



MasterFlow 9800

Bulk Supplied Offshore Grout:
Revolutionizing Productivity
and Safety





The New Revolutionary Offshore Grout



“The material’s consistent and reliable strength development, along with its proven durability and volume stability, has most certainly played a significant part in its rapid acceptance and uptake within the offshore wind industry.”

Jim Bell, Managing Director of FoundOcean Ltd.



MasterFlow 9800: Grout for Offshore Wind Turbine Foundations

MasterFlow 9800 is a new revolutionary high strength and fatigue resistant cement based ExagROUT for offshore wind turbine installations – making wind energy projects more durable, time-efficient and secure.

MasterFlow 9800 is formulated for foundations where a design strength in the range of 60 to 90 MPa is required. The material exhibits long term durability and guarantees the fastest, secure and most cost effective installation of the wind farm:

- Grouting of grouted connections in typical jacket foundations, installed using the pre- or post-piling techniques
- Grouting where excellent fatigue resistance and long term durability are required
- Grouting in the shortest weather windows possible
- All void filling from 20 mm to 600 mm, and offshore applications at temperatures as low as 2 °C

Making wind energy projects more effective

BASF helps the wind industry to be more successful by better understanding the needs of our partners and reducing the risks involved in the construction and exploration of modern wind farms. Managing risks means for BASF amongst others:

- MasterFlow 9800 ExagROUT installed by BASF Licensed Contractor
- Independent documentation of the material properties
- Detailed installation methods as part of the Quality Assurance
- Validation and “Fit for Purpose” verification by independent experts

Product benefits at a glance:

2 °C

Controlled and continuous material quality

Proven grout quality even at temperatures as low as 2 °C



≥ 20 m³/h

Grouting rates of ≥ 20 m³/h allow fast application in shortest weather windows



High early strength

High early strength development reduces the risk of early age cycling



Validation

Independent verification of MasterFlow 9800 for use in offshore wind turbine installations



Weather independent

MasterFlow 9800 grouting material is stored in closed silos



20+ years

High fatigue resistance guarantees excellent durability of wind turbine grouts



MasterFlow 9800 Product Overview – Advantages and Benefits

MasterFlow 9800 is a bulk supplied offshore grout which is installed using a continuous mixing and pumping equipment, with the aim to increase productivity and safety during

grouting works. The material exhibits long term durability and guarantees a fast, secure and cost reduced installation of the offshore wind farm.

Features	Advantages	Benefits
Grouting rate $\geq 20 \text{ m}^3/\text{h}$	<ul style="list-style-type: none"> Faster grouting Shorter weather windows 	<ul style="list-style-type: none"> Reduction of overall installation cost Time saving
Rapid strength development	<ul style="list-style-type: none"> Reduced risk of early age cycling 	<ul style="list-style-type: none"> Cost and time saving Save and durable installation
Bulk material	<ul style="list-style-type: none"> No crane use, no lifting nor moving objects, no warehouse at quay side 	<ul style="list-style-type: none"> Improved safety during operations Cost optimization
Continuous grouting process in closed circuit	<ul style="list-style-type: none"> Less overage nor dust formation Grouting independent of heavy rain 	<ul style="list-style-type: none"> Clean operations Lower cost for grouting works
Siloed material and use of Recirculating Jet Mixer (RJM)	<ul style="list-style-type: none"> Simplified grouting equipment and procedures No open top containers Reduced working area for grouting 	<ul style="list-style-type: none"> Optimized deck layout potentially allowing for additional foundation
Extremely low autogenous shrinkage	<ul style="list-style-type: none"> Volume stable Lower modulus of elasticity; less brittle grout Less stiff grouted connection 	<ul style="list-style-type: none"> Reduced maintenance costs
High fatigue resistance	<ul style="list-style-type: none"> Resistant to dynamic loads 	<ul style="list-style-type: none"> Excellent durability and long term security
Validated by industry experts; and independently and extensively tested	<ul style="list-style-type: none"> Certified quality Full process control 	<ul style="list-style-type: none"> Secure installation Improved risk assessment
Controlled material quality	<ul style="list-style-type: none"> Factory blended material, with extensive control on incoming and final goods Stabilized formulation; no segregation during transport and storage Low heat of hydration 	<ul style="list-style-type: none"> Optimized product quality – even under challenging offshore installation



Making Offshore Grouting more Cost Effective

MasterFlow 9800 from BASF revolutionizes the productivity and safety during grouting of offshore foundations, and consequently can considerably reduce the installation cost and cost of energy.

