



## MasterFlow 9650

Fast and Harsh Weather Grouting –  
Certified, Durable and Sustainable



“In the offshore oil and gas industry, rock socket or subsoil grouting is very often done with traditional Ordinary Portland Cement (OPC) grouts. Foundations of tall and slender wind turbine structures are exposed to multiple, much more extreme loads. Hence, such OPC grouts require project specific technical qualification. MasterFlow 9650, however, has demonstrated its suitability through vigorous testing according to the highest offshore standards. The grout comes with a Type Approval Certificate (TAC) from a renowned certification body, and thus avoids project specific qualifications with an uncertain outcome.”

**Luc Westhof**, Head of Global Product Management of Master Builders Solutions





# MasterFlow 9650: Bulk Supplied Grout for Offshore Foundations

MasterFlow 9650 is a rapid hardening, high strength grout for offshore foundations – making rock socket grouting low risk and installations in harsh weather more time and cost efficient

MasterFlow 9650 is especially formulated for foundations which are anchored to the seabed in boreholes. Due to its rapid hardening, the material is also ideally suited for grouting work in very short weather windows:

- For rock socket grouting
- As skirt backfill for monopile foundations with bolted connections
- Where rapid hardening and cold temperature grouting are important
- Applications as low as 0 °C
- Grouting of load carrying cylindrical connections
- Large volume grouting – Volume stable and durable

## Low risk foundation installation

Master Builders Solutions continuously strives to help the offshore industry to be more successful and at the same time become more cost effective. Furthermore, we aim to considerably reduce the risks involved during the construction and exploration of offshore wind farms. For us, managing risks means, amongst other things:

- Dedicated offshore grout materials for specific foundation designs and installation needs
- Type Approval Certification, avoiding the risk of uncertain project specific Technical Qualifications
- Installation by experienced Licensed Contractors

### Product benefits at a glance:



#### Low risk

Stability of fresh grout and rapid strength development reduce the risk for early age cycling.



#### High early strength

Allows installation in very short weather windows. Reducing time between subsequent installation steps.

0 °C  
to  
30 °C

#### Controlled material quality

Proven quality over a wide temperature range.



#### Validation

Type Approval Certification for offshore foundation installations. Certified for load carrying grouted connections. First ever blended grout certified for rock socket grouting.



#### Weather independent

MasterFlow 9650 is bulk supplied and stored on site in closed silos.



#### ≥ 40 m<sup>3</sup>/h

Grouting rates as high as 40 m<sup>3</sup>/h allow fast application in shortest weather windows, and minimize the impact on the critical vessel time.



# MasterFlow 9650: Product Overview – Advantages and Benefits

MasterFlow 9650 is validated by DNV according their offshore standard DNVGL-ST-C502, and a Type Approval Certificate (TAC) has been issued for

- Structural cylindrical grouted connections
- Rock socket grouted connections

Rock socket grouting is a feature of offshore design that is nothing new for the traditional oil and gas industry. However, it is new for offshore wind.

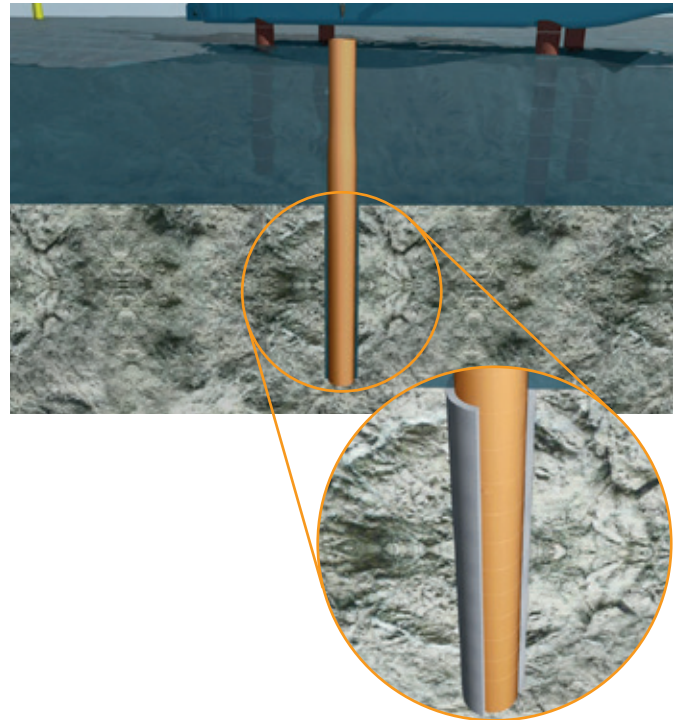
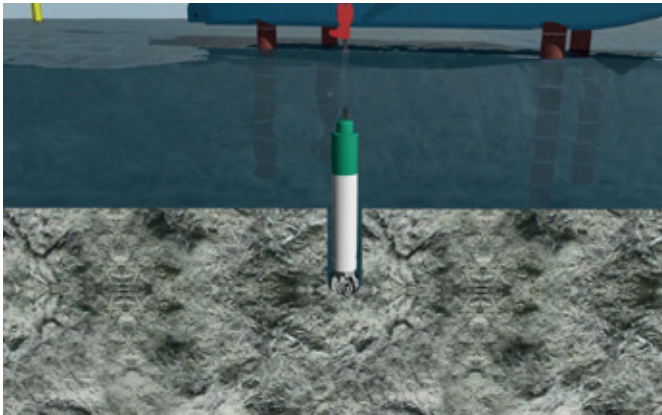
The TAC awarded to MasterFlow 9650 for use in subsoil grouting makes project specific technical qualifications unnecessary and takes away a lot of uncertainty with investors, designers and offshore contractors.

