Project 22+
AD

MSL

JOINT INDUSTRY PROJECT

DEVELOPMENT OF GROUTED TUBULAR JOINT TECHNOLOGY FOR OFFSHORE STRENGTHENING AND REPAIR

PRE-LOAD INVESTIGATION FOR SPECIMEN T1

DOC REF C14100R008 Rev 1 DECEMBER 1994

MSL Engineering Limited

Purpose of Issue	Rev	Date of Issue	Author	Agreed	Approved
Issued to PSC	0	March 1994	DJM	NS	ML
Final Issue	1	December 1994	DJM	ML	ML

JOINT INDUSTRY PROJECT

DEVELOPMENT OF GROUTED TUBULAR JOINT TECHNOLOGY FOR OFFSHORE STRENGTHENING AND REPAIR

PRE-LOAD INVESTIGATION FOR SPECIMEN T1

DOC REF C14100R008 Rev 1 DECEMBER 1994

MSL Engineering Limited
MSL House
5 - 7 High Street, Sunninghill,
Ascot, Berkshire. SL5 9NQ

Tel: +44 (0)1344-874424
Fax: +44 (0)1344-874338

NUMBER	DETAILS OF REVISION
0	Issued to PSC, March 1994
1	Final Issue, December 1994

JOINT INDUSTRY PROJECT

DEVELOPMENT OF GROUTED TUBULAR JOINT TECHNOLOGY FOR OFFSHORE STRENGTHENING AND REPAIR

TECHNICAL REPORT ON THE PRE-LOAD INVESTIGATION FOR SPECIMEN T1

CONTENTS

Page No.

1. INTRODUCTION

It is proposed that a full pre-load investigation be carried out on specimen T1 (see Appendix A for test specimen matrix). The findings from this pre-load investigation will be used to influence the test procedure for the remaining tests. Issues relating to the pre-load level, sign of load and loading condition are covered within this document.

Section 2 contains a technical appreciation of pre-load effects and reviews previous pre-load investigations conducted by others. Section 3 covers the proposed pre-load regime for specimen T1 and subsequent pre-load procedures for the remaining test specimens.

2. TECHNICAL APPRECIATION

2.1 General

The following subsections present a technical appraisal of the behaviour of grouted tubular joints.

Stress Concentration Factors (SCFs) may be dependent on the previous loading history for grouted tubular joints. This aspect is discussed further in Section 2.3.

2.2 Grouted Tubular Joint Behaviour

The presence of grout significantly stiffens the chord member in the beam bending sense and restricts ovalisation of the chord. The presence of grout has the effect of providing more even distribution of stresses local to the joint intersection and restricts chord wall deformations. However, under tensile loading or on the tension side of in-plane or out-of-plane bending, some level of local separation and yielding may occur, giving rise to the notion of potential SCF dependency on pre-load.

The likely reductions in SCFs for the above mentioned load cases are discussed in the following sections.

2.2.1 Axial Loading

It is expected that the reduction in SCFs, over as-welded SCFs, is greatest at the saddle location since resistance at this location to axial loading is predominantly by chord wall bending for small β ratio joints, and membrane action for high β ratio joints. The presence of grout restricts chord wall deformations and ovality and therefore result in a reduction in SCFs.

SCF reductions for compressive brace axial loading is expected to be greater than tensile loading, as the load transfer mechanism involves bearing onto the grout.

2.2.2 In-plane Bending

The reduction in SCFs for in-plane bending loads is expected to be low, given the greater relative stiffness at crown locations viz a viz saddle locations. The presence of grout causes the neutral axis to shift towards the compressive side of the crown. Therefore, the reduction in SCFs would differ between the tension side and the compressive side of the brace.

2.2.3 Out-of-Plane Bending

The expected reduction in SCFs would be similar to that for axial loading. Therefore, the reduction in SCFs would differ between the tension side and compressive side of the brace. However, with cyclic loading each point see's equal tension and compression loading. The chord provides the greatest resistance at the saddle location for both out-of-plane bending and axial loading.

2.3 Pre-load Effects

Pre-load and its magnitude and load sign are expected to effect SCFs for a grouted joint.

Pre-load investigations carried out by Veritec[(1)] indicated that a threshold value existed for double skin grouted joints. The threshold value is defined as being the highest SCF measured for a pre-load value. The threshold value was obtained by steadily increasing tensile pre-load prior to SCF measurements at lower working loads, until a drop in the measured SCF was observed. The threshold value was found when the pre-load resulted in the total strain at the hot spot location was substantially beyond yield, which caused considerable local yielding in the chord wall.

The behaviour for fully grouted tubular joints would be expected to be similar to double skin grouted joints.

