Crane Useful Life Assessment and Maintenance

TOC Asia 2005

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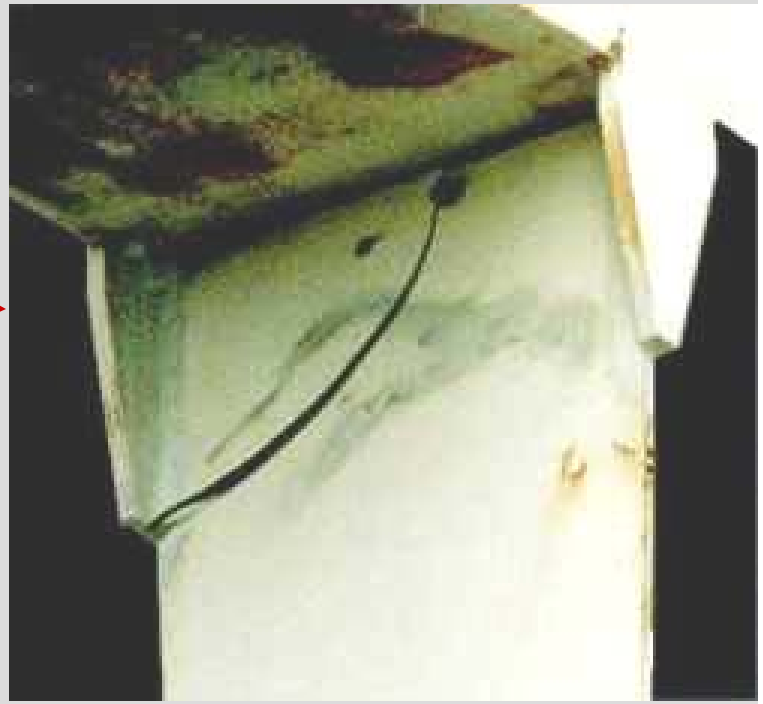
Forestay Failure

Boom Hanger Failure



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Trolley Support Failure

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Overview

Failures do occur!

