Methodology for structural integrity assessing of singular bridges in service assessment. The "Constitución de 1812" Bridge, over the Bay of Cádiz (Cádiz, Spain)

EIDEIC
2021

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21/05/2021

Content:

— Introduction and Objective
— Methodology for the structural integrity assessment
— Structural redundancy criteria
— Conclusions and future work
— Status of doctoral studies

Introduction and Objective

Today, it is mandatory to elaborate manuals for inspection and maintenance of bridges. If we have a steel bridge, these manuals should include a section for the inspection of cracks and defects in the steel plates, defining critical crack sizes.

PURPOSE

Propose a methodology to justify larger crack sizes that could eventually be detected by visual inspection

- **Detailed structural integrity assessment using BS7910**
- **Considering structural redundancy criteria**

Crack sizes of at least 10 cm can be detected during a visual inspection of the bridge

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- **Methodology for the structural integrity assessment**
- Structural redundancy criteria
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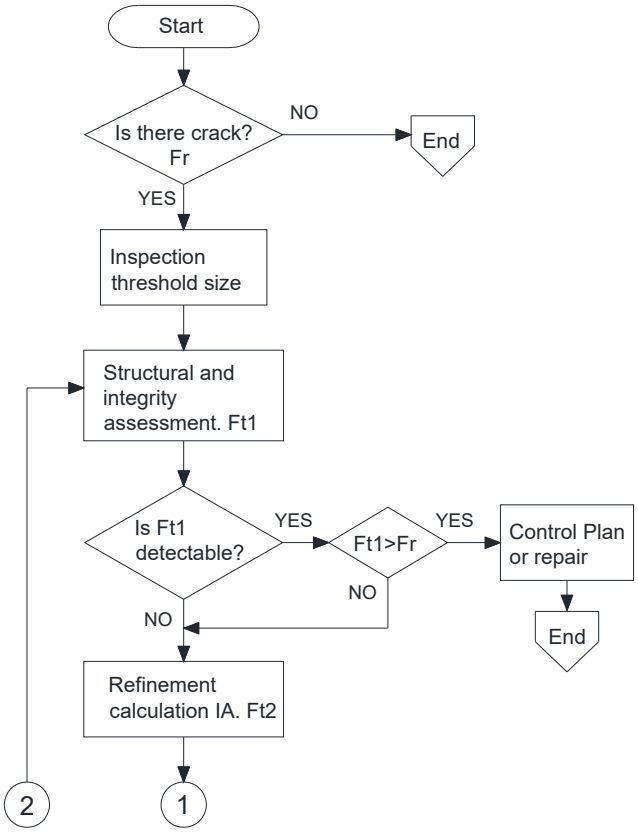
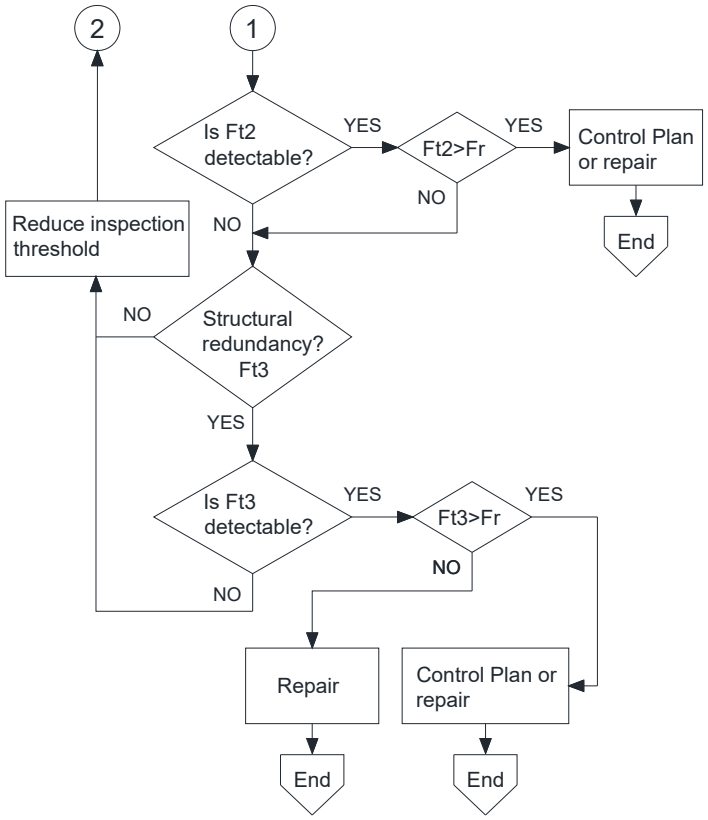
Methodology for the structural integrity assessment