MasterFlow 9800 is the result of three years of intense development with the goal to overcome most of the offshore challenges with offshore grouting, meaning to deliver significant and quantifiable improvements in productivity and safety when grouting offshore structures.

Unrivalled benefits in terms of application largely contribute to an overall cost reduction of the foundation installation: MasterFlow 9800 is shipped in silos rather than bags, facilitating quayside storage in all weather conditions and more flexibility in vessel deck layout. The excellent flow properties allow the material to be pumped through 2-inch grout lines, which could have a direct impact on the design and cost of the secondary steel.

Grout related project cost

Grout materials used in the offshore foundation installation considerably influence the overall foundation cost. Items that shall be considered in the Grout Related Project Cost (GRPC) are: the choice of the grout product, the grouting concept, grouting works, the grout properties and the risk associated to the grout and grout process, e.g. delays in the project planning. Cost reductions in terms of millions of Euros are feasible.

Compared to other products, MasterFlow 9800 can decrease the overall costs of the foundation sub-contract in an offshore wind energy project by 10 to 15 percent when integrated into project planning at an early stage.

The operational advantages combined with the technical properties of MasterFlow 9800 facilitate substantial time and cost savings during the installation of offshore foundations whilst also ensuring the extreme durability of the grouted connections. Aligning the excellent properties of MasterFlow 9800 with the operational advantages of our grouting contractor's specialized equipment, even improves health and safety significantly. The crucial advantage of MasterFlow 9800 is its silo-compatibility.



Gemini offshore windfarm – proven excellence

The MasterFlow 9800 high-strength grout was mainly chosen because of its unique delivery and installation method, which allowed to considerably reduce the offshore grouting time as part of the foundation installation. The 150 foundations in the Gemini offshore windfarm were grouted at average duration 32 minutes per structure.

The use of MasterFlow 9800 allowed the grout to be installed at much higher rates than previously seen with blended materials, resulting in reduced impact on the vessel's critical path, giving both time and cost savings to the project programme.



Offshore Projects Made more Secure

MasterFlow 9800 has been developed by the Master Builders Solutions experts' especially for application in offshore foundations used in the wind and oil & gas industry. Typical applications involve the grouted connections in steel jacket foundations or similar, e.g. with pile-sleeve or stab-in-pile connections. Other typical applications involve leg filling of damaged or corroded foundations, structural strengthening and clamp repairs.

Product validation

BASF has therefore instructed an industry expert and the AMPA Kassel to verify and validate MasterFlow 9800 for use in offshore wind turbine installations. Throughout the validation process the following activities were conducted:

- Definition and validation of the testing methodology, procedures and extent
- Laboratory testing at a wide range of temperatures, as low as 2 °C
- Evaluation and acceptance of fatigue resistance according to the DNV-OS-C502 guideline
- Evaluation, witnessing and acceptance of various mock-up applications and large scale pumping trials
- Verification of conformity according to EN 206 of the raw materials used in the grout material
- Verification of manufacturing and factory production control in general accordance with the DAfStB guidelines for grouts
- Evaluation and acceptance of the independent laboratory test results
- Validation and acceptance of the large scale mock-up trials
- Evaluation of grout suitability in offshore applications such as grouted connections in jacket foundations for wind turbine installations

Conclusions

The successfully completed verification program is a written assurance that MasterFlow 9800 conforms to specific strength, durability, functional and application requirements, and the product is fit for purpose for the intended offshore installations.

