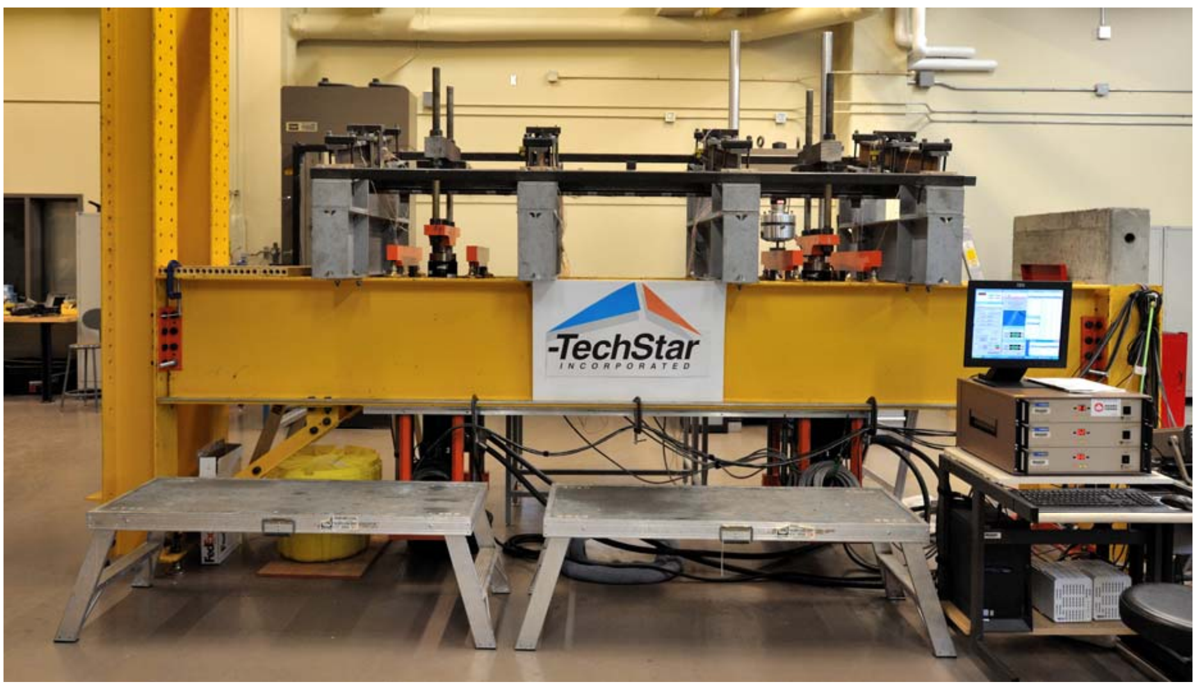
ÉCOLE DE TECHNOLOGIE SUPÉRIEURE
DÉPARTEMENT DE GÉNIE DE LA CONSTRUCTION
**DRSR** : **D**EVELOPMENT & **R**ESEARCH FOR **S**TRUCTURES AND **R**EHABILITATION

# EXECUTIVE SUMMARY REPORT

# FATIGUE TESTING OF TECHSTAR SINGLE SUPPORT BAR MODULAR BRIDGE EXPANSION JOINT WITH WELDED STIRRUPS




TechStar INCORPORATED

ÉTS
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# FATIGUE TESTING OF TECHSTAR SINGLE SUPPORT BAR MODULAR BRIDGE EXPANSION JOINT WITH WELDED STIRRUPS


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# FATIGUE TESTING OF TECHSTAR SINGLE SUPPORT BAR MODULAR BRIDGE EXPANSION JOINT WITH WELDED STIRRUPS

This executive report is a summary of an exhaustive study sponsored by TechStar Incorporated, and carried out in the structural laboratory of École de technologie supérieure, Université du Québec in Montreal. The detailed results of the study can be found in the technical report entitled: *Fatigue Testing of TechStar Single Support Bar Modular Bridge Expansion Joint with Welded Stirrups*, which was submitted to TechStar in April 2012.

## Context

In order to optimize the design of its Modular Expansion Joints for Bridges (MEJ), TechStar Inc. sponsored a study on fatigue performance of its system of **Single Support Bar (LG Type) Modular Bridge Expansion Joint (MBEJ) with Welded Stirrups**. The experimental study was carried out by the research team *DRSR: Development & Research in Structures and Rehabilitation* at the Structures Laboratory of The Departement of Construction Engineering, École de Technologie Supérieure (University of Quebec) in Montreal from January 2011 to April 2012.