Fatigue design philosophy

Useful life analysis & structural maintenance

Repair examples

Fatigue Design Philosophy

Safe Life Design

Space Station

1 in 10^6

Damage Tolerant Design

Cranes

1 in 50 without inspection

1 in 1,000 with inspection

How to Minimize the Effect of Fatigue Cracks

Proper design

Proper material selection

Proper fabrication and quality control

Proper attachments

Structural maintenance program

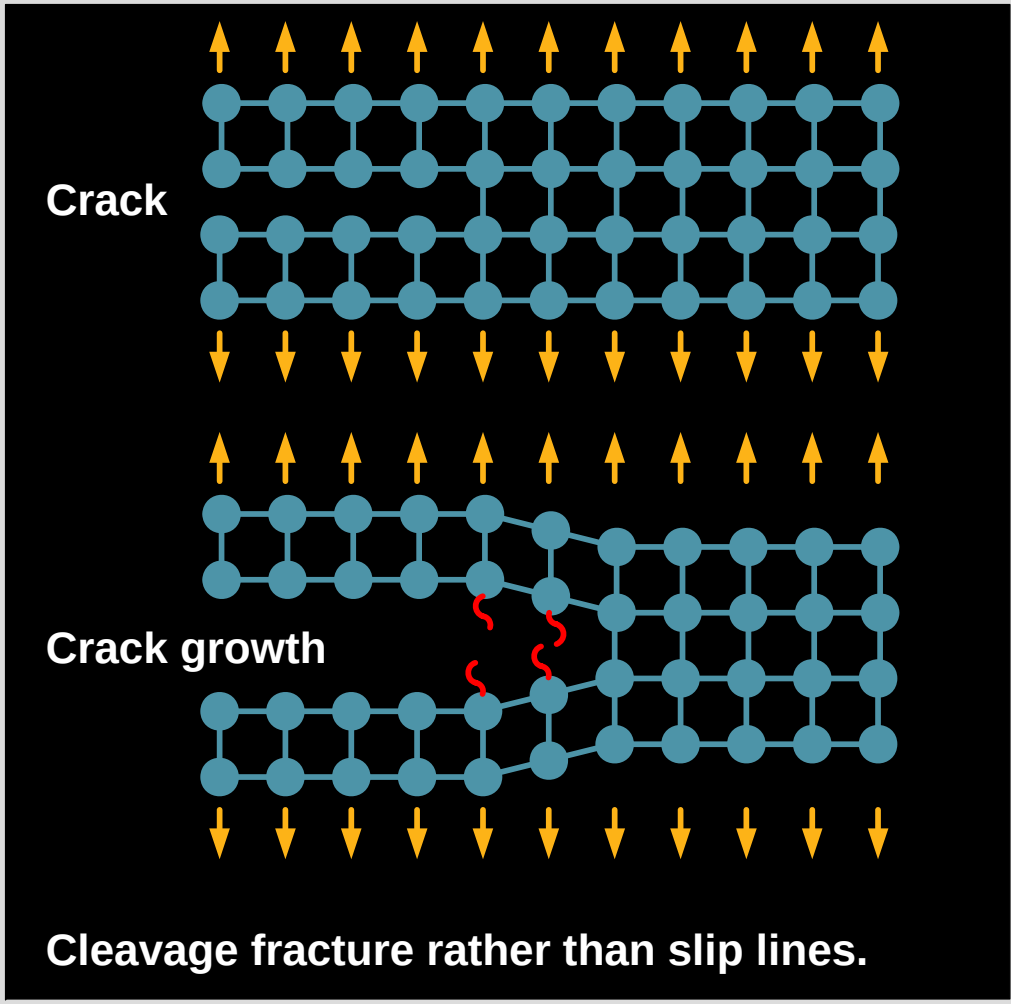
Fatigue Crack Growth

Stress range

Number of cycles

Detailing

Workmanship and quality control



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You Have an Aging Crane: What are Your Options?

Do nothing and ignore risks

Useful structural life assessment

- Prolong life with inspection and repair
- Reduce use and/or relocate
- Dispose

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Steps of a Useful Life Analysis