Type approved certificate

DNV GL has been instructed to validate the performance of MasterFlow 9800 according to the offshore guideline DNV-OC-C502 – Offshore Concrete Structures. Representatives of DNV GL witness the extensive laboratory testing and mock-up trials, while also validating the installation method statement and Quality Assurance documentation. Type approval certification will be available by January 2017.



Industry expert inspecting grouting mock-up

Test Report No. 14-2052-10-S3 plus/14	
Client:	BASF Bautechnik GmbH Dr. Albert-Frank-Strasse 12 83308 Trausnitz Deutschland
Commission:	Initial Type Testing of grout material "MasterFlow 9800" According to the information of the producer: Production number: 14-09-0706, -701, -702, -703 Production date: February 2014
Sampling:	---
Test performance period:	April 2014 - June 2014
This test report contains 14 pages and 3 appendices of 11 pages.	
Date:	22.09.2014
Ref:	XX
The client will be able to access the sample material for 21 days following the completion of the test report. On expiry of this period, the sample material will be disposed of without further notice.	
AMPA employees:	
Prof. Dr. K. Hübner Prof. Dr. J. K. Hübner Prof. Dr. H. G. Hübner	Prof. Dr. H. G. Hübner Prof. Dr. H. G. Hübner Prof. Dr. H. G. Hübner
UNIKASSEL-20 14-2052-10-S3	



Excellent Fresh Mortar Properties

Perfect workability even at cold temperatures

Flow properties and workability

The consistency of the fresh grout, its flow properties and flow retention were tested in accordance with EN 12 350-8 and the DAfStB guideline for Self Compacting Concrete (SCC directive). The tests were carried out using the so called Abrahams Cone (Figure 1).

The specific values of the fresh grout material were determined using the minimum mixing water amount, simulating the worst case. Flow properties and retention at different temperatures are shown in Figures 2 to 3.

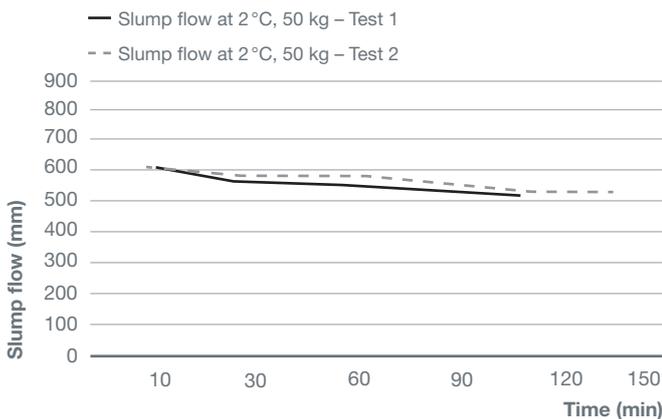
Concrete slump test with Abrams Cone

Figure 1



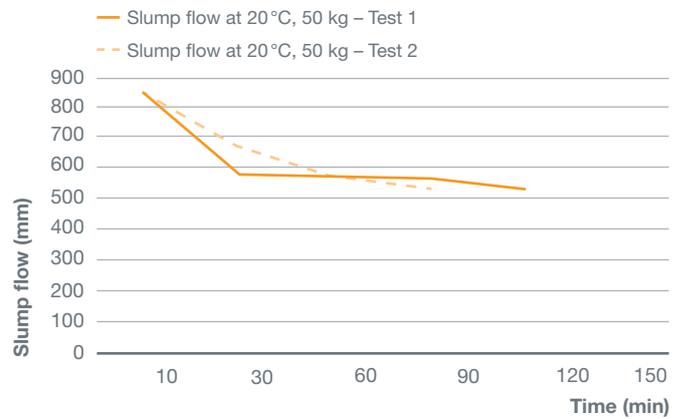
Flow properties at 2 °C

Figure 2



Flow properties at 20 °C

Figure 3



Air content and density

The air content was determined using a pressure compensation container (air void bucket) with a volume of 1 liter (Figure 4). The density of the fresh mortar was determined with the same 1 liter container. Air content and density results are summarized in Table 1.

