- MasterFlow 9500 Exagrount installed by BASF Licensed Contractors
- Independent documentation of the material properties
- Detailed installation methods as part of the Quality Assurance
- Validation and certification by DNV
- Compulsory training of BASF Licensed Contractors

Excellent durability:
- High fatigue resistance, absorbing dynamic loads
- Zero autogenous shrinkage; volume stable
- High flexural strength
- Very low porosity and water absorption

Secure installation:
- Ultra-high axial load capacity
- Excellent long-term load transfer
- Certification by Det Norske Veritas (DNV)
- High ultimate strengths

Fast and cost effective installation:
- Rapid strength build-up, even at cold temperatures down to 0 °C
- Short overall installation times
- Safeguarding project completion on time, earlier return on investment
BASF has instructed Det Norske Veritas (DNV) to verify MasterFlow 9500 for use in offshore wind turbine and oil and gas installations.

Throughout the validation process, DNV has conducted the following activities:

1. Validation and acceptance of testing methodology, procedures and extent.
2. Evaluation and acceptance of Aalborg University DCE Laboratory as an external, independent test laboratory.
3. Evaluation, witnessing and acceptance of mock-up application and large scale field pumping trials.
4. Audit, evaluation and acceptance of grout manufacturing equipment and facilities.
5. Audit of BASF laboratory and factory production/quality control.
6. Evaluation and acceptance of the independent laboratory test results and large scale grout pumping trials.
7. Evaluation of grout suitability in offshore applications such as grouted connections in offshore foundations.
8. Acceptance of TUM (Technische Universität München) as qualified test laboratory.
9. Evaluation and acceptance of laboratory tests carried out at TUM for grout at +2°C and +5°C.
10. Acceptance of LGAI Technological Center (Bellaterra, Barcelona) as qualified independent test laboratory.
11. Acceptance of laboratory tests carried out at LGAI Technological Center for MasterFlow grout at –1°C.

DNV has issued a certificate for MasterFlow 9500, based on the above verification programme. The certificate is a written assurance that MasterFlow 9500 conforms to specific strength, durability and functional requirements.

DNV – Conclusions and recommendations
- The verification programme for MasterFlow 9500 has been successfully completed by DNV according to the defined scope of work.
- Fatigue life has been tested and results compared with predictions for fatigue life in accordance with DNV-OS-C502 for equivalent stress conditions.
- MasterFlow 9500 shows as good a performance under cyclic loading as reinforced concrete.
- The ultra high modulus of elasticity may also give benefits with a stiffening effect.
- The results of the mock-up test confirm the functional properties of MasterFlow 9500 and indicate that the grout is suitable for the intended applications.
- MasterFlow 9500 exhibits very good pumpability and flowability over a long period of time. The grout is capable to be pumped through a 2 in hose over 200 m length and 20 m elevation.
MasterFlow 9500 Study Results

Compressive strength
Compressive strength of MasterFlow 9500 was tested in accordance with EN 12390-3, using 75 mm cubes. At each testing age 3 cubes were tested. The compressive strengths are plotted as a function of age in Figure 1. Strength development at cold and warm temperatures were determined in accordance with EN 12390-3. The results for MasterFlow 9500 tested at –1 °C, +20 °C and +30 °C are shown in Figure 2.

Flexural strength – Tensile splitting strength
The flexural strength was measured in accordance with EN 196-1 on 40 × 40 × 160 mm prisms while the splitting tensile strength was determined in accordance with EN 12390-5 on cylinders ø 100 × 200 mm. Results are shown in Table 1.

Table 1
<table>
<thead>
<tr>
<th>Time (days)</th>
<th>Flexural strength (MPa)</th>
<th>Tensile splitting strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>18.4</td>
<td>8.6</td>
</tr>
</tbody>
</table>

Static and dynamic modulus of elasticity
The static modulus of elasticity was measured on cylinders ø 100 × 200 mm cured in water during 28 days in accordance with EN 13412. Results are shown in Table 2. Dynamic modulus of elasticity at cold temperatures was measured on prisms cured in water according to the guideline for the “protection and repair of concrete structures” of the German Committee of Reinforced Concrete (Rili-SiB DAFStb). The results are plotted in Figure 3.

