Certificate no.:
TAK00002BW

TYPE APPROVAL CERTIFICATE

This is to certify:

that the Structural Cementitious Grout

with type designation(s)
PRE U-LOX OFW

issued to
Taiheiyo Materials Corporation
Tokyo, **Japan**

is found to comply with
DNV standard DNV-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 **2024-02-27**
This Certificate is valid until **2024-08-27**.
DNV local unit: **Oslo Marine Structures Verification**

for **DNV**

Approval Engineer: **Marie McGeorge**

Introduction

This Type Approval Certificate (TAC) has been issued in accordance with the DNV Type Approval scheme described in DNV-SE-0295, December 2018 (amended September 2021). Reference is made to the technical requirements specified in DNV-ST-C502, February, 2018 (amended October 2021).

This Type Approval Certificate should be read in conjunction with DNV Summary Report – 2024-1250 – Rev.0, providing references and background data for all presented information. This Type Approval Certificate does not act as an approval for design of any particular grouted connection.

Product description

Table 1 outlines general product information and validity range of the Certificate for PRE U-LOX OFW.

Table 1 Validity for Type Approval Certificate for PRE U-LOX OFW.

Details of Manufacturer / Owner of Certificate	Taiheiyo Materials Corporation
Maximum aggregate size	≤ 3.3 mm
Mixing Water Demand (fresh water)	146 to 150 litres of water per 1000 kg of dry powder, depending on grouting temperature
Approved Production Facility	Taiheiyo Materials Corporation, 6276, Ooaza onoda, SanyoOnoda-shi, Yamaguchi, Japan

Responsibility

The owner, stated as that to which the Certificate has been "issued to" on page 1, takes responsibility that both the design and production are in compliance with the standards listed on page 1 of this Certificate.

Marking of product

The delivered product shall be clearly marked with the manufacturer's name and production facility. Furthermore, the Production Batch Id., production date, shelf life, storage/handling instructions, weight and water demand shall be clearly identified by the label. The current TAC is applicable for production of PRE U-LOX OFW for big bag storage/transportation. Reference to the TAC shall be included on the product label.

Application

The application limitations for the PRE U-LOX OFW material have been determined by laboratory and mock-up tests independently witnessed by DNV. The subsequent application limitations in Table 2 have been established during the Certification Scheme.

Table 2 Main Operational Limitations for Application of PRE U-LOX OFW

Description	Unit	Limitations
Nominal Bore (NB) for grout hoses/lines[1)]	inch	$\geqslant 2$
Grout annulus thickness[2)3)]	mm	$30 \leqslant t \leqslant 1000$
Pumping length through 2” NB flexible hoses[4)]	m	$L \leqslant 200$
Pumping elevation head using 2” NB flexible hoses	m	$H \leqslant 25$
Minimum application temperature ($t_{app,min}$)[5)6)7)9)]	°C	3
Maximum application temperature ($t_{app,max}$)[8)9)]	°C	40
Verified free-fall height through water[10)]	mm	500

1) Limitation for nominal bore is also valid for valves/couplings between each segment of grouting lines/hoses. I.e. the valves/couplings shall not have a reduced nominal bore compared to the grouting lines/hoses.
2) Limitations for grout thickness are valid for annuluses in tubular/conical grouted connections.
3) Temperature gradients over the grouted section should be considered for the application in question.
4) The pumping lengths given for 2” NB grout hoses are considered to be conservative compared to larger diameter hoses. However, temperature effects shall be considered for evaluating the pumping lengths.
5) The minimum application temperature is defined based on a test temperature of 2°C, per DNV-ST-C502, App. H.
6) The minimum application temperature reflects the temperature limit where the material is Certified to develop strength during low temperature grouting.
7) The minimum application temperature shall be taken as the temperature limit of the structure, immediately adjacent to the grouted part, for not less than 72 hours after grouting, or after the grout has attained sufficient strength to resist early frost damage. In lieu of specified requirements related to resistance of early frost damage in DNV-ST-C502, this value may be taken conservatively as 35 MPa. In addition, the minimum application temperature shall be taken as the minimum temperature the material will be exposed to during mixing, pumping, placement.
8) Maximum application temperature shall be taken as the maximum temperature the material will be exposed to during mixing, pumping, placement and during the first 24hours after placement. This includes the temperature of ambient air, surfaces the grout will be in contact with, the structure immediately adjacent to the grouted part, and / or water temperature.
9) Due consideration shall be given to special measures, pre-conditioning of materials and equipment, as well as mixing of the grout, when performing grouting close to the extremes of the qualified temperature range. Reference is made to the Generic Method Statement (Table 12). Temperature effects/gradients for the application in question need to be considered specifically for each project.
10) The maximum stated free fall height is based on successful mock-up testing representative of a typical MP-TP connection. For large volume/wide annuli connections project specific testing may be required to confirm good quality grout is present throughout the entire effective length of the connection.