Table 1

Air content (%)	Wet density (kg/dm ³)
max. 2.9	2.3

Air content measurement

Figure 4





Compressive Strength

Guaranteeing long term load transfer

The compressive strength of MasterFlow 9800 was tested in accordance with EN 12390-3, using 100 mm cubes. The material was evaluated for the compressive strength at 2 °C, 5 °C and 20 °C. At each temperature, 3 cubes were tested at the age of 3 and 7 days, while 6 cubes were crushed to determine the 28 day strength. The average compressive strengths are plotted as a function of age and testing temperature in Figure 5.

Characteristic compressive strength

In view of designing the structural integrity of the offshore foundations, the characteristic compressive strength of MasterFlow 9800 was determined on 12 test cylinders d/h = 150/300 mm, in accordance with EN 12390-3.

A characteristic compressive strength of 96 MPa was calculated according EN 1992-1-1 using the equation below.

According DIN 1045, the material is classified as a C80/95 material.

$$Xk(n) = mx \times (1 - kn \times Vx)$$

with: $Xk(n)$ = characteristic compressive strength

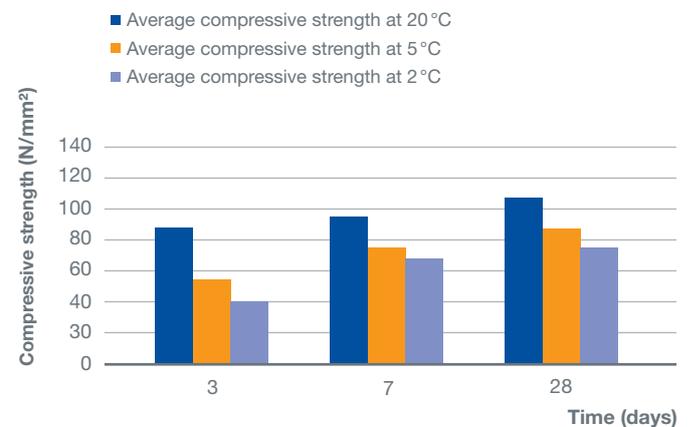
mx = average compressive strength

$kn = 1.888$ [-]

Vx = coefficient of variation

Compression strength at 2 °C, 5 °C, 20 °C

Figure 5



Conversion factor

The conversion factor for 150/300 mm cylinders to 100 mm cubes was determined based on the average compressive strength at 20 °C (Table 2).

Table 2

100 mm cubes	150/300 mm cylinders	Conversion factor
104.8 MPa	99.7 MPa	0.95



Better Early Strength Development

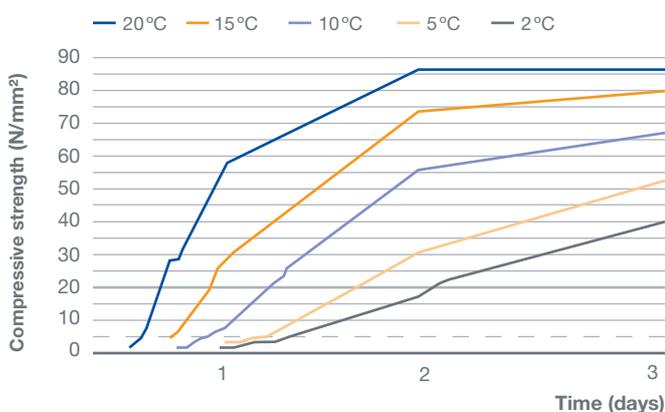
Reducing risk of early age cycling

The early strength development of MasterFlow 9800 was determined on 100 mm cubes. Tests were conducted at temperatures of 20°C, 15°C, 10°C, 5°C and 2°C, with the powder, mixing water and the steel molds pre-conditioned at the given temperatures. The cubes were tested in accordance with EN 12390-3.

Figure 6 shows the strength development of MasterFlow 9800 at early ages for temperatures varying from 2 to 20°C.