Risk management is key in offshore construction. Rather than following lengthy and uncertain project qualifications, MasterFlow 9650 reduces project risks as it has been found fit for use for all rock socket grouting.

Features	Advantages	Benefits
<b>TAC from industry experts</b>	<ul style="list-style-type: none"> <li>▪ Certified quality</li> <li>▪ Full process control</li> </ul>	<ul style="list-style-type: none"> <li>▪ No need for project specific Technical Qualification (TQ)</li> <li>▪ Improved risk assessment</li> </ul>
<b>Sustainable solution</b>	<ul style="list-style-type: none"> <li>▪ Reduced cement content vs. OPC grout</li> <li>▪ Use of latent hydraulic cement alternatives</li> </ul>	<ul style="list-style-type: none"> <li>▪ Improved eco-efficiency</li> <li>▪ Lower CO2 footprint</li> </ul>
<b>Controlled material quality from production to foundation</b>	<ul style="list-style-type: none"> <li>▪ Factory blended material, with extensive control on incoming and final goods</li> <li>▪ No modification on jobsite</li> </ul>	<ul style="list-style-type: none"> <li>▪ Optimized and uniform product quality</li> </ul>
<b>Rapid strength development</b>	<ul style="list-style-type: none"> <li>▪ Grouting in shorter weather windows</li> <li>▪ Faster continuation with next installation steps</li> </ul>	<ul style="list-style-type: none"> <li>▪ Reduced risk of early age cycling</li> <li>▪ Safe and durable installation</li> <li>▪ Cost and time saving</li> <li>▪ Reduced critical vessel time</li> </ul>
<b>Siloed material</b>	<ul style="list-style-type: none"> <li>▪ No open top containers</li> <li>▪ Reduced working area for grouting</li> </ul>	<ul style="list-style-type: none"> <li>▪ Optimized deck layout</li> <li>▪ Safe operations and improved EHSQ</li> </ul>
<b>Bulk supplied material</b>	<ul style="list-style-type: none"> <li>▪ No craneage, no lifting during grouting works</li> <li>▪ No warehouse needed at marshalling harbor</li> </ul>	<ul style="list-style-type: none"> <li>▪ Improved safety during operations</li> <li>▪ Cost optimization</li> </ul>
<b>Grouting rate <math>\geq 40 \text{ m}^3/\text{h}</math></b>	<ul style="list-style-type: none"> <li>▪ Faster grouting</li> <li>▪ Shorter weather windows</li> </ul>	<ul style="list-style-type: none"> <li>▪ Reduced overall installation cost</li> <li>▪ Time saving</li> <li>▪ Reduced critical vessel time</li> </ul>



## Making Offshore Grouting more Secure



Rock socket grouting as a feature of offshore foundation design is nothing new. In seabed conditions where piles cannot be easily driven, it is often the case that a rock seabed is drilled into before the piles can be placed. The annulus between the piles and the rock is subsequently grouted. The grouted connection between the steel pile and the rock has a structural purpose in transferring the load from the pile to the surrounding rock.