Fresh Properties

Fresh properties of PRE U-LOX OFW grout documented during the laboratory test programs are presented in Table 3, Table 4 and Table 5. Properties are based on tests undertaken after mixing with laboratory equipment.

Table 3 Summary of fresh properties for PRE U-LOX OFW for testing at 20°C

Test Id.	Type of Test	Test Method	Test Temperature	Test Values		
				Min	Max	Mean
FG1[2)3)]	Flow test (2 min)	ASTM C230/C1437	20°C	245 mm	265 mm	253 mm
	Flow test (30 min)			220 mm	230 mm	227 mm
	Flow test (60 min)			210 mm	240 mm	222 mm
	Flow test (90 min)			205 mm	220 mm	212 mm
	Flow test (120 min)			200 mm	210 mm	205 mm
FG2[2)3)]	Fresh density	EN 1015-6		2210 kg/m³	2270 kg/m³	2237 kg/m³
FG3[2)]	Bleeding	ASTM C940		No observed bleeding		
FG4[2)3)]	Air content	EN 1015-7		3.3 %	3.9 %	3.6 %
FG5[2)3)]	Initial setting time[1)]	EN 196-3		07:55 hh:mm	08:40 hh:mm	08:14 hh:mm
	Final setting time[1)]	EN 196-3		09:25 hh:mm	09:50 hh:mm	09:33 hh:mm

1) Weight of moving parts 1000 grams instead of 300 grams as specified in EN 196-3.
2) Test results are from material testing at MPA (205403). See DNV summary report rev 0 for details.
3) Initial flow, fresh density, air content and setting time was additionally tested at MPA (231975). See DNV summary report rev 0 for details.

Table 4 Summary of fresh properties for PRE U-LOX OFW for testing at 2°C

Test Id.	Type of Test	Test Method	Test Temperature	Test Values		
				Min	Max	Mean
FG1[2)]	Flow test (2 min)	ASTM C230/C1437	2°C	240 mm	290 mm	268 mm
	Flow test (30 min)			225 mm	250 mm	242 mm
	Flow test (60 min)			220 mm	240 mm	230 mm
	Flow test (90 min)			215 mm	220 mm	218 mm
	Flow test (120 min)			190 mm	220 mm	207 mm
FG2[2)]	Fresh density	EN 1015-6		2190 kg/m³	2210 kg/m³	2203 kg/m³
FG3[2)]	Bleeding	ASTM C940		No observed bleeding		
FG4[2)]	Air content	EN 1015-7		3.6 %	4.0 %	3.8 %
FG5[2)]	Initial setting time[1)]	EN 196-3		06:25 hh:mm	07:45 hh:mm	07:16 hh:mm
	Final setting time[1)]	EN 196-3		08:50 hh:mm	09:10 hh:mm	09:00 hh:mm

1) Weight of moving parts 1000 grams instead of 300 grams as specified in EN 196-3.
2) Test results are from material testing at MPA (205403). See DNV summary report rev 0 for details.