## Objectives of the Study

The main objective of the study is to evaluate the fatigue resistance of critical details of this modular joint system, with particular emphasis on the welded stirrups. Specific objectives were set as follows: (**a**) establish an experimental fatigue curve, with at least 10 points, for the details of the stirrups welding to the center-beam, and (**b**) verify that the stirrup details of the MBEJ identified above meet fatigue Category C of the AASHTO LRFD 2007 Bridge Design Code requirements.

## Description of Test Specimens

Three identical subassemblies of the modular joint system were tested in fatigue. Details of the test specimen are shown in **Figure 1**. Each specimen is made of a 3020 type center-beam (**I**-beam with overall dimensions: 130×80 mm) supported by four equally spaced 1081 mm long support bars and forming three spans of 910 mm each. Support bars are maintained in place through 4 stirrups (S1 to S4, see Figure 1) which are welded to the center-beams.

## Test Procedure

All the tests were carried out in conformity with the requirements and guidelines of the procedure of AASHTO LRFD 2007 Bridge Design Code, *Section 14.5.6.9 – Model Bridge Joint System*, which is based on the National Cooperative Highway Research Program, NCHRP-402 Report entitled: *Fatigue Design Criteria for Modular Bridge Expansion Joints* (NCHRP, 1997). This includes the test procedure, the calculation of the stresses due to the loading cases used and the rupture criteria.

*Testing Frame:*

The fatigue testing was undertaken in the finite life range. Both vertical and horizontal load ranges were applied to the test specimen simultaneously in the following proportions: (a) Vertical Load Range = $\Delta P_v$; and (b) Horizontal Load Range = 0.2 $\Delta P_v$. To that end, the test specimen was seated on the test frame at an inclination of 11.3° from the horizontal plane and the resultant load was applied through actuators oriented in the vertical plane.

*Instrumentation:*

The test specimens were instrumented in order to measure nominal strain ranges for the planned load range. Each specimen was comprehensively instrumented with more than 40 gages installed along the center-beam as well as on the stirrup legs (see **Figure 2**). Displacement transducers were also used to monitor horizontal as well as vertical displacements.

*Fatigue Loading:*

The loads were applied using two synchronized actuators under force control conditions (distance between the two actuators = 1946 mm), as illustrated in **Figure 3**. Different load ranges, varying between 130kN/actuator and 175kN/actuator, were applied for each specimen in order to obtain a sufficient number of points defining the experimental fatigue (S-N) curve. The number of cycles varied between 1 200 550 and 3 163 276 cycles. **Table 1** provides a summary of applied loads, load amplitudes and number of cycles for each of the specimens.

*Calibration Tests:*

Prior to fatigue testing, each specimen was submitted to static calibration tests. These calibration tests allowed the structural models to be validated, and the robustness of the data acquisition system and the repeatability of experimental data to be verified, all in conformity with the requirements of the AASHTO LRFD 2007 Bridge Design Code and the NCHRP-402 Report (NCHRP, 1997).

**Table 1: Applied Load and Amplitude of the Load per Actuator**

| Specimen | Applied static load (kN) | Load range per actuator (kN) | Frequency (Hz) |
|---|---|---|---|
| MJ1 | 95 | ± 65 | 2.0 |
| MJ2 | 105 | ± 75 | 2.0 |
| MJ3 | 117.5 | ± 87.5 | 1.5[a] |

[a] Frequency reduced with increasing stress range to maintain an acceptable level of vibration.

## Results

Test results are summarised in **Table 2** for the three test specimens, which were labelled MJ1, MJ2 and MJ3.

**Table 2: Test Results**

| | | **Nb. of cycles at first crack** | **Crack type** | **Nb. of cycles at failure** | **Crack Propagation** | **Comments** | |
|---|---|---|---|---|---|---|---|
| **MJ1** | S1 | - | - | - | - | No crack | Test stopped at **3 163 276** |
| | S2 In | 2 300 000 | B | 2 927 965 | Top Stirrup | Failure | |
| | S3 | - | - | - | - | No crack | |
| | S4 | - | - | - | - | No crack | |
| **MJ2** | S1 In | 2 125 000 | B’ | 2 299 521 | Stirrup leg | Failure | Test stopped at **2 877 500** |
| | S2 In | 1 334 000 | A | - | Center-beam | No failure | |
| | S3 Out | 1 334 000 | A | - | Center-beam | No failure | |
| | S4 | - | - | - | - | No crack | |
| **MJ3** | S1 | - | - | - | - | No crack | Test stopped at **1 200 550** |
| | S2 | - | - | - | - | No crack | |
| | S3 Out | 710 000 | A | - | Center-beam | No failure | |
| | S4 | - | - | - | - | No crack | |