Where traditional oil and gas industry fixed installations are concerned, the loading is predominantly axial. The enormous weight of the typical oil and gas topside helps to counteract the hydrodynamic forces acting upon the jacket structure in the water column. Reduced dynamic loading means relatively low strength grout mixes can be used. Where offshore wind installations fundamentally differ from oil and gas grounded installations is both at once in the absence of enormous axial load from a bulky topside and the presence of complex dynamic loading from the thin, tall, moving turbine atop the foundation.

As such, specifications for rock socket grouting in the offshore wind industry place particular emphasis on grout material performance levels over and above that achievable with basic Ordinary Portland Cement (OPC). Another noteworthy consideration with regard to grout material selection in rock socket applications for the offshore wind industry comes in the form of operability.

That is to say: how quickly will the material achieve the required critical minimum strength to ensure a safe and durable installation?

Typically, lengthy project specific technical qualifications (TQ) under supervision of a certification body, are required. A Type Approval Certification (TAC) for these rock socket applications largely overcomes the need for such project specific TQs. MasterFlow 9650 is certified for subsoil grouting works according DNVGL-ST-C502 and comes with a valid TAC, which is a written proof of the material's suitability for rock socket applications.

In a project where scores of foundations are to be installed, rapid subsequent foundation installations are a far more valuable consideration than in an oil and gas scenario, where only a one-off foundation is to be installed. Exploitation of available and shorter weather windows are key in sequential foundation installation. Repetitive installations still require safe and secure foundations, which is achievable with MasterFlow 9650.



# Low risk Rock Sockets – Safe Grouted Connections

## Subsoil grouting

The specifications for rock socket grouting in the offshore wind industry pay particular attention to grout material performance levels over and above that achievable with basic Ordinary Portland Cement.

There is the focus not only on compressive strength but also, importantly, on volume stability. OPC is not volume stable and will undergo major autogenous shrinkage, also known as chemical shrinkage, as it cures in the annulus. The resulting potential for voids presents a particular problem for the foundation designer since the pile to rock connection via the grout is vital to the long-term structural integrity of the installation.

Another noteworthy consideration with regard to grout material selection in rock socket applications for the offshore wind industry comes in the form of operability, that is to say: how quickly will the material achieve the required critical minimum strength value for the offshore construction project to move on to the next installation?

The above considerations explain the need for a volume stable, rapid strength gain, bulk supplied grout product. MasterFlow 9650 has been designed with this in mind and offers unparalleled performance in precisely the areas of utmost importance for offshore wind industry rock socket grouting scopes.

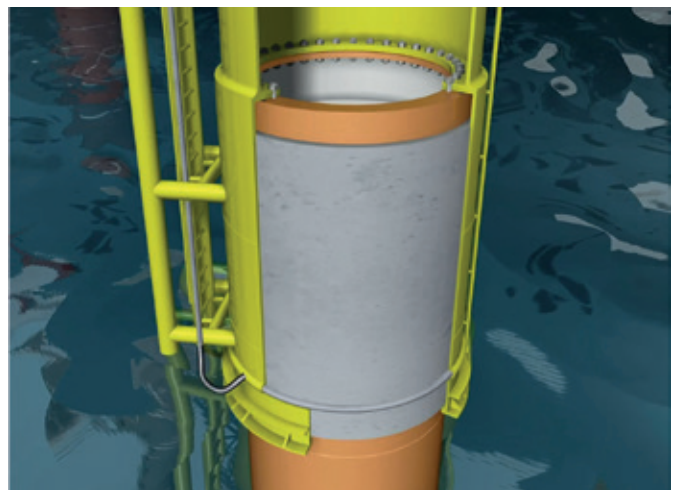
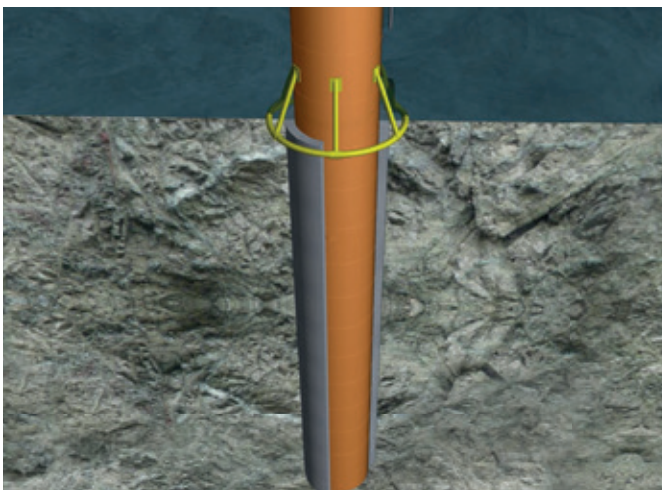
## Steel grouted connections

This rapid strength build-up is also a major benefit for other more traditional grouted connections which are installed in cold environmental conditions. The hardening rate of traditional cementitious materials is considerably retarded by cold temperatures, which makes the grouted connection vulnerable to damage in the early phases of the foundations installation.