The Veritec work also measured residual strains as the specimens went through the first SCF measurement cycle. These residual strains increased as the pre-load levels increased. Subsequent shake down procedures were adopted. A number of cycles, at a working load corresponding to a maximum stress within yield at the hot spot location, were conducted until measured residual strain was less than 1%.

It was found that SCFs measured in specimens which had received reversed pre-loads, ie. tensile and compressive, were larger than those which had experienced one-side pre-load.

3. TESTING

3.1 Pre-load Investigations on Specimen T1

Examination and assessment of public domain information has indicated that pre-load and the magnitude of pre-load may have a significant effect on the SCF values for a fully grouted tubular joint. It is therefore proposed that the first test specimen (T1) be used to investigate the effects of pre-load. The specimen will be investigated for SCF determination for in-plane, out-of-plane, axial compression and axial tension loading cases, in turn. SCFs will be calculated for loading in the above-noted sequence, since in-plane loading results in the lowest SCFs and axial tension gives rise to the highest SCFs. The following test procedure and sequence are proposed for specimen T1:

STEP	FORM	LOAD CONDITION
1	Ungrouted	Apply ten cycles of in-plane bending load on the brace of a set percentage of the predicted ultimate load of the ungrouted joint subjected to in-plane bending. The purpose of this is to 'shake' out residual strains.
2	Ungrouted	Apply in-plane bending loads to the brace in three equal increments, upto to a maximum of 20% of the predicted ultimate load of the ungrouted joint subjected to in-plane bending. At each load increment level, measure SCFs. Reduce the load in three stages, taking SCF measurements at each load level.
3	Ungrouted	Repeat steps 1 and 2 for out-of-plane bending, axial compression and axial tension, in turn. For each load condition the shake out loading and the limiting load will be taken as 20% of the appropriate predicted ultimate load of the ungrouted joint for the load condition under investigation.
4	Grouted	Repeat steps 1, 2 and 3.
5	Grouted	Apply axial pre-load (tension and compression) to the brace member. The magnitude of pre-load shall be 20% of the predicted ultimate strength of the joint under axial tension.
6	Grouted	Remove load from the brace member.

STEP	FORM	LOAD CONDITION
7	Grouted	Repeat steps 1, 2 and 3.
8	Grouted	Repeat step 5 and 6, but with a pre-load of 30%.
9	Grouted	Repeat steps 1, 2 and 3.
10	Grouted	Repeat steps 8 and 9 for 40% and thereafter in 10% increments to beyond 60% of the predicted ultimate strength of the joint under axial tension.
11	Grouted	Terminate the test at point of threshold - ie. at point where SCFs begins to decrease or become constant.

3.2 Pre-load Regime for Remaining Specimens

The pre-load regime for remaining specimens will be determined after completion of test T1 and assessment of the results of this test. It is considered unlikely that the remaining specimens will be investigated to point of threshold.

3.3 Instrumentation

The Veritec work used single filament strain gauges to determine the hot spot location for both the ungrouted and grouted specimens. Once located, the specimens were re-instrumented with single filament and rosette strain gauges.

For this JIP, it is proposed to 'crowd' one quadrant of each specimen with strip gauges. This will ensure that the hot spot is accurately located and enable determination of the hot spot SCF.

REFERENCES

1. VERITEC, 'Double Skin Grout Reinforced Tubular Joints' Trial Report No. 84-3564, Volumes 1 and 2, November 1984.

APPENDIX A

TEST SPECIMEN MATRIX

Braces / Chords	β = 0.414		β = 0.672		β = 1.0	
406.4 x 16 γ = 12.7 Fe 360(1)	**168.3 x 16** τ = 1.0 Fe 510(2)	**T1**	**273 x 16** τ = 1.0 Fe 510(2)	**DT2**	**406.4 x 16** τ = 1.0 Fe 510(2)	**DT3** **T3**
406.4 x 9.5 γ = 21.4 Fe 360(1)	**168.3 x 10** τ = 1.05 Fe 510(2)	**DT4**	**273 x 10** τ = 1.05 Fe 510(2)	**DT5** **T5**	**406.4 x 9.5** τ = 1.0 Fe 510(2)	**DT6**
406.4 x 7.9 γ = 25.7 Fe 360(1)	**168.3 x 8** τ = 1.01 Fe 360(1)	**T7**	**273 x 7.8** τ = 0.99 Fe 360(1)	**DT8**	**406.4 x 7.9** τ = 1.0 Fe 360(1)	**DT9** **T9**

Notes

(1) or equivalent , $Fy_{nominal} = 240$ N/mm^2

(2) or equivalent , $Fy_{nominal} = 355$ N/mm^2

Table 1

Finalised Test Matrix