MASTER® BUILDERS SOLUTIONS

MasterFlow 9800

Bulk Supplied Offshore Grout: Revolutionizing Productivity and Safety

A brand of MBCC GROUP

The 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 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 filing from 20 mm to 600 mm, and offshore applications at temperatures as low as 2 °C and as high as 42°C

Making wind energy projects more effective

Master Builder Solutions 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 us amongst others:

- MasterFlow 9800 Exagrout installed by our 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 to 42 °C
Controlled and continuous material quality
Proven quality at wide temperature range

High output
≥ 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

Excellent durability
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 ≥ 20 m^3/h	▪ Faster grouting ▪ Shorter weather windows	▪ Reduction of overall installation cost ▪ Time saving
Rapid strength development	▪ Reduced risk of early age cycling	▪ Cost and time saving ▪ Save and durable installation
Bulk material	▪ No crane use, no lifting nor moving objects, no warehouse at quay side	▪ Improved safety during operations ▪ Cost optimization
Continuous grouting process in closed circuit	▪ Less overage nor dust formation ▪ Grouting independent of heavy rain	▪ Clean operations ▪ Lower cost for grouting works
Siloed material and use of Recirculating Jet Mixer (RJM)	▪ Simplified grouting equipment and procedures ▪ No open top containers ▪ Reduced working area for grouting	▪ Optimized deck layout potentially allowing for additional foundation
Extremely low autogenous shrinkage	▪ Volume stable ▪ Lower modulus of elasticity; less brittle grout ▪ Less stiff grouted connection	▪ Reduced maintenance costs
High fatigue resistance	▪ Resistant to dynamic loads	▪ Excellent durability and long term security
Validated by industry experts; and independently and extensively tested	▪ Certified quality ▪ Full process control	▪ Secure installation ▪ Improved risk assessment
Controlled material quality	▪ Factory blended material, with extensive control on incoming and final goods ▪ Stabilized formulation; no segregation during transport and storage ▪ Low heat of hydration	▪ Optimized product quality – even under challenging offshore installation

Making Offshore Grouting more Cost Effective

MasterFlow 9800 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 several 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.

Unrivaled 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 wind farm – 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 wind farm 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

Master Builder Solutions has therefore instructed an industry expert and various test institutes 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 the DNVGL-ST-C502 guideline
- Evaluation, witnessing and acceptance of various mock-up applications and large scale pumping trials
- Verification of conformity according 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

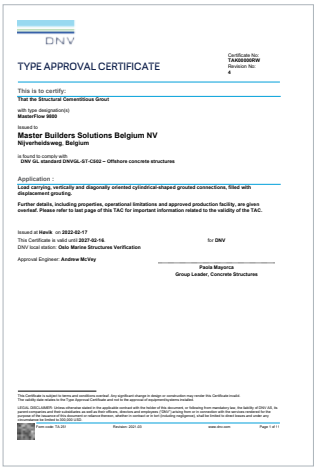
Conclusions

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 validated the performance of MasterFlow 9800 according the offshore guideline DNVGL-ST-C502 – Offshore Concrete Structures. Representatives of DNV GL witnessed the extensive laboratory testing and mock-up trials, while also validating the installation method statement and Quality Assurance documentation. The Type Approval Certificate TAK00000RW, Revision 4 was granted in early 2022.

Industry expert inspecting grouting mock-up



DNV

TYPE APPROVAL CERTIFICATE

Certificate No: TAK00000RW
Revision No: 4

This is to certify:
That the Structural Cementitious Grout

with type designation(s)
MasterFlow 9800

Issued to
Master Builders Solutions Belgium NV
Nijverheidsweg, Belgium

is found to comply with
DNV GL standard DNVGL-ST-C502 – Offshore concrete structures

Application :
Load carrying, vertically and diagonally oriented cylindrical-shaped grouted connections, filled with displacement grouting.

Further details, including properties, operational limitations and approved production facility, are given overleaf. Please refer to last page of this TAC for important information related to the validity of the TAC.