**Notes:** **In =** Inner side = cracks occurs between stirrups and loading point
**Out** = Outer side = cracks occurs between the two central stirrups

*Observed Failure Modes:*

All the observed failures are of three cracking types as defined in **Figure 4**. Note that the failure criteria were inspired from NCHRP-402 Report. Three **Type A** cracks occurred: two in the second test specimen at the inner side of stirrup S2 and outer side of stirrup S3, and one in the third test specimen at the outer side of stirrup S3. These cracks originated at the center-beam weld toe and progressed into the center-beam before reaching the rupture criterion (**Figure 5**). One **Type B** (top weld) and one **Type B'** (bottom weld) cracks also occurred respectively in the first test specimen (Type B, inner side of stirrup S2) and the second test specimen (Type B', inner side of stirrup S1). These cracks progressed in a plane parallel to the transversal axis of the stirrup leg (**Figure 6**).

*Compatibility with Fatigue Category C:*

The twelve S-N (**S**tress range versus **N**umber of cycles) experimental points obtained are drawn in **Figure 7** along with the S-N lower limit curves specified by the AASHTO LRFD 2007 Bridge Design Code for selected fatigue categories, including the targeted category C. As can be seen from these figures, the fatigue resistance of the welded stirrup details of the MBEJ is compatible and meets category C requirements as defined by the AASHTO LRFD 2007 Bridge Design Code.

**Conclusions**

Fatigue results confirm that **the fatigue resistance of the welded stirrup connection details of the TechStar Single Support Bar MBEJ is compatible with (and meets) the fatigue Category C requirements** of the AASHTO LRFD 2007 Bridge Design Code.