Structural condition survey

Useful life estimate before inspection

Inspection program

Structural inspection

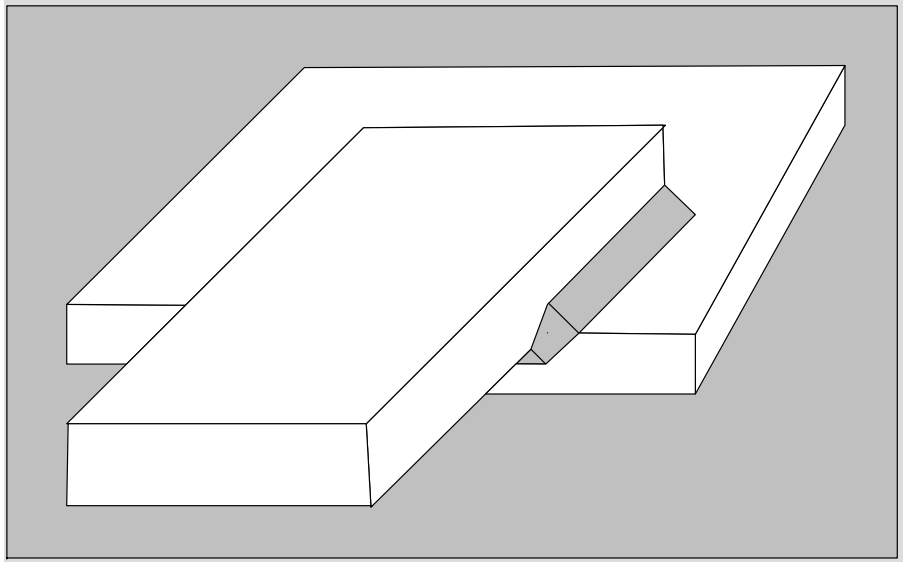
Useful life estimate after inspection

Structural Condition Survey

Look for

- Distress
- Suspect details
- Attachments

Make photo record for the NDT inspection



Useful Life Estimate Before Inspection

Calculate cumulative damage to date

Estimate remaining cumulative damage for expected operation

Convert to useful life

Owner can decide best course of action

Useful Life Analysis: Example

Description	Design	Crane 1	Crane 2	Crane 3
Loads	tons	tons	tons	tons
Trolley Wt	13.0	13.0	13.0	13.0
Head block	3.1	3.1	3.1	3.1
Spreader	12.0	12.0	12.0	12.0
Rated Load	40.0	40.0	40.0	40.0
Design Fatigue Load	30.0	30.0	30.0	30.0
Avg Container Wt (root mean cubed)	30.0	30.0	20.0	40.0
Years in operation (Through 2003)	15.0	15.0	15.0	15.0
No. of cycles	1,500,000	1,500,000	2,250,000	1,500,000
cycles/year	100,000	100,000	150,000	100,000
Predicted future usage rate (cycles/year)	100,000	150,000	150,000	100,000
Des cycles/yr	100,000	100,000	100,000	100,000
Cumulative Damage				
R (act)	2.942E+11	2.942E+11	2.504E+11	4.737E+11
R(des)	**3.922E+11**	**3.922E+11**	**3.922E+11**	**3.922E+11**
Cumulative damage ratio R	0.750	0.750	0.638	1.208
Predicted No. of fatigue cracks /crane				
No. of std deviations below mean	2.554	2.554	2.865	1.636
Reliabity	0.9947	0.9947	0.9979	0.9491
No. of joints/crane	1500	1500	1500	1500
Predicted fatigue cracks/crane	7.9	7.9	3.1	76.4
Predicted Fatigue Cracks / Crane	**5 to 10**	**5 to 10**	**0 to 5**	**60 to 90**
Structural Useful Life in present condition				
Years in operation	15.0	15.0	15.0	15.0
Remaining structural life = $Years_{left}$ (predicted rate)	5.0	3.3	7.2	-4.2
Estimate of remaining useful life prior to NDT inspection	**5**	**3 to 4**	**7 to 8**	**zero**

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Structural Maintenance & Inspection Program

Inspection manuals

- Details to be inspected
- Classification: FCM or NFCM
- Inspection method: VT, MT, UT, RT
- Acceptance criteria
- Inspector's qualifications
- Reporting procedures

Inspection frequencies

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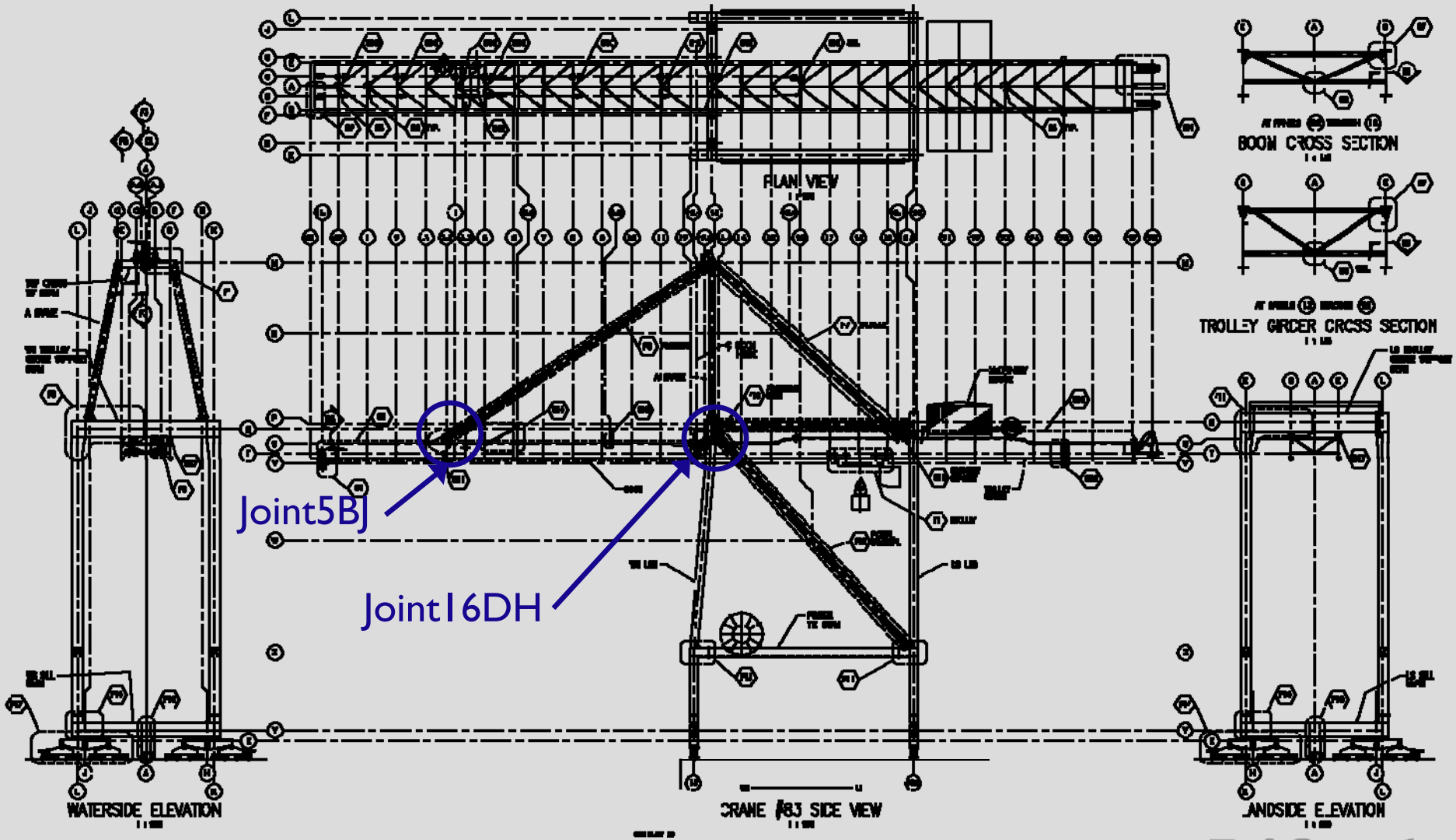
Inspection Program:
Typical General Arrangement