Issued at Høvik on 2022-02-17
This Certificate is valid until 2027-02-16.
DNV local station: Oslo Marine Structures Verification

for DNV

Approval Engineer: Andrew McVey

Paola Mayorca
Group Leader, Concrete Structures

This Certificate is subject to terms and conditions overleaf. Any significant change in design or construction may render this Certificate invalid.
The validity date relates to the Type Approval Certificate and not to the approval of equipment/systems installed.

LEGAL DISCLAIMER: Unless otherwise stated in the applicable contract with the holder of this document, or following from mandatory law, the liability of DNV AS, its subsidiaries and affiliates, their officers, employees, agents and any third party acting on behalf of DNV AS, its subsidiaries and affiliates, for any loss or damage for the purpose of the issuance of this document or reliance thereon, whether in contract or in tort (including negligence), shall be limited to direct losses and under any circumstances be limited to 300,000 USD.

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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).

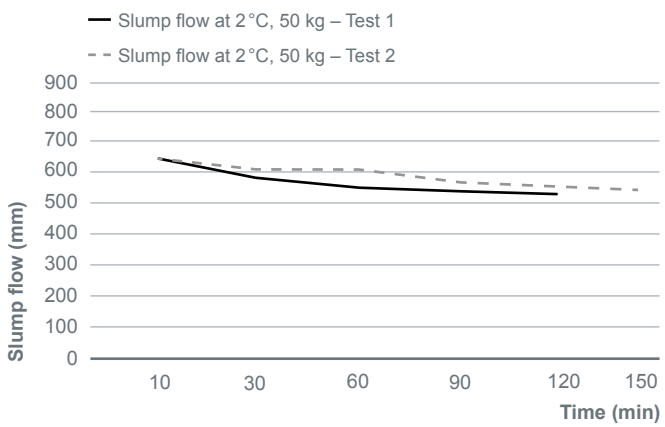
The specific values of the fresh grout material were determined using the minimum mixing water amount, simulating the worst case. Flow properties and retention at different temperatures are shown in Figures 2 to 3.

Concrete slump test with Abrams Cone

Figure 1

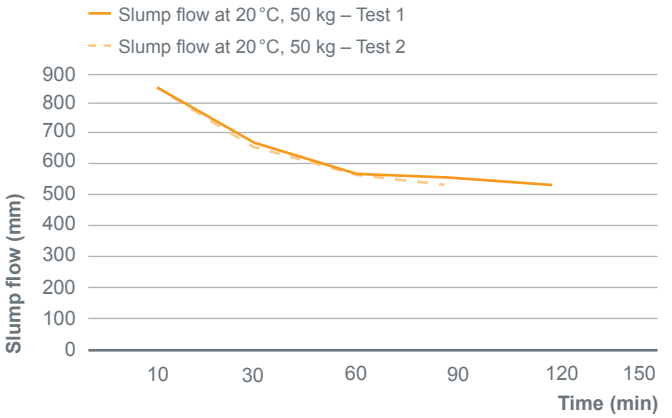
Flow properties at 2 °C

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/dm³)
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.

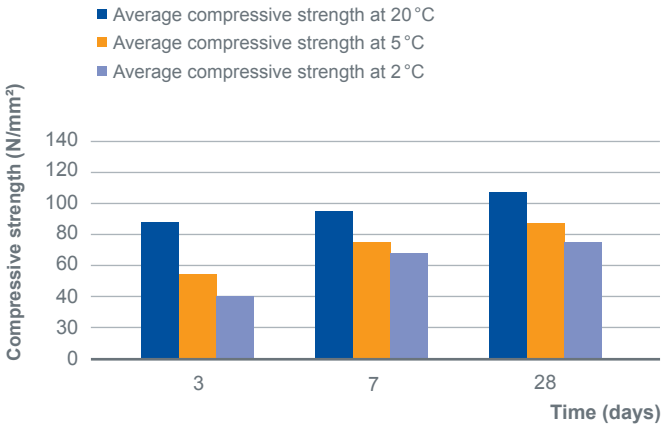
According DIN 1045, the material is classified as a C80/95 material.