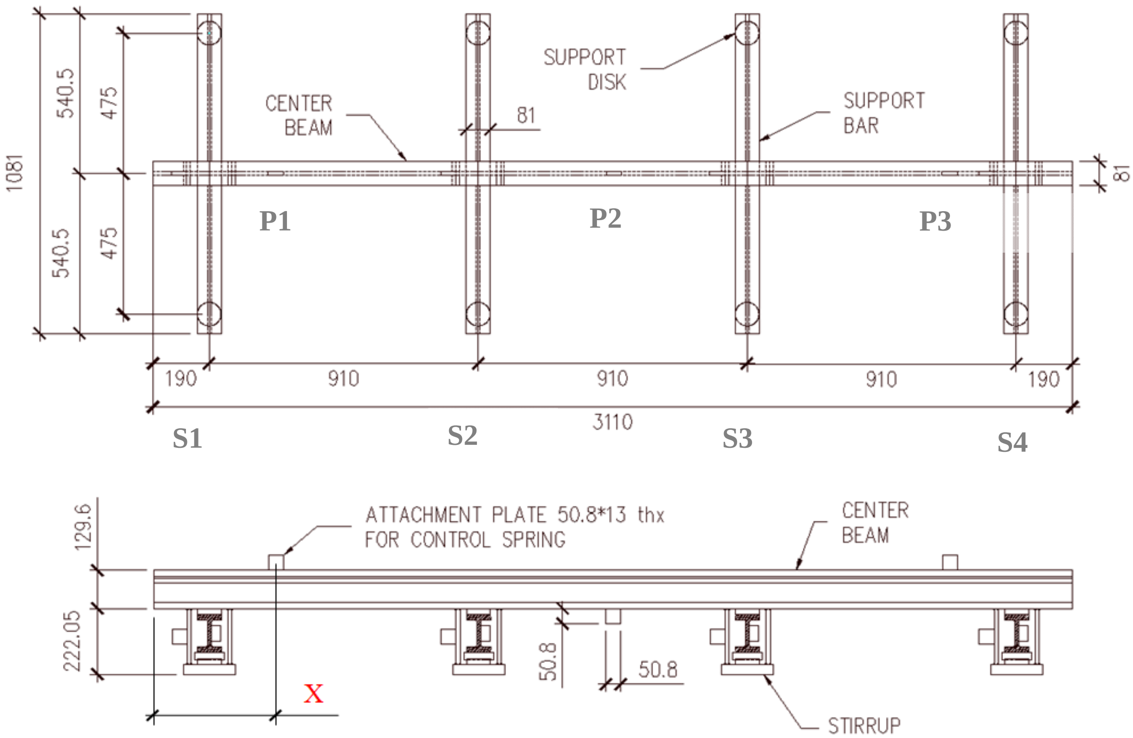


**Figure 1 – Details of the Specimen**

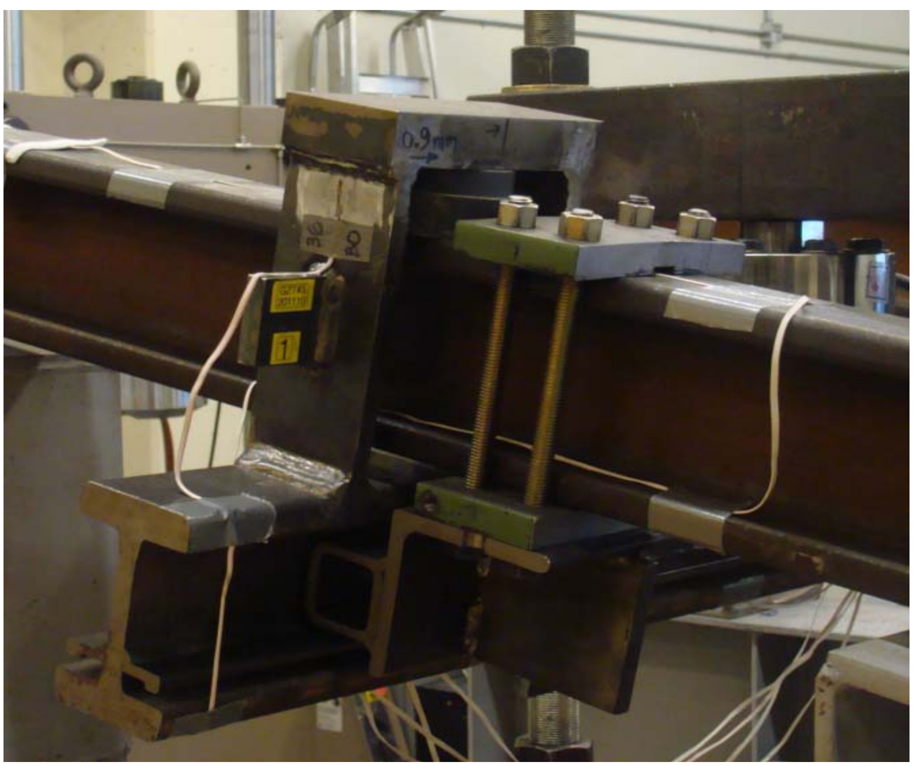

**Figure 2 – View of Instrumented Welded Stirrup Detail**

**Figure 3 – Instrumented Specimen Mounted on the Specially Designed Test Frame**

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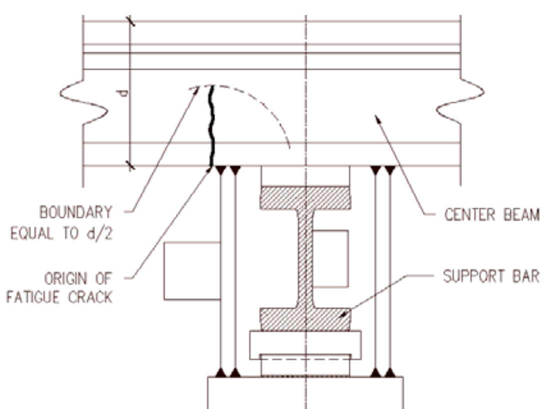
<td>
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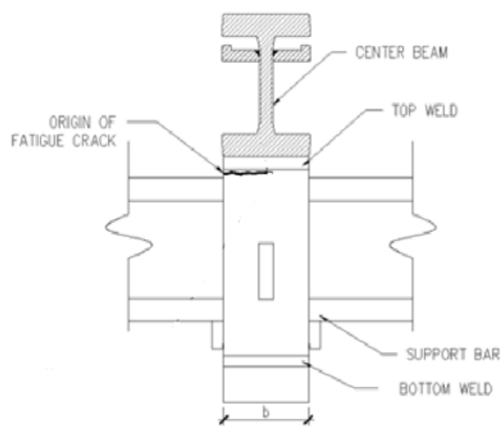
<td>
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<td>Type A cracking originates at the center-beam near the stirrup (welded) connexion and propagates straight into the center-beam. A specimen shall be considered as failed due to Type A cracking when a crack has grown on any vertical face to a length of d/2 from the point of origin, where d = depth of the center-beam.</td>
<td>Type B (or B') cracking originates at the top (or bottom for B') of the stirrup leg near the weld head and grows in a plane parallel to the transversal axis of the stirrup leg. A specimen shall be considered as failed due to Type B (or B') cracking when a crack has reached a length of b (depth of the stirrup leg) from the point of origin through any stirrup leg.</td>
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**Figure 4 – Types A, B and B' Cracking and Failure Criteria**