Early strength development even at low temperatures

Figure 6



Two values are of importance:

- 5 MPa grouts strength is generally considered in view of the weather windows, wave heights, release of grippers, early age cycling, etc. MasterFlow 9800 achieves this value after approximately 14 hours at 20°C and less than 48 hours at just 2°C.
- 20 MPa is being considered a safe haven in relation to frost resistance of the grout. MasterFlow 9800 reaches such value in less than 18 or 72 hours at respectively 20°C or 2°C.

Mitigating early age cycling

According the DNV guideline DNV-OS-J101, only a limited relative movement between the grouted steel members is allowed during the initial curing of the grout and during the grout hardening period thereafter, in order to ensure proper load transfer between the different steel members of the foundation.

If the expected relative axial movement at the grout-steel interface exceeds a maximum set value during the hardening of the grout, the movement shall be limited/prevented by implementing suitable means.

One way of controlling this relative movement during the hardening phase of the grout is by using mechanical measures. Another way of limiting the risk for Early Age Cycling (EAC) is a rapid strength gain of the grout material, allowing to work in shortest possible weather windows.

The critical strength value of 5 MPa, as a requirement for EAC, is observed with MasterFlow 9800 within 24 hours for environmental conditions $\geq 10^\circ\text{C}$ or 32 hours at only 2°C.



Optimized Mortar Properties

Stabilized formulation and low brittleness factor

Sedimentation stability

The sedimentation stability of the grout was tested and assessed according to the DAfStB guideline on Self Compacting Concrete. The grout, with maximum water content and temperatures of 2 °C, 5 °C and 20 °C, was cast into plastic cylinders. After hardening of the material, the cylinders were sawn in half in the axial direction, to visually assess the aggregate distribution inside the hardened grout material. Figure 7 clearly indicates that no aggregate sedimentation appears over the cylinder's height of 500 mm. The aggregates visible on the cut surface are homogeneously distributed.

Flexural strength

The flexural strength of MasterFlow 9800 was tested on specimens ($l \times w \times h = 150 \times 150 \times 700$ mm) according to DIN EN 12390-5 after 28 days. The average flexural strength is given in Table 3.

Modulus of elasticity

The static and dynamic modulus of elasticity of the MasterFlow 9800 grout was tested on 3 test cylinders ($d/h = 150/300$ mm) in general accordance with DIN 1048-5, at an age of 28 days, and curing at 20 °C under water. The results are summarized in Table 3.

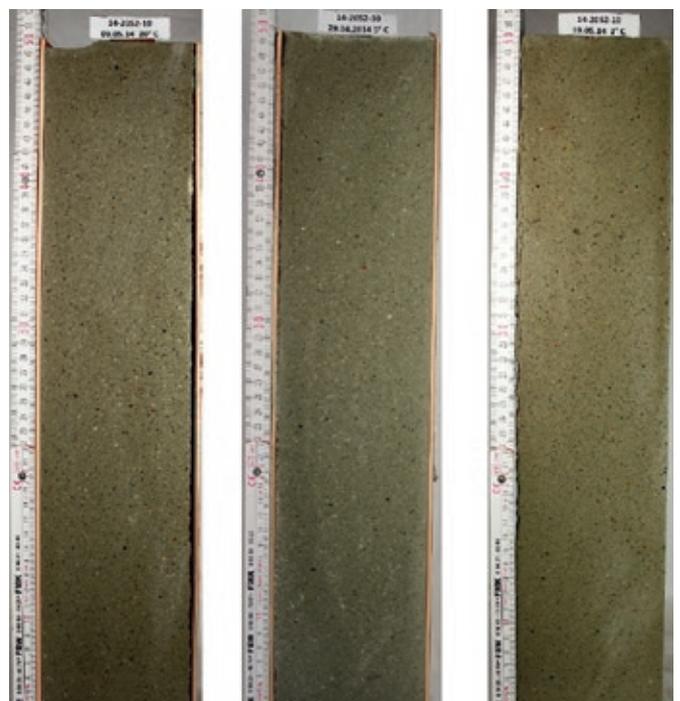
Flexural strength & modulus of elasticity

Table 3

Flexural strength (MPa)	Static modulus of elasticity (GPa)	Dynamic modulus of elasticity (GPa)
10.4	34.1	41.3

No appearance of aggregate sedimentation

Figure 7





Long Term Volume Stability

Shrinkage compensated formulation

Autogenous shrinkage

What is autogenous shrinkage?