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Inspection Program:
Typical NDT Manual Pages

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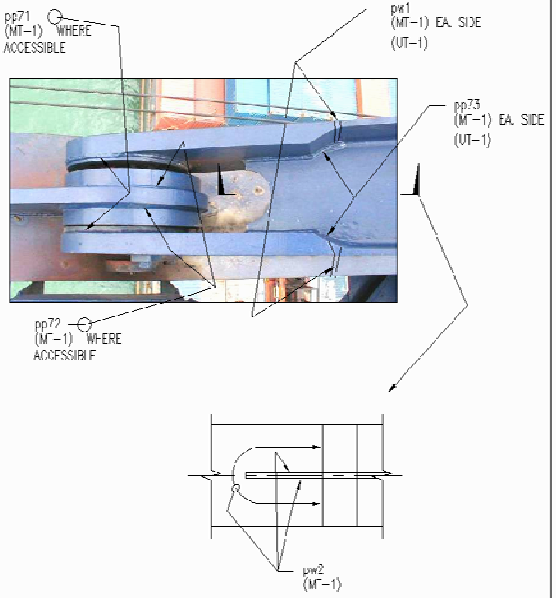

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Weld I.D.	Type of Test VT	MT	UT	Accept	Reject	Remarks	By	Date

Equipment used:

If cefect detected, indicate if:
RS,ITS,WS,IS, B,OB,U,I.

Joint: **5BJ**

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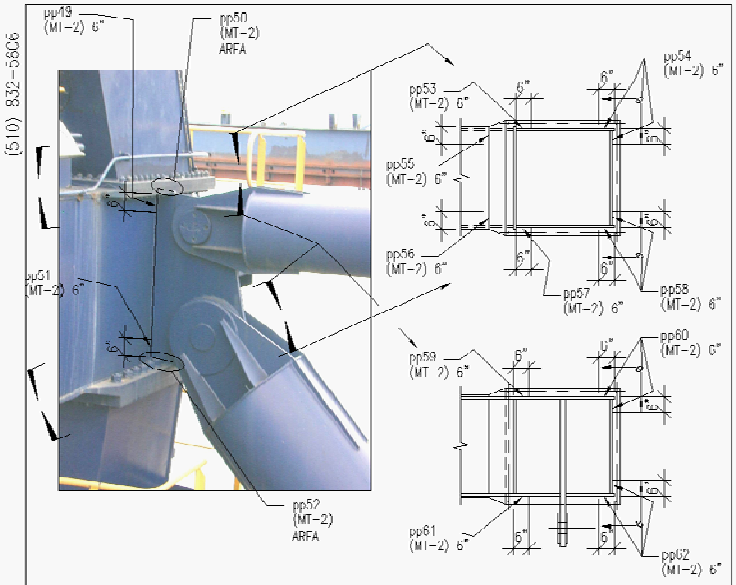

NOTE: VISUALLY VERIFY THAT BOLTS ARE TIGHT AND PLATES HAVE NOT BUCKLED. IN ADDITION, INSPECT MINIMUM OF 10% OF ALL BOLTS PER AISC (AT LEAST TWO BOLTS PER CONNECTION).