Modified structural integrity assessment technique

- Refined FAD.
- Real tensile properties.
- Real fracture toughness.
- Consideration of working temperature.
- Detailed calculation of residual stresses.

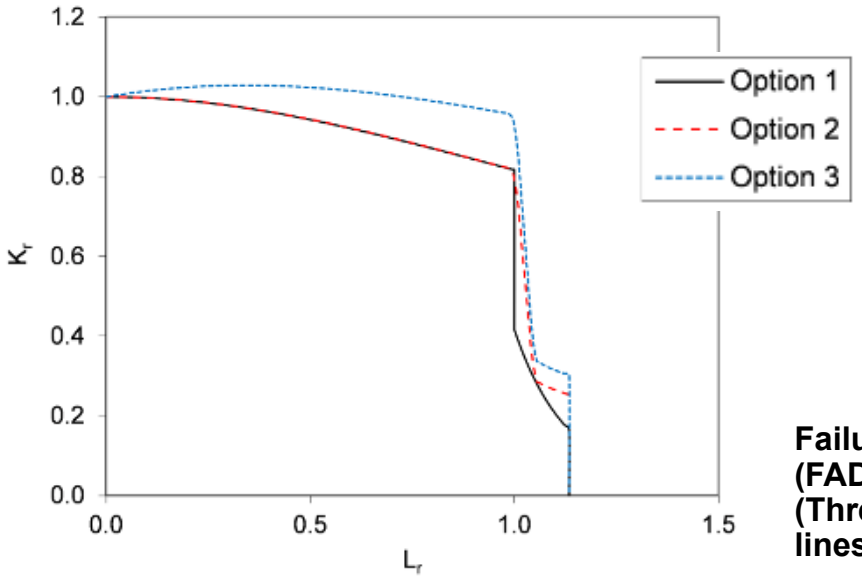
Modified structural integrity assessment technique
Refined FAD according to BS7910

BS 7910: 2013

Option 1: Conservative procedure. Do not require detailed stress-strain data

Option 2: Use of full stress-strain curve of the material

Option 3: Uses numerical analysis to generate the FAD



Failure assessment diagram (FAD) with three options (Three failure assessment lines, FAL)

LESS CONSERVATIVE MORE COSTLY

Option 2 and 3 require specific laboratory testing and/or simulation

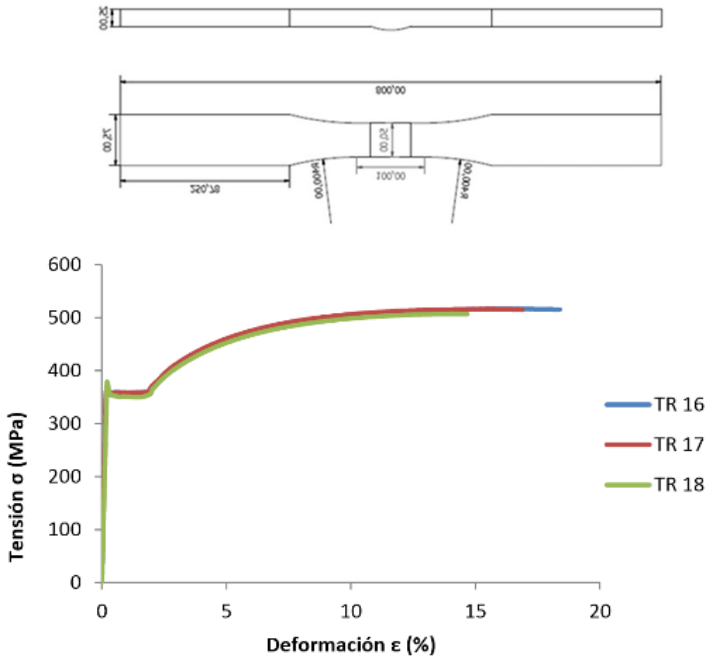
Modified structural integrity assessment technique
Real tensile properties of the steel

Traceability of the materials used in the bridge is considered to be essential.