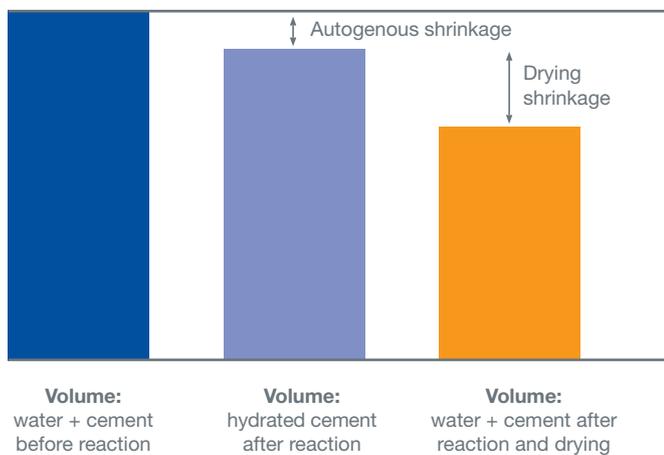
Autogenous shrinkage is the result of the chemical reaction between water and a cementitious material. The volume of the components before the reaction is typically larger than the volume of the end products i.e. hydrated cement (see Figure 8). Autogenous shrinkage can occur in wet conditions, in contradiction to drying shrinkage which occurs only in dry conditions.

Autogenous shrinkage can result in debonding 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 wind turbine installations.

Volume stability is of utmost importance in the long term durability of foundations in offshore wind turbine installations. Verification of the autogenous shrinkage is therefore vital in the validation of the grouting material used in offshore grouted connections.

Volume change before and after water and cement reaction

Figure 8



Measurements with the schleibinger shrinkage drain method

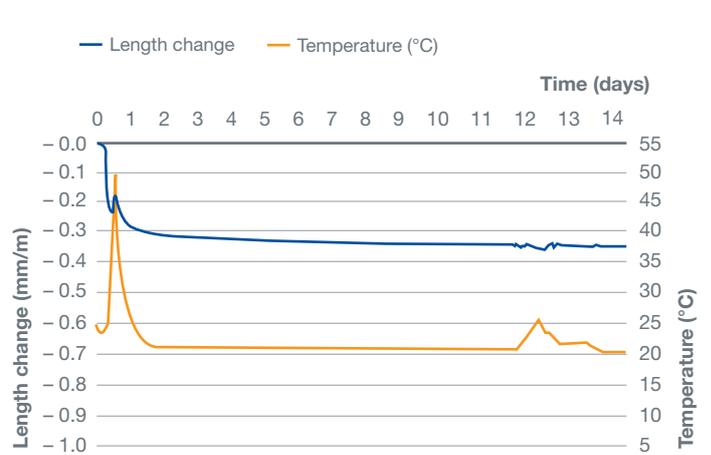
The autogenous shrinkage of the grout material was measured by using the Schleibinger shrinkage drain method at a temperature of 20°C. During the first 14 days the samples were air-sealed to prevent any drying shrinkage from happening. Measurements started approximately 90 minutes after the grout was cast into the drain channel. Figure 10 shows the results of the autogenous shrinkage and grout temperature during curing.

Autogenous shrinkage in MasterFlow 9800 is minimized by shrinkage compensation techniques and chemicals from BASF.

The results shown in Figure 9 clearly indicate a strongly reduced cracking tendency which could result from autogenous shrinkage of the grout material.

After 14 days: Almost no autogenous shrinkage measurable

Figure 9





Outstanding Fatigue Resistance

Managing cyclic loading

Fatigue resistance is the resistance to the progressive and localized 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 resistance

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.