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Weld I.D.	Type of Test VT	MT	UT	Accept	Reject	Remarks	By	Date

Equipment used:

If defect detected, indicate if:
RS,ITS,WS,IS,IB,OB,U,I.

Joint: **16DH**

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Inspection Frequency

Not all joints need inspection at the same interval

- More frequent inspection:
  - Fracture critical members (FCMs)
  - Joints with higher stress ranges
- Less frequent inspection:
  - Non-fracture critical members (NFCMs)
  - Joints with lower stress ranges
  - Joints in secondary members

Example Inspection Intervals

Component	Fracture Critical?	No. of Moves	Interval (Years)
Trolley Girder Hanger	Yes	300,000	3
Forestay	Yes	600,000	6
Lower Legs	No	1,200,000	12
Portal Beam	No	2,400,000	24

This example is not suitable for all cranes.

Structural Inspection

Inspect and compare predictions with findings

Repair procedures

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Useful Life Estimate After Inspection

Review inspection reports

Identify fatigue cracks

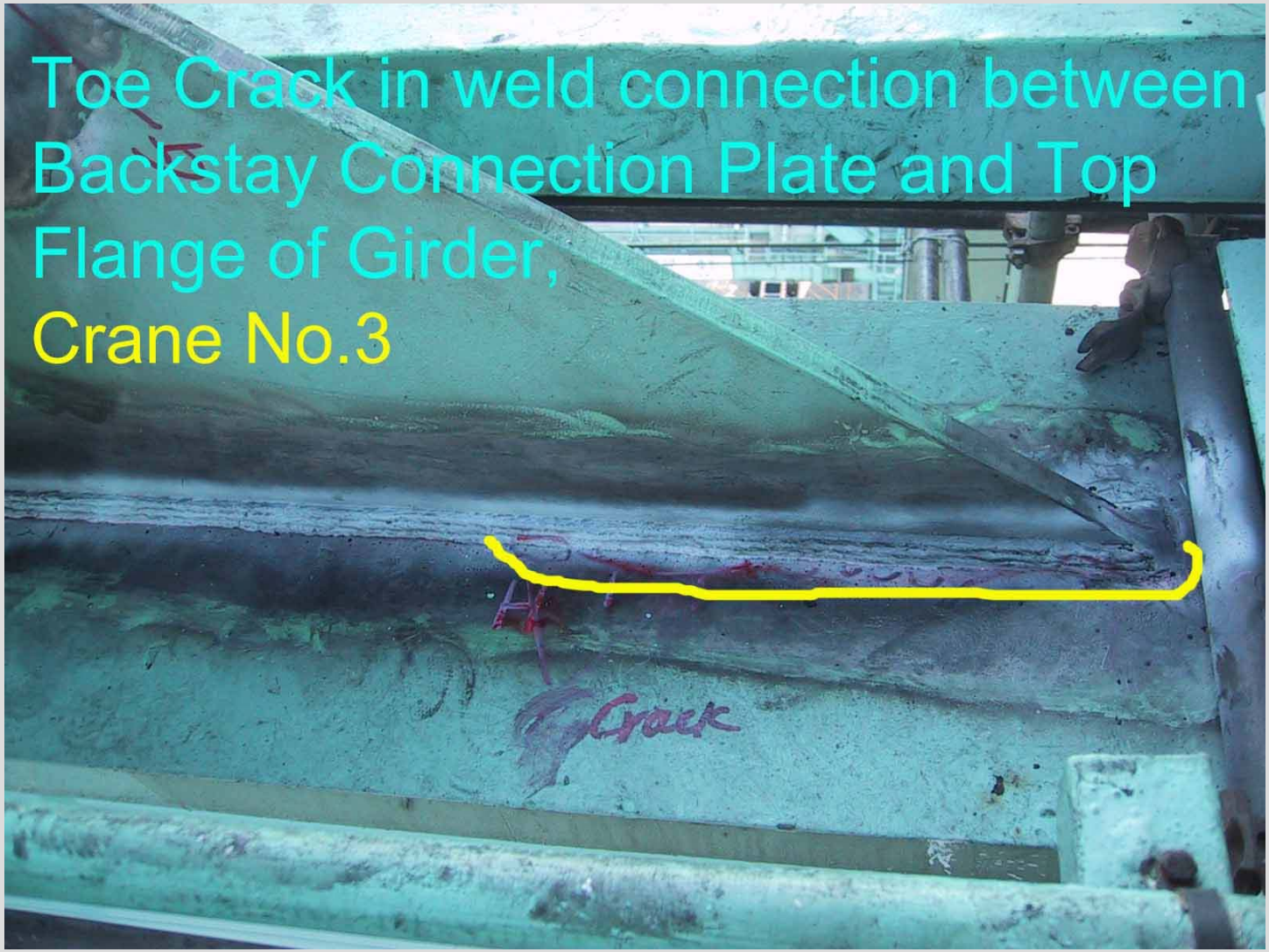
Compare identified cracks with prediction

