

TYPE APPROVAL CERTIFICATE

This is to certify:**That the Structural Cementitious Grout**with type designation(s)
ShifuGrout U799

Issued to

Ruentex Materials Co., Ltd
Taipei, Taiwanis found to comply with
DNV GL standard DNVGL-ST-C502 – Offshore concrete structures**Application :****For use in load carrying grouted connections.****Further details, including properties, operational limitations and approved production facility, are given overleaf.**Issued at **Høvik** on **2019-09-20**This Certificate is valid until **2020-03-31**.for **DNV GL**DNV GL local station: **Oslo Marine Structures**
VerificationApproval Engineer: **Ole Martin Hauge**

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.



This Type Approval Certificate should be read in conjunction with *DNV GL Summary Report - 2019-0973 – Rev0* 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. Reference is made to DNVGL-ST-C502 (February, 2018) for details and requirements for the Certification Scheme.

Product description

Table 1 outlines general product information and validity range of the Certificate for ShifuGrout U799.

Table 1 - Validity for Type Approval Certificate for ShifuGrout U799

Details of Manufacturer / Owner of Certificate	Ruentex Materials Co. Ltd
Maximum aggregate size	≤ 4 mm
Water Demand (fresh water)	Depending on grouting temperature the initial water demand is set to: 83-93 litres of water per 1000 kg of dry powder, 5 – 30 °C 100-110 litres of water per 1000 kg of dry powder, 30 – 35 °C
Approved Production Facility	Ruentex Materials Co. Ltd: Dongshan Factory, No. 357, Da-An Road, Dongshan Township, Yilan County 26948, Taiwan

As the final review of the laboratory test report, including the one-year creep results, is pending DNV GL review, TAK00001SZ Rev. 0 is issued with a limited validity period of six months.

Marking of product

The packed product shall be clearly marked with the manufacturer's name and production facility i.e. Ruentex Materials Co. Ltd, Yilan, Taiwan. Furthermore, Bag Id., production date, shelf life, weight and water demand shall be clearly identified by the label.

Application/Limitation

The application limitations for the ShifuGrout U799 material have been established during the Certification Scheme based on laboratory and mock-up tests independently witnessed by DNV GL. The application limitations for Shifugrout U799 are presented in Table 2.

Table 2 - TAC General Operational Limitations for Application of ShifuGrout U799

Description	Unit	Limitations
Nominal Bore (NB) for grout hoses	inch	≥ 2
Grout annulus thickness ¹⁾	mm	$40 \leq t \leq 800$
Pumping length through 2" NB hoses ²⁾³⁾	m	$L \leq 160$
Pumping elevation head using 2" NB hoses ²⁾	m	$H \leq 20$
Minimum application temperature ($t_{app,min}$) ⁴⁾	°C	5
Maximum application temperature ($t_{app,max}$) ⁵⁾	°C	35
Verified free-fall height through water ⁶⁾	mm	350

1) Limitations for grout thickness are valid for annuluses in tubular/conical grouted connections.

2) The above limitations for pumping lengths/elevations are not absolute as they are representing performed test setups where no problems were encountered. For applications requiring different lengths/elevations, pumpability tests are recommended on a project basis.

3) 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.

4) The minimum application temperature is defined based on the limitation in DNVGL-ST-C502 for normal temperature testing, as minimum application temperature has not been tested.

5) Due consideration shall be given to pre-conditioning of materials/equipment at elevated temperatures.

6) When the inlets are located at a distance exceeding 350 mm above the seal or bottom of the form, additional measures shall be implemented to limit the risk of segregation due to free-fall through water.

Fresh Properties

The tests of fresh properties of ShifuGrout U799 grout witnessed by DNV GL as part of the Certification Scheme are listed in Table 3 and Table 4. Properties are based on tests undertaken after mixing with laboratory equipment.

Table 3 - Summary of fresh properties for ShifuGrout U799 for testing at 20°C

Test Id.	Type of Test	Test Method	Test Temperature	Test Values		
				Min	Max	Mean
FG1	Flow test (2 min)	ASTM C230/C1437	20°C	285 mm	290 mm	288 mm
	Flow test (30 min)			265 mm	270 mm	267 mm
	Flow test (60 min)			235 mm	260 mm	250 mm
	Flow test (90 min)			225 mm	240 mm	235 mm
	Flow test (120 min)			225 mm	240 mm	233 mm
FG2	Fresh density	EN 1015-6		2320 kg/m ³	2330 kg/m ³	2327 kg/m ³
FG3	Bleeding	ASTM C940		No observed bleeding		
FG4	Air content	EN 1015-7		2.1 %	3.0 %	2.4 %
FG5	Initial setting time	EN 196-3		13:50 hh:mm	14:30 hh:mm	14:08 hh:mm
	Final setting time	EN 196-3		14:45 hh:mm	15:30 hh:mm	15:13 hh:mm

Table 4 - Summary of fresh properties for ShifuGrout U799 for testing at t_{test, max} (35°C)