Table 5 Summary of fresh properties for PRE U-LOX OFW for testing at 40°C

Test Id.	Type of Test	Test Method	Test Temperature	Test Values		
				Min	Max	Mean
FG1[2)]	Flow test (2 min)	ASTM C230/C1437	40°C	275 mm	285 mm	280 mm
	Flow test (30 min)			220 mm	250 mm	233 mm
	Flow test (60 min)			205 mm	215 mm	210 mm
	Flow test (90 min)			195 mm	210 mm	200 mm
	Flow test (120 min)			195 mm	200 mm	198 mm
FG2[2)]	Fresh density	EN 1015-6		2190 kg/m³	2200 kg/m³	2193 kg/m³
FG3[2)]	Bleeding	ASTM C940		No observed bleeding		
FG4[2)]	Air content	EN 1015-7		4.0 %	4.8 %	4.5 %
FG5[2)]	Initial setting time[1)]	EN 196-3		10:10 hh:mm	10:45 hh:mm	10:30 hh:mm
	Final setting time[1)]	EN 196-3		11:10 hh:mm	12:05 hh:mm	11:40 hh:mm

1) Weight of moving parts 1000 grams instead of 300 grams as specified in EN 196-3.
2) Test results are from material testing at MPA (205403). See DNV summary report rev 0 for details.

Hardened Properties

Characteristic 28-days strengths of relevant hardened material properties for PRE U-LOX OFW are given in Table 6. The 5 % characteristic values are determined in accordance with Appendix D of EN 1990 on the basis of each individual test result from all production batches being tested as part of the laboratory test program. Properties are based on tests undertaken after mixing with laboratory equipment and revaluated based on the mock up test results.

Table 6 Characteristic 28-days strengths for PRE U-LOX OFW acc. to EN 1990

Material Property	Test Specimen	Curing/Testing Temperature [°C]	Notation	Characteristic Value [MPa]
Compressive Strength[1)]	150 x 300 mm cylinders	2	f_{cck}	101.7
		20		119.6
	75 mm cubes	20	f_{ck}	123.5
	40 x 40 x 160 mm prisms	20	$f_{ck,prisms}$	110.6
Flexural Strength[1)]	40 x 40 x 160 mm prisms	2	$f_{ctk,fl}$	15.7
		20		17.6

1. Test results are from material testing at MPA (205403), with the exception of f_{ck} which is calculated based on the test results from retesting at MPA (231975), see DNV summary report rev 0 for details.

Mean values of hardened material properties of PRE U-LOX OFW documented during the laboratory test programs are presented in Table 7, Table 8 and Table 9. Additional hardened properties are presented in Table 10.

Table 7 Summary of hardened properties for PRE U-LOX OFW for testing at 20°C

Test Id.	Type of Test	Test Method	Testing / Curing Temperature	Test Values			Unit
				Min	Max	Mean	
HG1[1)]	Hardened density	EN 12390-7	20°C	2210	2310	2242	kg/m³
HG2[1)]	1 day compressive strength (150 x 300 mm cyl)	EN 12390-3	20°C	66.5	78.1	72.4	MPa
	3 days compressive strength (150 x 300 mm cyl)		20°C	95.8	109.2	101.6	MPa
	7 days compressive strength (150 x 300 mm cyl)		20°C	112.1	123.0	117.2	MPa
	28 days compressive strength (150 x 300 mm cyl)		20°C	120.3	132.2	125.3	MPa
	90 days compressive strength (150 x 300 mm cyl)		20°C	124.5	135.2	130.2	MPa
HG3[2)]	28 days compressive strength (75 mm cubes)	EN 12390-3	20°C	120.4	142.0	131.8	MPa
HG4[1)]	28 days flexural strength (40 x 40 x 160 mm prisms)	EN 196-1	20°C	17.5	22.4	19.9	MPa
HG5[1)]	Creep coefficient after 1 day loading	ASTM C512	20°C	-	-	0.199	-
	Creep coefficient after 28 days loading			-	-	0.578	-
	Creep coefficient after 90 days loading			-	-	0.749	-
	Creep coefficient after 365 days loading			-	-	0.944	-
HG6A[2)]	Autogenous shrinkage strain after 1 day curing	ASTM C1698	20°C	-	-	-0.469	mm/m
	Autogenous shrinkage strain after 28 days curing			-	-	-0.522	mm/m
	Autogenous shrinkage strain after 56 days curing			-	-	-0.577	mm/m
HG6B	Restrained shrinkage strain after 7 days curing	ASTM C1581	20°C			-[3)]	mm/m
	Restrained shrinkage strain after 28 days curing					-[3)]	mm/m
HG7[1)]	Static Young's modulus	ASTM C469	20°C	37.0	38.6	37.7	GPa
	Poisson's ratio	ASTM C469	20°C	0.20	0.22	0.21	-

1) Test results are from material testing at MPA (205403), see DNV summary report rev 0 for details.
2) Test results are from material testing at MPA (231975), see DNV summary report rev 0 for details.
3) Restrained shrinkage values pending, retesting is to be performed within 6 months, see DNV summary report rev 0 for details.