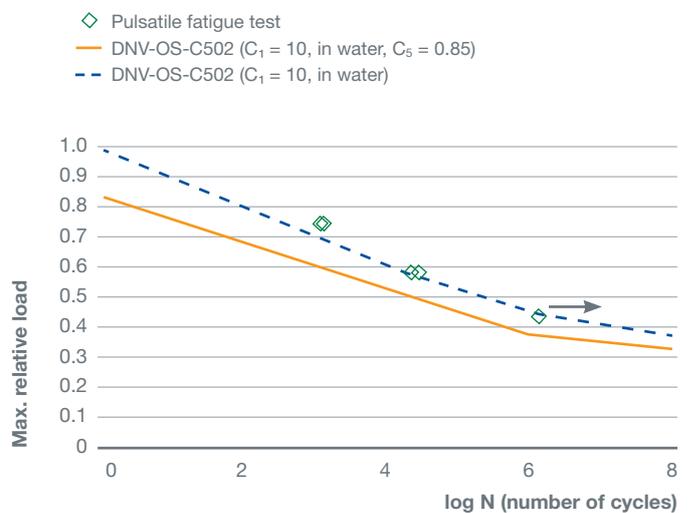
The behavior of MasterFlow 9800 under cyclic loading was studied using 100 mm × 200 mm cylindrical specimens. Fatigue resistance testing for the grout material was conducted with the specimens immersed in water, at a frequency of 4 Hz.

Fatigue equation according the DNV standard

The observed number of cycles to failure under cyclic loading corresponds well with the prediction according to DNV-OS-C502 (Figure 10). It can be concluded that the fatigue design of the grouted connections using MasterFlow 9800 can be carried out using the formulation for fatigue life prediction as given in DNV-OS-C502. Further, safe fatigue calculations can be made using a C_5 factor of 0.85 in the fatigue equation according the DNV standard.

Fatigue resistance according to DNV-OS-C502

Figure 10





Ease of Installation of MasterFlow 9800

Proven performance in mock-up trials

Several mock-up trials were conducted to assess the material and installation properties of the MasterFlow 9800. The dry powder material was delivered in bulk silos to the testing site, where the grout was mixed and pumped through 80 m length – 2” grout hoses, normally used for offshore grouting operations. Typical QA testing was conducted throughout the trials, whereby the mechanical and fresh mortar properties of the grout were tested.

Assessment of the mechanical properties of the grout

To simulate the filling of a grouted connection, several formwork walls were grouted in the same manner as would be carried out during a real offshore operation. This also allowed the mechanical properties of the grout to be assessed after the formwork was removed, by evaluating core strengths and segregation stability of the hardened MasterFlow 9800 (Figure 11).

Compressive strength results

The results of the quality assurance testing have revealed similar results as obtained in the laboratory testing, while the grouting operations clearly indicated the ease of installation of MasterFlow 9800. Compressive strength results measured on 75 mm cubes and cylindrical cores (ratio 1/1) taken from the wall are shown in Table 4.