Unique technology from Master Builders Solutions has been deployed in the formulation of MasterFlow 9650, which provides rapid grout hardening even in cold temperatures while maintaining long workability times found with traditional grout materials. MasterFlow 9650 thus combines operability during grouting with secure installation already at an early age.

Foundations that are exposed to considerable wave loads and currents can safely be installed in harsh weather with MasterFlow 9650, as the risk for damage due to Early Age Cycling (EAC) is strongly reduced thanks to the fast hardening nature of the offshore grout material.

Furthermore, this rapid strength build-up also allows the material to be installed at temperatures as low as zero degrees (0 °C), which make the product ideally suited for grouting work in the colder periods of the year. As a result, the available weather windows for installation are considerably increased.





# MasterFlow 9650: Proven and Certified Technology

The innovation of MasterFlow 9650 builds upon more than 100 years of experience with cementitious products and cement additives, combined with the skills from pioneering the bulk supplied grouts that have been successfully deployed at multiple offshore windfarms in Europe and Asia.

MasterFlow 9650 is a blended product, meaning that the powder is delivered to site without any requirement for dosing special admixtures on site. Indeed, each batch, whether it is a bagged product, or a bulk supplied product in batch sizes of 25Te, is subjected to factory production control QC procedures in controlled laboratory conditions before leaving the factory for the job site. In an application where poor quality cannot be repaired inexpensively, such exacting quality regimes are paramount to protect project timelines and long-term structural peace of mind.

## Type Approval Certificate

MasterFlow 9650 is validated by DNV according their offshore standard DNVGL-ST-C502, and a Type Approval Certificate (TAC) has been issued in accordance with the approval scheme described in DNVGL-SE-295.

The TAC is applicable for MasterFlow 9650 used for

- Load carrying, vertically and diagonally oriented cylindrical grouted connections and due to its versatile application fields, the material is also suitable for
- Load carrying, vertically oriented cylindrical rock socket grouted connections


## Product validation

To obtain this TAC, a major test program was conducted that included multiple lab tests and various mock-up trials simulating offshore grouting works and applications. The following main activities were conducted:

- Laboratory testing at large temperature range, as low as -1 °C
- Fresh mortar testing including workability over time, but not limited to.
- Hardened mortar testing to determine, e.g., early and final strength, volume stability, bleeding/segregation.
- Large scale simulation of grouted connections being filled using different techniques and grouting equipment.
- Define operational limitations for the offshore grouting works, e.g., minimum diameter and maximum length of grout lines, minimum and maximum water demand, etc.
- Installation procedures and in-situ QA documentation.

## Conclusions

The successful completed validation program is a written assurance that MasterFlow 9650 conforms with the specific offshore requirements and the product is fit for the intended offshore installations.

		Certificate No: <b>TAK000202</b> Revision No: <b>2</b>
<b>TYPE APPROVAL CERTIFICATE</b>		
This is to certify:		
<b>That the Structural Cementitious Grout</b>		
with type designation(s) <b>MasterFlow 9650</b>		
Issued to <b>Master Builders Solutions</b> <b>Nijverheidsweg, Belgium</b>		
is found to comply with <b>DNV GL standard DNVGL-ST-C502 – Offshore concrete structures</b>		
Application:		
<b>Load carrying, vertically and diagonally oriented cylindrical-shaped grouted connections, filled with displacement grouting.</b>		
and		
<b>Load carrying, vertically oriented cylindrical-shaped rock-socket grouted connections, filled with an extracted stringer placement method or displacement grouting.</b>		
<b>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.</b>		
Issued at <b>Høvik</b> on <b>2021-06-18</b>	for <b>DNV</b>	
This Certificate is valid until <b>2026-02-25</b> .		
DNV local station: <b>Oslo Marine Structures Verification</b>		
Approval Engineer: <b>Andrew McVey</b>	<b>Paola Mayorca</b> Group Leader, Concrete Structures	
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<small>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.</small>		
<small>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 parent companies and their subsidiaries as well as their officers, directors and employees ("DNV") arising from or in connection with the services rendered 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 circumstance be limited to 300,000 USD.</small>		
<small>Form code: TA 251</small>	<small>Revision: 2021-03</small>	<small>www.dnv.com Page 1 of 11</small>