Table 8 Summary of hardened properties for PRE U-LOX OFW for testing at 2°C

Test Id.	Type of Test	Test Method	Testing / Curing Temperature	Test Values			Unit
				Min	Max	Mean	
HG1[1)]	Hardened density	EN 12390-7	2°C	2210	2250	2238	kg/m³
HG2[1)]	3 days compressive strength (150 x 300 mm cyl)	EN 12390-3	2°C	56.6	69.1	64.0	MPa
	7 days compressive strength (150 x 300 mm cyl)		2°C	78.3	84.3	81.6	MPa
	28 days compressive strength (150 x 300 mm cyl)		2°C	101.5	108.1	104.9	MPa
	90 days compressive strength (150 x 300 mm cyl)		2°C	111.1	122.6	117.4	MPa
HG4[1)]	28 days flexural strength (40 x 40 x 160 mm prisms)	EN 196-1	2°C	16.5	21.7	18.8	MPa

1) Test results are from material testing at MPA (205403), see DNV summary report rev 0 for details.

Table 9 Summary of hardened properties for PRE U-LOX OFW for testing at 40°C

Test Id.	Type of Test	Test Method	Testing / Curing Temperature	Test Values			Unit
				Min	Max	Mean	
HG1[1)]	Hardened density	EN 12390-7	40°C	2190	2220	2209	kg/m^3
HG2[1)]	3 days compressive strength (150 x 300 mm cyl)	EN 12390-3	40°C	107.1	118.1	110.5	MPa
	7 days compressive strength (150 x 300 mm cyl)		40°C	104.8	120.0	111.2	MPa
	28 days compressive strength (150 x 300 mm cyl)		40°C	109.8	120.1	115.1	MPa
	90 days compressive strength (150 x 300 mm cyl)		40°C	120.2	129.4	123.8	MPa
HG4[1)]	28 days flexural strength (40 x 40 x 160 mm prisms)	EN 196-1	40°C	18.3	21.4	19.7	MPa

1) Test results are from material testing at MPA (205403), see DNV summary report rev 0 for details.

Table 10 Summary of additional hardened properties for PRE U-LOX OFW for testing at 20°C

Type of Test	Test Method	Testing / Curing Temperature	Test Values	Unit
			Mean	
28 days compressive strength (40 x 40 x 160 mm prisms)[1)]	EN 196-1	2°C	110.1	MPa
		20°C	121.4	MPa
		40°C	121.4	MPa
Fatigue factor C5 – submerged[2)]	DNV-ST-C502	General	0.95	
Fatigue factor C5 – in air[2)]	DNV-ST-C502	General	0.94	

1) Test results are from material testing at MPA (205403), see DNV summary report rev 0 for details.
2) Fatigue test results are from material testing at IFB Leibniz Universität Hannover, see DNV summary report rev 0 for details.

Relevant conversion factors between strength properties obtained on different test specimens are given in Table 11. The conversion factors are based on mean values presented in Table 7.

Table 11 Conversion factors for 28-days strengths for PRE U-LOX OFW

Conversion factor	
f_{ccm} / f_{cm}	0.95
f_{ccm} /$f_{cm.prims}$	1.03
f_{cm} / $f_{cm.prisms}$	1.09

Approved Procedures

The approved procedural documentation for application of PRE U-LOX OFW is shown in Table 12. This Type Approval Certificate is only valid when Taiheiyo Material Corporation's approved Contractors are performing the grouting operation in accordance with the referenced generic method statement and offshore QC procedure.