Actual tensile properties of the materials (yield stress and ultimate tensile strength) can be taken into account for the calculations.

Coefficient of reduction of the mechanical properties not required

Increase in the load bearing capacity of the structure



Modified structural integrity assessment technique
Real fracture toughness

Conservative common practice in conventional structural integrity assessment

→ **Estimations of fracture toughness obtained from Charpy results**

→ **Lowest fracture toughness value obtained in the tests. (Base material, HAZ and weld bead)**

REFINEMENT

- **Use especific toughness values for the situation being analysed**
  - **WELD BEAD**
  - **HEAT AFFECTED ZONE (HAZ)**
  - **BASE MATERIAL**
- **If number of test is high enough: Probability of failure rather than using minimum values**

Modified structural integrity assessment technique
Consideration of temperature

Fracture test carried out at a temperature recommended by applicable regulations: -20ºC

Minimum temperature recorded in Cadiz since 1954 is -1ºC (AEMET)

REFINEMENT

Fracture toughness tests performed are conservative. The fracture toughness of the material can be significantly higher when considering a temperature closer to the real operating temperature.

Modified structural integrity assessment technique
Detailed calculation of residual stresses

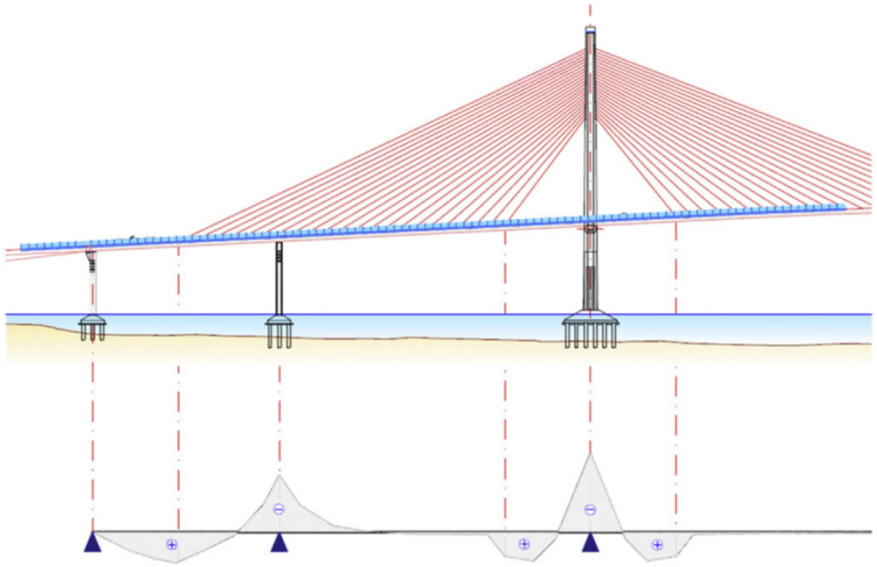
BS7910 proposes a series of expressions to determine the residual stresses in different types of joints.

REFINEMENT

- **Perform detailed calculations to determine the actual residual stresses in the joint being analysed**

Modified structural integrity assessment technique
"Constitución de 1812" Bridge, over the Bay of Cádiz. First results

Critical crack values (ac) obtained at specific positions on the deck of the Bridge of the Constitution of 1812 and for the 3 hypotheses of crack geometries being considered..



b)

PK	Punto superior	Tensión (MPa)	Espesor sup (mm)	a_c (mm)		
				Fisura pasante	Fisura semielíptica (a/2c=0.5)	Fisura semielíptica (a/2c=0.1)
886	1	224	20	10.4	10.6	6.1
912	2	316	100	3.4	4	1.5
1084	3	168	80	7.6	23	6.8
1110	4	316	110	3.3	3.2	1.2
1385	5	140	18	15.3	13	7.9
1655	6	295	110	3.6	3.8	1.45
1853	7	252	100	4.6	6.7	2.45
1960	8	224	70	6.2	17.1	5.4