**Figure 5 – Type A Cracking at Stirrup S3 at 1 200 500 cycles**


**Figure 6 – Type B Cracking at Stirrup S2 at 2 300 000 and 2 927 965 cycles**

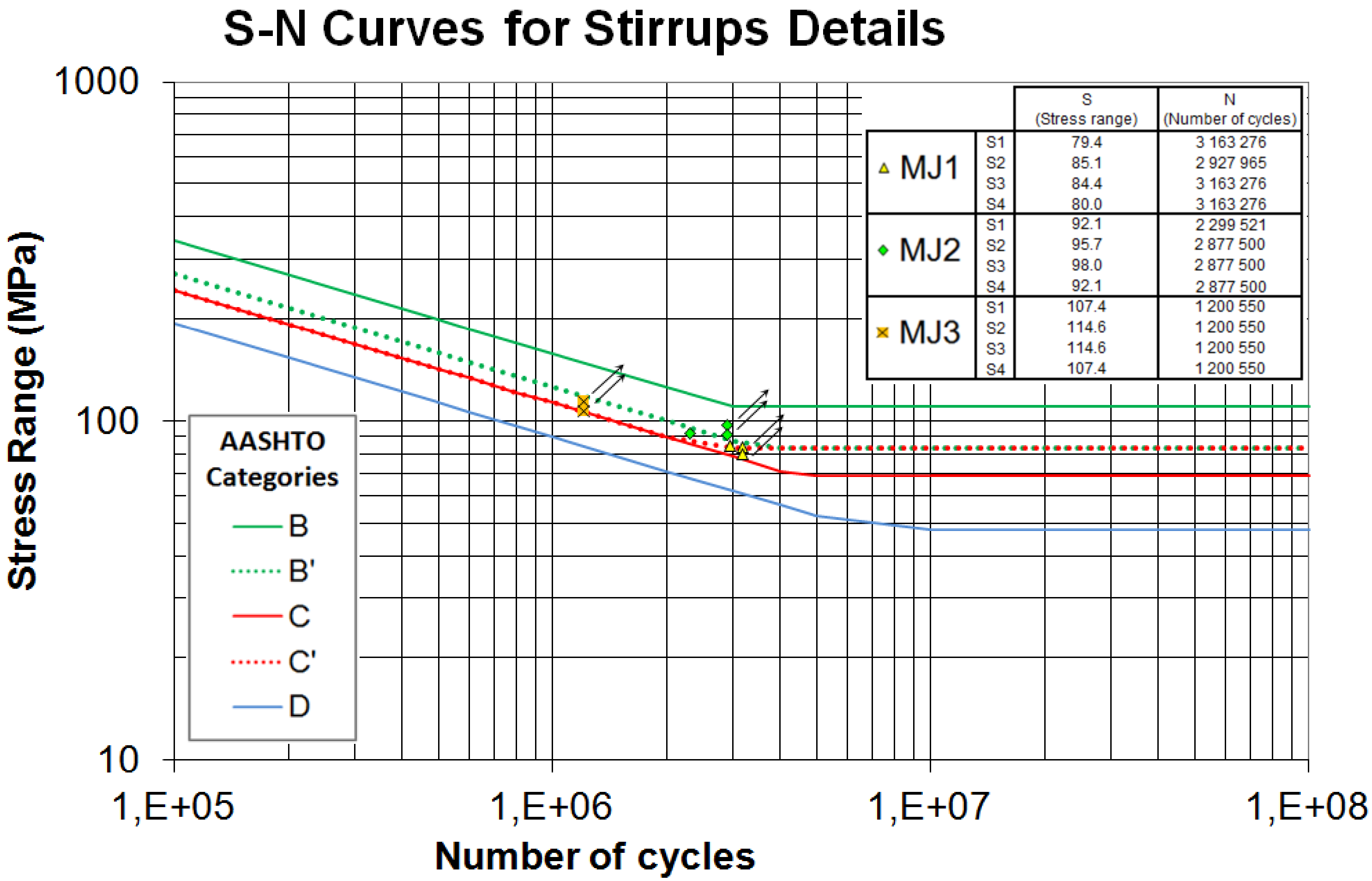


**Figure 7 –Twelve S-N Points Obtained for Stirrup Details from Fatigue Tests in Conformity to AASHTO and NCHRP-402**