Table 2
<table>
<thead>
<tr>
<th>Time (days)</th>
<th>Modulus of elasticity (GPa)</th>
<th>Poisson’s ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>50.9</td>
<td>0.199</td>
</tr>
</tbody>
</table>

Figure 1
Compressive strength – 75 mm cubes

Figure 2
Compressive strength – 150 × 300 mm cylinders

Figure 3
Dynamic modulus of elasticity
MasterFlow 9500 Study Results

Autogenous shrinkage
Autogenous shrinkage is the result of the chemical reaction between water and a cementitious material. The volume of the components before the reaction is typically larger than the volume of the end products i.e. hydrated cement (see Figure 4). Autogenous shrinkage can result in de-bonding of the grout from the steel in grouted connections and consequently poor load transfer of the dynamic loads that act on the foundations in offshore structures. Volume stability is of utmost importance in the long term durability of fixed foundation.

Laboratory testing
Autogenous shrinkage was measured using a method developed at Aalborg University. After mixing MasterFlow 9500, corrugated plastic tubes were filled with the grout, sealed by a plastic stopper in each end of the tube and then placed in a temperature controlled room at 20 °C. After final set, the length of each specimen was measured as a function of time, using a micrometer gauge. Autogenous shrinkage results found in the technical literature most often refer to measurements starting at an age of one day when the specimens are de-moulded. Figure 5 shows the autogenous shrinkage measured over time starting at the age of one day. Zero autogenous shrinkage is measured after approximately one year.

Axial load capacity of grouted connection
The main purpose of this test is to determine the maximum compressive axial force required to produce a slip on the interface between the steel surface and the grout. This force will be defined as the failure load or the ultimate resistance capacity of the connection against static compressive axial loading. A set of two concentric steel tubes was used for making test specimens. The annulus between the inner and outer tubular was filled with MasterFlow 9500 (see Figure 6). The grouted connection was exposed to pre-defined loads and relaxation before the compressive axial load was increased until a first slip occurred. After almost complete relaxation, loads were re-applied in subsequent load testing and the shear forces were determined between the grout and the steel. Compressive load versus time recorded during the test is presented in Figure 7. MasterFlow 9500 exhibits a compressive axial load capacity which is more than twice as high as for other grout materials used under similar test conditions.

Figure 4

Autogenous shrinkage
Drying shrinkage

Volume: Water + Cement before reaction
Volume: Hydrated Cement after reaction
Volume: Water + Cement after reaction and drying

Time (days)

Strain after 1 day (%)

0,005

0,000

0,000

-0,010

-0,010

-0,015

0 100 200 300 400

0 1,000 2,000 3,000 4,000 5,000 6,000 7,000 8,000

Compressive load (kN)

log N (numbers of cycles)

First slip (1,123 kN)

Step 12 (1,379 kN)

Step 14 (1,287 kN)
Fatigue behavior
Fatigue resistance is the resistance to the progressive and localised structural damage that occurs when a material is subjected to cyclic loading. The nominal maximum stress values are less than the ultimate stress limit, and may be below the yield stress limit of the material. Fatigue occurs when a material is subjected to repeated loading and unloading. If the loads are above a certain threshold, microscopic cracks will begin to form. Eventually a crack will reach a critical size, and the structure will suddenly fracture. The offshore design standard DNV-OS-C502 gives design guidelines for how to take into account maximum and minimum stress levels for fatigue life predictions (see Figure 8).