Table 12 Approved Procedural Documentation for application of PRE U-LOX OFW

Description	Title of Document
Generic Method Statement	Standard Construction Manual, Rev. 07, dated 27.02.2024
Qualification Scheme for 3rd Party Grouting Contractor	Appendix 1 of Standard Construction Manual, Rev. 07, dated 27.02.2024
Offshore QC Procedure	Standard Construction Manual, Rev. 07, dated 27.02.2024

Traceability

In order to operate under a valid Type Approval Certificate for PRE U-LOX OFW, a comprehensive traceability system of all delivery shall be maintained on a project specific basis. This system shall allow the location of all production blends at any point along the delivery line.

Manufacturing Site Approval

The initial audit of Taiheiyo Material Corporation's primary facility at Onoda Plant, Yamaguchi, Japan was successfully carried out August 2nd and 3rd 2022 according to App. I of DNV-ST-C502 (February 2018, amended October 2021)

DNV shall at any time, upon request, be given access to all areas and facilities for production and quality control at the manufacturing facility. The frequency and timing of periodical surveys shall be confirmed in advance with the manufacturer, see Sec 5.4 of DNV–SE-0295.

2 and 3.5 year periodical inspections are required within a 5 year valid period to maintain the certificate valid. The start of the 5 year period is normally the same as the issue date. Per DNV–SE-0295: "The exact timing of the inspections shall be arranged in advance with DNV by the manufacturer."

The main elements of the Periodical Assessment are to:

- Review design, materials, production process, and performance with respect to possible changes, in order to ensure compliance with Type Approval documentation and/or referenced material specifications.
- Ensure traceability between manufacturer's product marking and the DNV Type Approval Certificate.

Renewal Assessment

The scope of the Renewal Assessment is to verify that the conditions stipulated for the Type Approval are complied with and that no alterations are made to the product design or selection of materials. The renewal assessment shall be performed after five (5) years of issuance of this Certificate (Certificate Renewal).

Validity of Type Approval

The following information is provided for all structural grout TACs issued by DNV in accordance with the requirements of DNV-ST-C502, and in accordance with the Type Approval scheme set out in DNV-SE-0295.

The TAC is valid for the grouting of structural connection types for which generic grouting procedures / method statements have been approved as part of the Type Approval process. In this case vertically and diagonally oriented cylindrical-shaped grouted connections, filled with displacement grouting. Operational limitations are specified within the approved procedures. If applicable, additional precautions may be specified within the approved procedures without details explicitly stated on this TAC. The approved procedures are listed in DNV summary report No. 2024-1250, Rev 0, Section 3.2.

The TAC is valid when the material is applied by the owner of the TAC, or by an approved 3rd Party contractor, when the qualification scheme has been approved as part of the Type Approval process. The approved 3rd Party contractor qualification scheme is given in DNV summary report No. 2024-1250, Rev 0, Section 3.3.

The TAC is valid when the material is tested, and field records are kept, in accordance with approved QC procedure. The approved QC procedures are listed in DNV summary report No. 2024-1250, Rev 0, Section 3.4.

The TAC is valid when the material is transported and stored, and traceability records are kept, in accordance with approved QC procedures. The approved QC procedures are listed in DNV summary report No. 2024-1250, Rev 0, Section 3.4.

The TAC is valid when grout is transported, mixed, pumped and installed in line with procedures documented through the Validation testing conducted as part of the Type Approval process. For primary / contingency applications significantly outside of that tested during the Type Approval process in scale, grout line arrangement, duration, or complexity, additional testing may be required on a project specific basis. This should be assessed by the designer, or specifier. If the extent, or limitations of the testing conducted during the Type Approval process is questioned, the manufacturer shall be contacted. The approved Validation test reports are listed in DNV summary report No. 2024-1250, Rev 0, Section 3.5.

Validation tests are based on idealised conditions and sometimes on reduced scale equivalents. While every effort has been made to capture conservatisms, some combinations of application parameters may unintentionally result in conditions which are outside of that documented through the Validation testing. The designer, or specifier, should account for project specific demands of the particular design and / or installation operation, and shall assess if additional testing is required on a project specific basis.

END OF CERTIFICATE