Test Id.	Type of Test	Test Method	Test Temperature	Test Values		
				Min	Max	Mean
FG1	Flow test (2 min)	ASTM C230/C1437	35°C	300 mm	315 mm	310 mm
	Flow test (30 min)			210 mm	245 mm	225 mm
	Flow test (60 min)			110 mm	130 mm	117 mm
	Flow test (90 min)			100 mm	100 mm	100 mm
FG2	Fresh density	EN 1015-6		2300 kg/m ³	2300 kg/m ³	2300 kg/m ³
FG3	Bleeding	ASTM C940		No observed bleeding		
FG4	Air content	EN 1015-7		2.2 %	2.8 %	2.4 %
FG5	Initial setting time	EN 196-3		04:35 hh:mm	05:45 hh:mm	05:10 hh:mm
	Final setting time	EN 196-3		06:30 hh:mm	07:00 hh:mm	06:45 hh:mm

Hardened Properties

Characteristic 28-days strengths of relevant hardened material properties for ShifuGrout U799 are given in Table 5. 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 programs. Properties are based on tests undertaken after mixing with laboratory equipment.

Table 5 - Characteristic 28-days strengths for ShifuGrout U799 acc. to EN 1990

Material Property	Test Specimen	Curing/Testing Temperature [°C]	Notation	Characteristic Value [MPa]
Compressive Strength	150 x 300 mm cylinders	20	f_{cck}	120.3
	75 mm cubes		f_{ck}	131.2
	40 x 40 x 160 mm prisms		$f_{ck,prisms}$	127.9
Flexural Strength	40 x 40 x 160 mm prisms		$f_{ctk,fl}$	15.3

Several cubes were cast for quality control purposes during the mock-up trials. These cubes showed a lower strength than the calculated 28 day characteristic strength presented above. Due to this, Ruentex proposed a lower f_{ck} to be stated on the TAC. The characteristic strengths are presented in Table 6. The f_{cck} value stated below is calculated based on a conversion factor of 0.91 between the cube and cylinder strength. The characteristic strengths presented in Table 6 should be applied to derive design compressive strength.

Table 6 - Characteristic 28-days strengths for ShifuGrout U799 acc. to EN 1990 – Based on test results obtained during Mock-ups and derived by Ruentex

Material Property	Test Specimen	Curing/Testing Temperature [°C]	Notation	Characteristic Value [MPa]
28 day characteristic compressive strength	150 x 300 mm cylinders	20	f_{cck}	115.5
	75 x 75 mm cubes		f_{ck}	127.0

Mean values of hardened material properties of ShifuGrout U799 documented during the laboratory test programs are presented in Table 7 and Table 8.

Table 7 - Summary of hardened properties for ShifuGrout U799 for testing at 20°C

Test Id.	Type of Test	Test Method	Testing / Curing Temperature	Test Values			Unit
				Min	Max	Mean	
HG1	Hardened density	EN 12390-7	20°C	2360	2400	2382	kg/m ³
HG2	3 days compressive strength (150 x 300 mm cyl)	EN 12390-3	20°C	83.7	94.9	91.2	MPa
	7 days compressive strength (150 x 300 mm cyl)		20°C	102.5	109.3	105.3	MPa
	28 days compressive strength (150 x 300 mm cyl)		20°C	119.3	139.5	128.7	MPa
	90 days compressive strength (150 x 300 mm cyl)		20°C	130.3	142.9	137.4	MPa
HG3	28 days compressive strength (75 mm cubes)	EN 12390-3	20°C	129.6	149.7	140.8	MPa
HG4	28 days flexural strength (40 x 40 x 160 mm prisms)	EN 196-1	20°C	15.1	17.7	16.6	MPa
HG5	Creep coefficient after 1 day loading	ASTM C512	20°C	-	-	0.229	-
	Creep coefficient after 2 days loading			-	-	0.282	-
	Creep coefficient after 3 days loading			-	-	0.324	-
	Creep coefficient after 7 days loading			-	-	0.441	-
	Creep coefficient after 14 days loading			-	-	0.546	-
	Creep coefficient after 28 days loading			-	-	0.666	-
	Creep coefficient after 56 days loading			-	-	0.785	-
	Creep coefficient after 91 days loading			-	-	0.849	-
HG6A ¹⁾	Autogenous shrinkage strain after 1 day curing	ASTM C1698	20°C	-	-	-0.719	mm/m
	Autogenous shrinkage strain after 3 days curing			-	-	-0.691	mm/m
	Autogenous shrinkage strain after 7 days curing			-	-	-0.676	mm/m
	Autogenous shrinkage strain after 14 days curing			-	-	-0.655	mm/m
	Autogenous shrinkage strain after 28 days curing			-	-	-0.655	mm/m
	Autogenous shrinkage strain after 56 days curing			-	-	-0.627	mm/m
HG6B	Restrained shrinkage strain after 1 day curing	ASTM C1581	20°C	-	-	-0.011	mm/m
	Restrained shrinkage strain after 3 days curing			-	-	-0.005	mm/m
	Restrained shrinkage strain after 7 days curing			-	-	-0.014	mm/m
	Restrained shrinkage strain after 14 days curing			-	-	-0.027	mm/m
	Restrained shrinkage strain after 28 days curing			-	-	-0.041	mm/m
HG7	Static Young's modulus	ASTM C469	20°C	43.0	47.8	44.8	GPa
	Poisson's ratio	ASTM C469	20°C	0.18	0.22	0.20	-
HG8	28 days compressive strength (40 x 40 x 160 mm prisms)	EN 196-1	20°C	125.7	143.4	134.9	MPa
HG9	28 days splitting tensile strength (150 x 300 mm cyl)	EN 12390-6:2009	20°C	6.3	7.5	6.9	MPa

1) The autogenous shrinkage strain test results presented show larger autogenous shrinkage than Ruentex's internal testing. The current results from the main certification test program will be reported until more data is available.