PK	Punto superior	Tensión (MPa)	Espesor sup (mm)	a_c (mm)		
				Fisura pasante	Fisura semielíptica (a/2c=0.5)	Fisura semielíptica (a/2c=0.1)
886	1	224	20	13	10,6	6.1
912	2	316	100	4.2	11	4
1084	3	168	80	9.6	41	10.5
1110	4	316	110	4	10.3	3.8
1385	5	140	18	20	13	7.9
1655	6	295	110	4.4	11.5	4.2
1853	7	252	100	5.7	17	5.6
1960	8	224	70	7.8	29	8.3

Structural redundancy criteria (NCHRP 406)

Safety criteria

- **The bridge provides a reasonable level of safety against failure of the fist member**
- **Does not reach its ultimate capacity under extreme load conditions**
- **No major deformations occur under expected load conditions**
- **Capable of supporting some traffic load after the damage of a component**

Limit states

- **One Member Failure, Ultimate Limit State, Functionality Limit State, Limit state of Damage Condition**

Actions considered

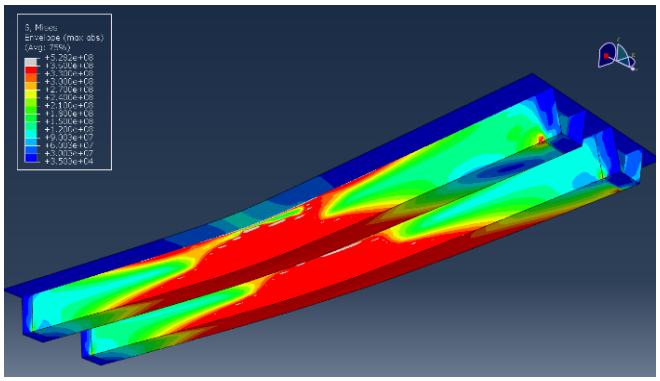
- **Dead loads + two H20 truck + distributed service load (unfactored)**
- **Energy released during the fracture of steel elements**

Limit deformations

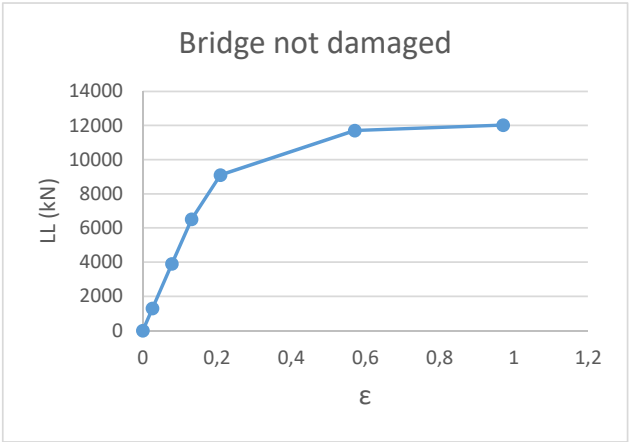
- **Maximum limit deflection should not be lower than L/100 (Unfactored service loads)**

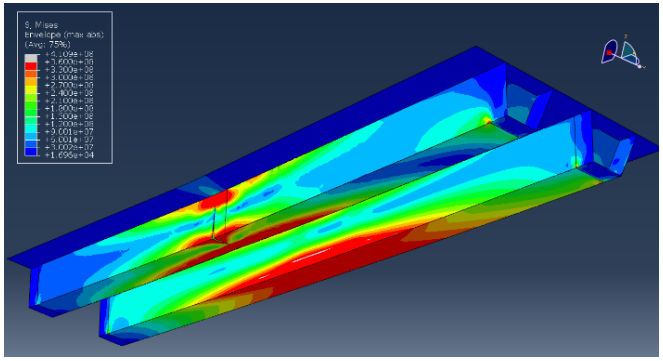
Structural redundancy criteria (NCHRP 406)

- **Finite element models considering elastic and inelastic behaviour of the materials and second order geometric effects.**