Reevaluate the reliability and useful life based on inspection

Owner can decide best course of action

Fatigue Crack Repairs

Example: Repair Original Detail



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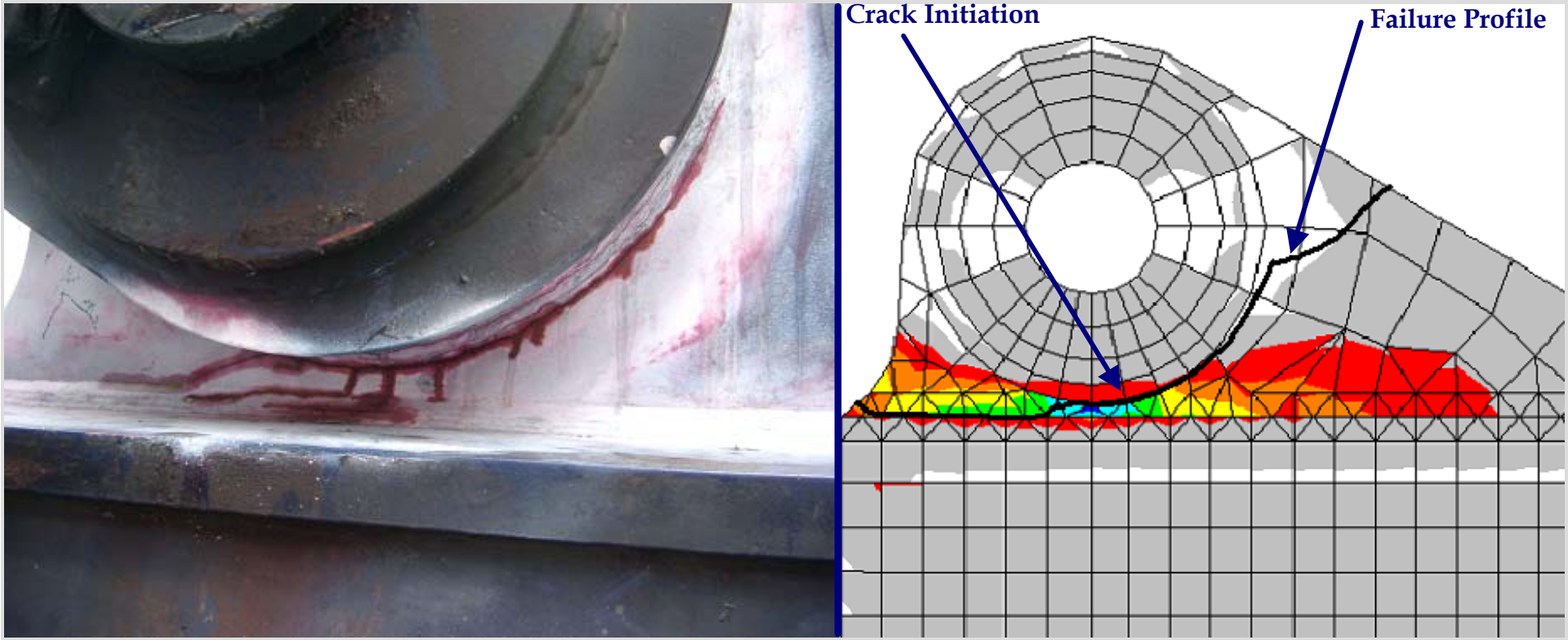
Fatigue Crack Repairs