# Excellent Fresh Mortar Quality

Perfect workability, large volume application without segregation

## Flow properties and workability

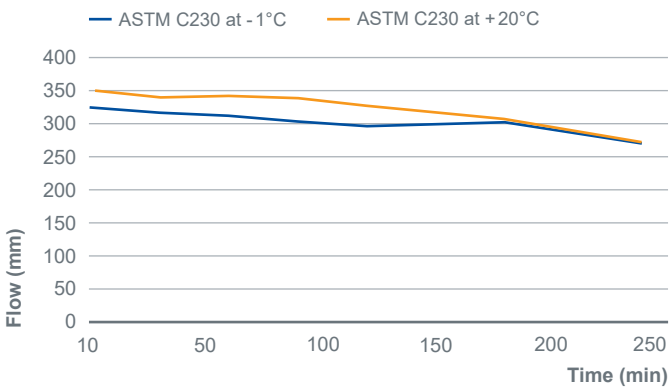
The consistency of the fresh grout and flow retention have been tested in accordance with EN 12350-8 and ASTM C230 to demonstrate the excellent workability of MasterFlow 9650 (Table 1 and Figure 1).

## Flow properties

Table 1

Temperature	Workability time	
	Lower bound	Higher bound
-1 °C	≥ 3 h	≥ 4 h
+20 °C	≥ 2 h 30	≥ 4 h

Figure 1



## Long workability but rapid setting

MasterFlow 9650 ideally combines long workability of the fresh grout with rapid setting. Hence, the grouted connection is safe and secure in a very short time. The risk of early age cycling effects is limited to the minimum. Table 2 shows the setting time at -1 and +20 °C.

## Setting time at -1 °C and +20 °C

Table 2

Setting time	Temperature	
	-1 °C	+20 °C
Initial set	9 h	5 h
Final set	10 h	5 h 30

## Large volume grouting – Risk of bleeding

Subsoil grouting is typically associated with large volume grouting, often more than 100 m<sup>3</sup> per foundation. Volume and segregation stability is key for the materials used. MasterFlow 9650 does not exhibit any bleeding in tests such as ASTM C940 or EN445 (Figure 2).

Figure 2







# Outstanding Mortar Properties

## Rapid strength build-up and high ultimate strength

### Innovative solution

Cold temperatures delay the strength development of cementitious materials, while harsh weather may have a detrimental effect on the structural integrity of the grouted structures. Rapid strength build-up considerably reduces the risk of early age cycling (EAC), but it also allows installation in the shortest weather windows, even in cold environmental conditions.

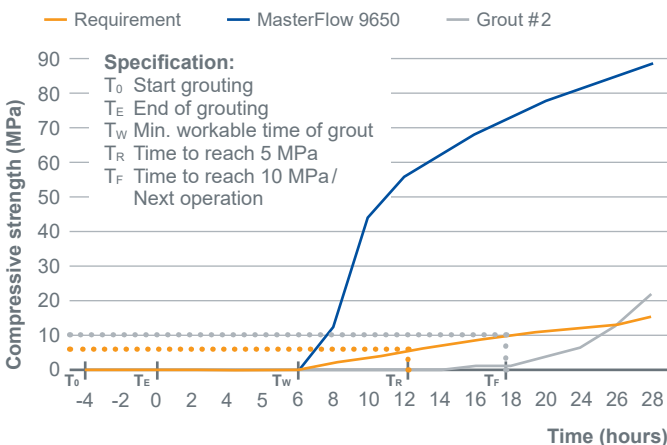
MasterFlow 9650 holds an innovation that ensures such rapid strength development under all conditions and temperatures.

### Optimizing weather windows by selection of grout

Foundation installation contractors aim to make optimal use of weather windows, allowing fast installation and timely completion of the projects. The selection of the grout largely contributes to meeting the targeted installation times of the foundations. A real project example is shown in Figure 3, revealing the time that can be saved with MasterFlow 9650, allowing for a major cost saving through a faster foundation installation campaign.