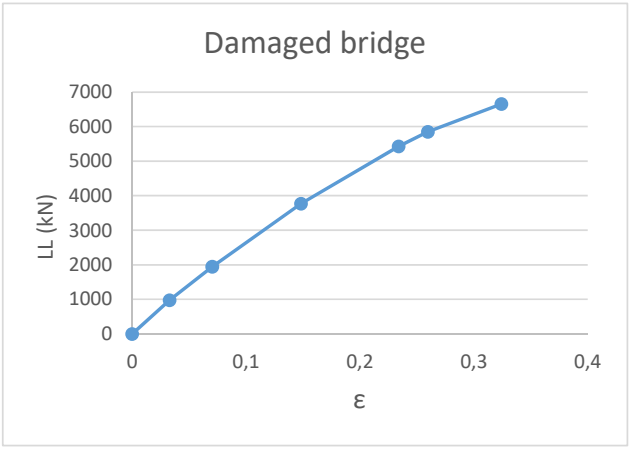


nº of two HS-20	Live load (kN)	Vertical Displ. LL (m)
0	0	0
2	1300	0,026
6	3900	0,079
10	6500	0,132
14	9100	0,209
18	11700	0,572
18,5	12025	0,971





nº of two HS-20	Live load (kN)	Vertical Displ. LL (m)
0	0	0
1,5	975	0,033
3	1950	0,070
5,8	3770	0,148
8,35	5427,5	0,234
9	5850	0,260
10,24	6656	0,324



Conclusions and future work

- **A structural integrity assessment methodology for steel bridges has been defined.**
- **Larger critical crack sizes can be justified with the new methodology.**
- **The methodology will be applied to the “Constitution de 1812” bridge, over the bay of Cadiz.**

Status of doctoral studies

❑ Achievement of competencies

Training and evaluation	
Basic Transversal Training	Completed
Advanced Transversal Training	Pending 15 h
Evaluation of anual PIs throughout the doctorate	Favorable

Presentations at conferences	
Encuentro del GRUPO ESPAÑOL DE FRACTURA (GEF). 30/Apr/2017	Evaluación de la integridad estructural del puente de la Constitución de 1812
2nd International Conference on Structural Integrity ICSI 2017, 4-7 September 2017, Funchal, Madeira, Portugal	Structural Integrity Evaluation of the "Constitución de 1812 bridge", over the Cádiz bay (Cádiz, Spain)
EIDEIC 2018	Structural integrity assessment of the welded joints of the constitution of 1812 bridge, Cádiz, Spain
International Symposium on Risk Analysis and Safety of Complex Structures and Components (IRAS2019). Faculty of Engineering, University of Porto, Porto, Portugal. 01-02 July 2019	Methodology for the Structural integrity assessment of the "Constitución de 1812" bridge, over the Cádiz bay (Cádiz, Spain)

Status of doctoral studies

❑ Achievement of competencies

Scientific Publications	
VII CONGRESO DE LA ACHE 2017	Estructuras singulares frente a su fase de explotación. El caso del Puente de la Constitución de 1812
VII CONGRESO DE LA ACHE 2017	Plataforma con encofrado autodeslizante para refuerzo y reparación de un silo de hormigón
VII CONGRESO DE LA ACHE 2017	La importancia del "revisor independiente" en el diseño y uso de los medios auxiliares en obra
VII CONGRESO DE LA ACHE 2017	Concepto y obra en la rehabilitación de un puente metálico diseñado en el siglo XIX: Puente de Treto
Structural Integrity Procedia 2017	Structural Integrity Evaluation of the "Constitución de 1812 bridge", over the Cádiz bay (Cádiz, Spain)
ENGINEERING FAILURE ANALYSIS RG Journal 2018. Impact: 1.93	Structural integrity assessment of the welded joints of the constitution of 1812 bridge (Cádiz, Spain)
Structural Integrity Procedia 2019	Methodology for the Structural Structural Integrity assessment of the "Constitución de 1812" Bridge, over the Bay of Cádiz (Cádiz, Spain)

❑ Submission of the thesis

- **The estimated date for submission of the thesis is late 2021 or early 2022.**

Thank you!

The authors of this work would like to express their gratitude to the University of Cantabria for the financial support of the project “Aplicación de Técnicas de Integridad Estructural y Fiabilidad de Materiales en la Determinacion del Ciclo de Vida de Puentes Metalicos y Mixtos” (03.DI09.649), programme of industrial doctorates.

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