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

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

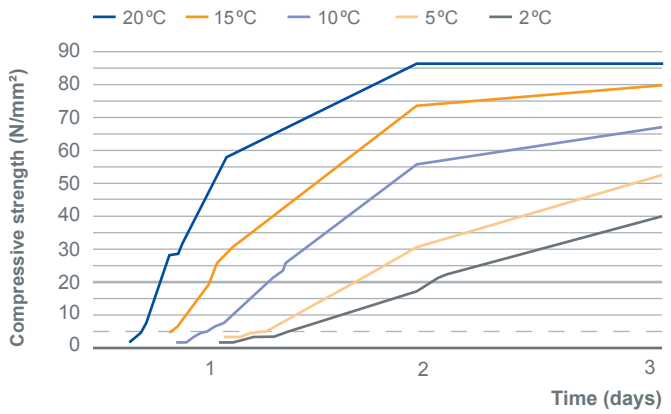
Reducing risk of early age cycling

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 GL guideline DNVGL-ST-0126, 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 ≥ 10 °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 × w × h = 150 × 150 × 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.

Measurements with the schleibinger shrinkage drain method

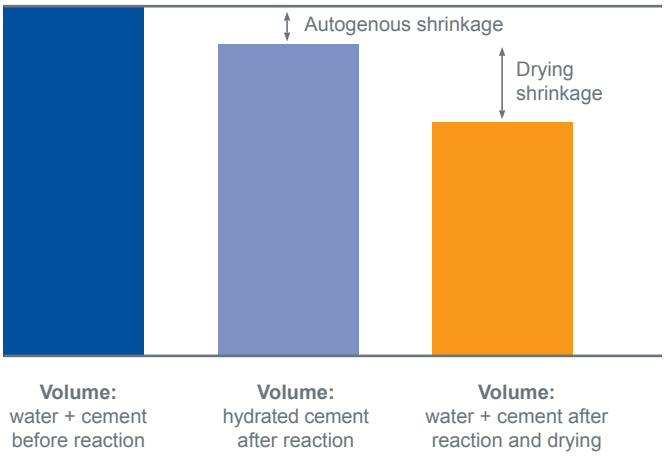
The autogenous shrinkage of the grout material was measured by using the Schleibinger shrinkage drain method at a temperature of 20 °C. During the first 14 days the samples were air-sealed to prevent any drying shrinkage from happening. Measurements started approximately 90 minutes after the grout was 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 highly special chemicals.

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

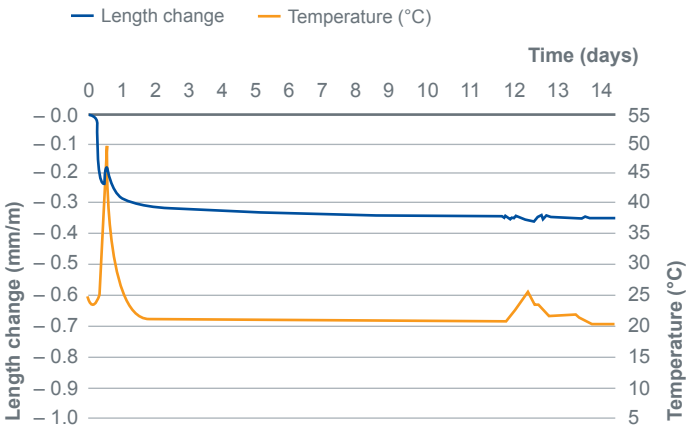
Volume change before and after water and cement reaction

Figure 8



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.

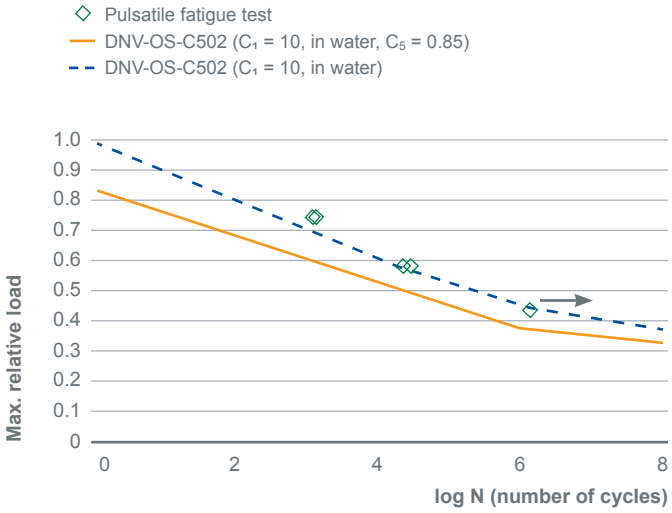
The behavior of MasterFlow 9800 under cyclic loading was studied using 100 mm × 200 mm cylindrical specimens. Fatigue resistance testing for the grout material was conducted with the specimens immersed in water, at a frequency of 4 Hz.