### Actual versus targeted weather window

Figure 3

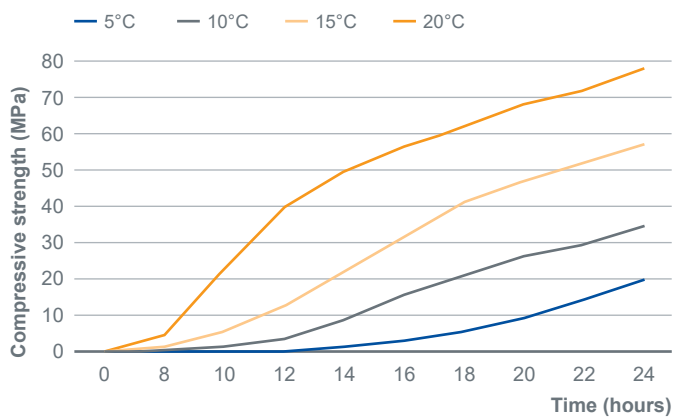


### Rapid hardening is key for a successful installation

Early compressive strength has been measured at various temperatures and for different specimen sizes. Figure 4 shows the strength development using 75 mm cubes at 5°C, 10°C, 15°C and 20°C.

### Early strength development at various temperatures

Figure 4



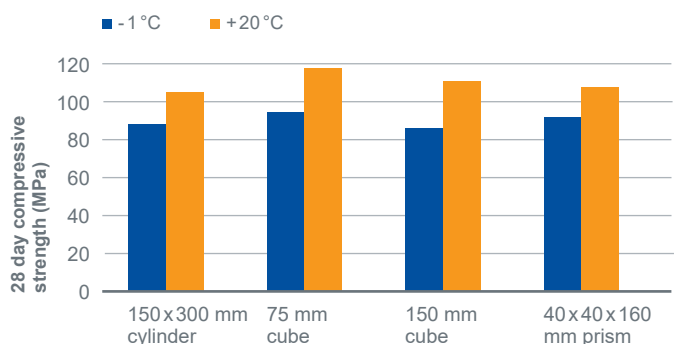
### Meeting typical design strength requirements

Bolted monopile foundations often require a grout skirt backfill material for corrosion protection, but more so to take the loads from boat landings avoiding deformation of the structures. Grout strength requirements are defined depending on the vessels used during the operational phase of the windfarm. Typically, strength classes as high as C60/75 are required. MasterFlow 9650 complies with these requirement, even when hardened at temperatures as low as -1 °C.

Strength classes are defined according concrete norms and refer to cylinders and/or 150 mm cube specimens. However, in the offshore industry it is common to use smaller specimens for QC/QA on site. Figure 5 shows the mean 28 day compressive strength for MasterFlow 9650 using different specimens.

### Compressive strength for various specimens

Figure 5





## Ease of Installation with Different Grouting Equipment



### Bulk supply

MasterFlow 9650 has been developed to provide a stable powder without the risk of segregation of the matrix. This allows for easy installation and guarantees uniform quality of the installed grout.

The material may be delivered by any means of bulk delivery methods, e.g. using road tankers, ISO containers, Cronos silos or similar. MasterFlow 9650 has been vigorously tested during the type approval certification process to demonstrate its suitability for multiple pneumatic transfers, prior to being mixed and installed on site. Equally, it is possible to load the powder into silos that are hoisted on board the installation vessels, without the need for such pneumatic transfers.

### Revolutionary grouting equipment

Typically, MasterFlow 9650 is installed using the traditional RJM (Recirculating Jet Mixer) type of mixers which yield a grout output rate of 15 to 25 m<sup>3</sup>/hour. Such grouting equipment is ideally suited for skirt backfill grouting of bolted monopiles.

Grout volumes to be installed in the grouted connections of the foundations continue to increase, since offshore foundations are becoming ever bigger as a result of the development of the latest, larger wind turbines. Subsoil grouting requires even much larger volumes, and the correct choice of the grout needs to marry with the optimum grouting equipment. Specialist grouting contractors have worked on developing revolutionary grouting equipment for the successful installation of MasterFlow 9650 in such huge volumes typically associated with rock socket grouting.

Large capacity RJMs and specialist batching systems with grout output rates of > 40 m<sup>3</sup>/hour can be used to install MasterFlow 9650. Both installation methods have been validated by DNV as part of the TAC certification process, and are successfully used on different projects using MasterFlow 9650 for rock socket grouting.



# 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