Table 8 - Summary of hardened properties for ShifuGrout U799 for testing at $t_{test, max}$ (35°C)

Test Id.	Type of Test	Test Method	Testing / Curing Temperature	Test Values			Unit
				Min	Max	Mean	
HG1	Hardened density	EN 12390-7	35°C	2300	2330	2318	kg/m ³
HG2	3 days compressive strength (150 x 300 mm cyl)	EN 12390-3	35°C	86.8	94.5	90.3	MPa
	7 days compressive strength (150 x 300 mm cyl)		35°C	91.1	105.6	99.9	MPa
	28 days compressive strength (150 x 300 mm cyl)		35°C	122.8	137.2	130.4	MPa
	90 days compressive strength (150 x 300 mm cyl)		35°C	132.0	150.0	140.9	MPa
HG3	28 days compressive strength (75 x 75 mm cubes)	EN 12390-3	35°C	138.1	159.8	148.5	MPa
HG4	28 days flexural strength (40 x 40 x 160 mm prisms)	EN 196-1	35°C	16.2	19.2	17.9	MPa
HG8	28 days compressive strength (40 x 40 x 160 mm prisms)	EN 196-1	35°C	119.3	151.4	134.2	MPa
HG9	28 days splitting tensile strength (150 x 300 mm cyl)	EN 12390-6:2009	35°C	7.3	9.1	7.8	MPa

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 9 and Table 10. Where test results are available at different temperatures for both properties the conversion factors are presented for both temperatures tested.

Table 9 - Mean 28-days strengths for ShifuGrout U799 for testing at 20°C

Material Property	Test Specimen	Curing/Testin Temperature [°C]	Notation	Mean Value [MPa]
Compressive Strength	150 x 300 mm cylinders	20	f_{ccm}	128.7
	75 mm cubes		f_{cm}	140.8
	40 x 40 x 160 mm prisms		$f_{cm,prisms}$	134.9
Flexural Strength	40 x 40 x 160 mm prisms		$f_{ctm,fl}$	16.6

Job Id: **262.1-032423-1**
 Certificate No: **TAK00001SZ**

Table 10 - Mean 28-days strengths for ShifuGrout U799 for testing at 35°C

Material Property	Test Specimen	Curing/Testing Temperature [°C]	Notation	Mean Value [MPa]
Compressive Strength	150 x 300 mm cylinders	35	f_{ccm}	130.4
	75 x 75 mm cubes		f_{cm}	148.5
	40 x 40 x 160 mm prisms		$f_{cm,prisms}$	134.2
Flexural Strength	40 x 40 x 160 mm prisms		$f_{ctm,fl}$	17.9

Table 11 - Conversion factors for 28-days strengths for ShifuGrout U799

Conversion factor	
f_{ccm} / f_{cm}	0.91 (20°C) / 0.88 (35°C)
$f_{ccm} / f_{cm,prisms}$	0.95 (20°C) / 0.97 (35°C)
$f_{cm} / f_{cm,prisms}$	1.04 (20°C) / 1.11 (35°C)

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Approved Procedures

The approved Ruentex procedural documentation for application of ShifuGrout is shown in Table 12. This Type Approval Certificate is only valid when Ruentex's approved contractors is performing the grouting operation in accordance with the referenced generic method statement and offshore QC procedures.

Table 12 - Approved Procedural Ruentex Documentation for application of ShifuGrout U799

Description	Title of Document
Generic Method Statement	Generic Method Statement, Product: ShifuGrout U799, Method Statement, Rev 03, dated 29.08.2019
Qualification Scheme for 3 rd Party Grouting Contractor	Generic Method Statement, Product: ShifuGrout U799, Method Statement, Rev 03, dated 29.08.2019
Offshore QC Procedure	Generic Method Statement, Product: ShifuGrout U799, Method Statement, Rev 03, dated 29.08.2019

Traceability

In order to operate under a valid Type Approval Certificate for ShifuGrout, 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 Ruentex's primary production facility at Ruentex Materials Co. Ltd in Yilan. Taiwan was successfully carried out during the 21st to the 23rd November 2018, according to App. I of DNVGL-ST-C502 (February 2018).

DNV GL shall at any time, upon request, be given access to all areas and facilities for production and quality control at the manufacturing facility (Certificate Retention). The frequency and timing of periodical surveys shall be confirmed in advance with 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).

END OF CERTIFICATE