Mean cube and core strength

Table 4

Mean cube strength 75 mm	Mean core strength ø 100 mm/h 100 mm
115 MPa	112 MPa

Evaluation of core strengths

Figure 11

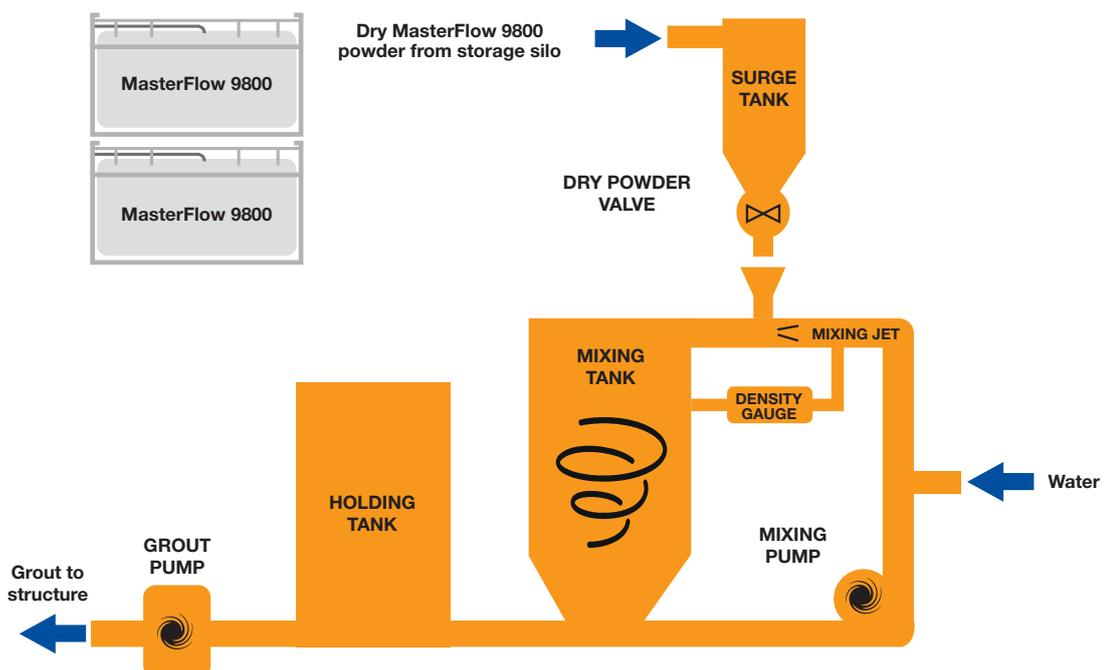




Faster Installation with Recirculating Jet Mixer (RJM)

Recirculating Jet Mixer (RJM) for projects requiring large volumes of grout

Figure 12



Case study

A comparison of traditional offshore grouting with grout material packed in big bags versus the revolutionary grouting using MasterFlow 9800 supplied in bulk silos is presented

below, for a four-legged jacket foundation. The data are based on a project comprising 70 foundations.

Features	Recirculating Jet Mixer (RJM)	Industry Standard Pan Mixer
Grouting rate	≥ 20 m ³ /h	8 m ³ /h
Grouting time of complete jacket	2 h 30	≥ 10 h
No. of slinger banksman	None	2
Crane and crane operator	No	Yes
Deck space	Stacked silos; footprint: 1 x 20 ft frame	5 x 20 ft containers in parallel
Grout waste produced per jacket	0.4 m ³	2.2 m ³
Required utilities	Water, air, electricity	Water, air, electricity and diesel



Master Builders Solutions from BASF

The Master Builders Solutions brand brings all of BASF's expertise together to create chemical solutions for new construction, maintenance, repair and renovation of structures. Master Builders Solutions is built on the experience gained from more than a century in the construction industry.

The know-how and experience of a global community of BASF construction experts form the core of Master Builders Solutions. We combine the right elements from our portfolio to solve your specific construction challenges. We collaborate across areas of expertise and regions and draw on the experience gained from countless construction projects world-wide. We leverage global BASF technologies, as well as our in-depth knowledge of local building needs, to develop innovations that help make you more successful and drive sustainable construction.

Our comprehensive portfolio

- Concrete admixtures
- Cement additives
- Chemical solutions for underground construction
- Waterproofing solutions
- Sealants
- Concrete repair and protection solutions
- Performance grouts
- Performance flooring solutions





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

MasterCem

Solutions for cement manufacture

MasterEase

Low viscosity for high performance concrete

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

BASF Construction Solutions GmbH

Product Management
c/o PCI Augsburg GmbH
Piccardstrasse 11
86159 Augsburg ■ Germany
www.master-builders-solutions.basf.com

BASF plc

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

BASF A/S

Hallandsvej 1
DK-6230 Røddekro
Denmark
P +45 74 66 1511
www.master-builders-solutions.basf.dk

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. It is the responsibility of the recipient of our product to ensure that any proprietary rights and existing laws and legislation are observed (06/2016).

® = registered trademark of BASF group in many countries.

EEBE 1627en