Fatigue calculations are made according to the formulation

$$\log_{10} N = C_1 \left( \frac{\sigma_{\text{max}}}{\sigma_{\text{y}}} \right)^{C_2} \left( \frac{\sigma_{\text{min}}}{\sigma_{\text{y}}} \right)^{C_3}$$

where:

- $C_1 = 12$ for structures in air
- $C_1 = 10$ for structures in water, and stress blocks having variation in the compression-compression range
- $C_1 = 8$ for structures in water and stress blocks having variation in the compression-tension range
- $\sigma_{\text{max}}$ is the numerically largest compressive stress, calculated as average within each stress-block
- $\sigma_{\text{min}}$ is the numerically lowest compressive stress, calculated as average within each stress-block (for tension = 0)
- $C_5 = \text{strength reduction factor for the specific grout}$
- $C_5 = 0.85$ shall be taken for MasterFlow 9500

The observed number of cycles to failure in the tests under cyclic loading corresponds well with the prediction according to DNV-OS-C502 (Figure 9). It can be concluded that MasterFlow 9500 shows a performance under cyclic loading that is as good as for reinforced concrete. Based on the tests, it is concluded that the design for fatigue can be carried out using formulations for fatigue life prediction in DNV-OS-C502 for reinforced concrete.

The behavior of MasterFlow 9500 under cyclic loading was studied using cylindrical specimens, 60 mm in diameter and 120 mm high.

The grout material has been tested for fatigue resistance in air and in water. Tests conducted in air were performed at high frequency (10 Hz), while tests in water were conducted at low frequency (0.35 Hz) in order to simulate the effect of wave actions on the foundations of offshore wind turbines.
More References

Our reference in the Danish sector Tyra West (Denmark):
Structural strengthening of bridge chords and braces
© Østermark Grouting A/S

Our reference in the Danish sector Tyra West (Denmark):
Structural strengthening of bridge chords and braces
© Østermark Grouting A/S
Master Builders Solutions from BASF for the Construction Industry

MasterAir
Complete solutions for air entrained concrete

MasterBrace
Solutions for concrete strengthening

MasterCast
Solutions for the manufactured concrete product industry

MasterCom
Solutions for cement manufacture

MasterEmaco
Solutions for concrete repair

MasterFinish
Solutions for formwork treatment and surface improvement

MasterFlow
Solutions for precision grouting

MasterFiber
Comprehensive solutions for fiber reinforced concrete

MasterGlenium
Solutions for high performance concrete

MasterInject
Solutions for concrete injection

MasterKure
Solutions for concrete curing

MasterLife
Solutions for enhanced durability

MasterMatrix
Advanced rheology control for concrete

MasterPel
Solutions for water tight concrete

MasterPolyheed
Solutions for mid-range concrete

MasterPozzolith
Solutions for water-reduced concrete

MasterProtect
Solutions for concrete protection

MasterRheobuild
Solutions for high strength concrete

MasterRoc
Solutions for underground construction

MasterSeal
Solutions for waterproofing and sealing

MasterSet
Solutions for set control

MasterSure
Solutions for extraordinary workability retention

MasterTop
Solutions for industrial and commercial floors

Master X-Seed
Advanced accelerator solutions for concrete

Ucrete
Flooring solutions for harsh environments

The data contained in this publication are based on our current knowledge and experience. They do not constitute the agreed contractual quality of the product and, in view of the many factors that may affect processing and application of our products, do not relieve processors from carrying out their own investigations and tests. The agreed contractual quality of the product at the time of transfer of risk is based solely on the data in the specification data sheet. Any descriptions, drawings, photographs, data, proportions, weights, etc. given in this publication may change without prior information. The responsibility of the recipient of our product to ensure that any proprietary rights and existing laws and legislation are observed (05/2014).

® = registered trademark of BASF group in many countries.

BASF plc
Construction Chemicals
PO Box 4 ▪ Earl Road ▪ Cheadle Hulme
Cheadle ▪ Cheshire ▪ SK8 6QG ▪ United Kingdom
P +44 (0)161 485 6222 ▪ F +44 (0)161 488 5220
www.master-builders-solutions.basf.co.uk

BASF plc
Construction Chemicals
19 Broad Ground Road ▪ Lakeside ▪ Redditch
Worcestershire ▪ B98 8YF ▪ United Kingdom
P +44 (0)1527 512 255 ▪ F +44 (0)1527 503 576
www.master-builders-solutions.basf.co.uk

BASF Construction Solutions GmbH
Key Account Wind Power
c/o PCI Augsburg GmbH
Piccardstrasse 11
86159 Augsburg, Germany