Fatigue equation according the DNV GL standard

The observed number of cycles to failure under cyclic loading corresponds well with the prediction according to DNVGL-ST-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 DNVGL-ST-C502. Further, safe fatigue calculations can be made using a C_5 factor of 0.85 in the fatigue equation according the DNV GL standard.

Fatigue resistance according to DNVGL-ST-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

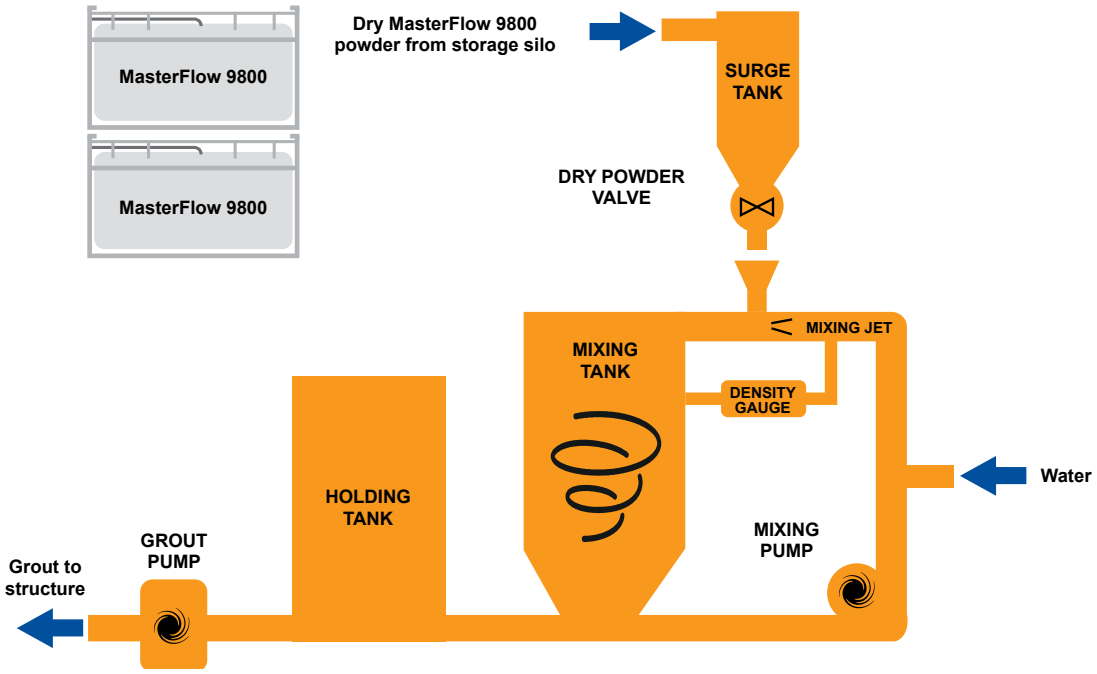
Evaluation of core strengths

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

The Master Builders Solutions brand brings all of our 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 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 worldwide. We leverage global 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.

The comprehensive portfolio under the Master Builders Solutions brand encompasses concrete admixtures, cement additives, solutions for underground construction, waterproofing solutions, sealants, concrete repair & protection solutions, performance grouts, performance flooring solutions and solutions for on- and offshore wind energy.

Our comprehensive portfolio

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

Master Builders Solutions 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
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Comprehensive solutions for fiber reinforced concrete

MasterGlenium
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Solutions for concrete injection

MasterKure
Solutions for concrete curing

MasterLife
Solutions for enhanced durability

MasterMatrix
Advanced rheology control for concrete

MasterPel
Solutions for hydrophobization, anti-efflorescence and surface protection

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

MasterSphere
Solutions for guaranteed freeze-thaw resistance

MasterSuna
Solutions for sand and gravel in concrete

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

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