Example: Modify and Repair Detail

Forestay Failure Profile



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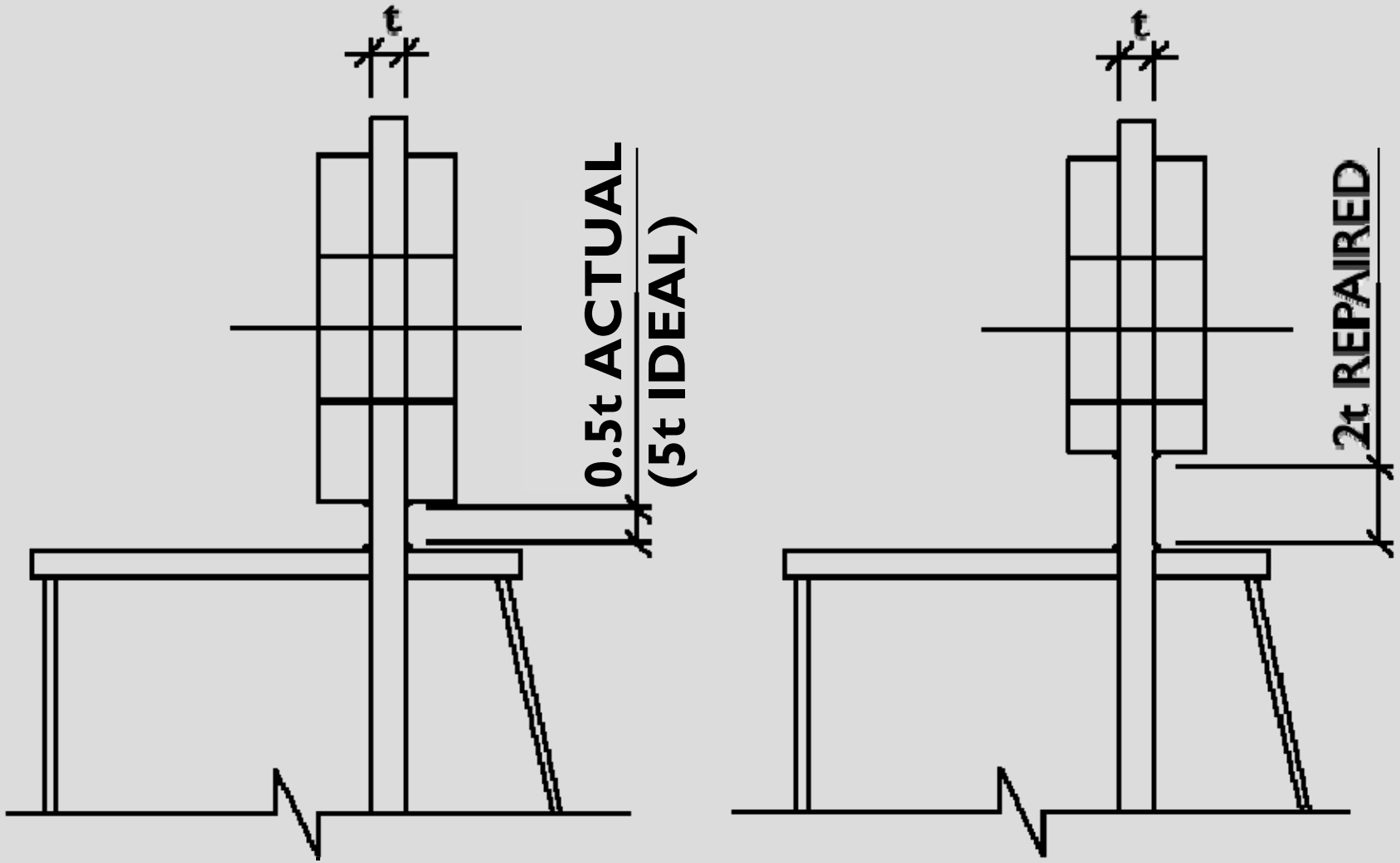
Modified Detail: Plate Flexing



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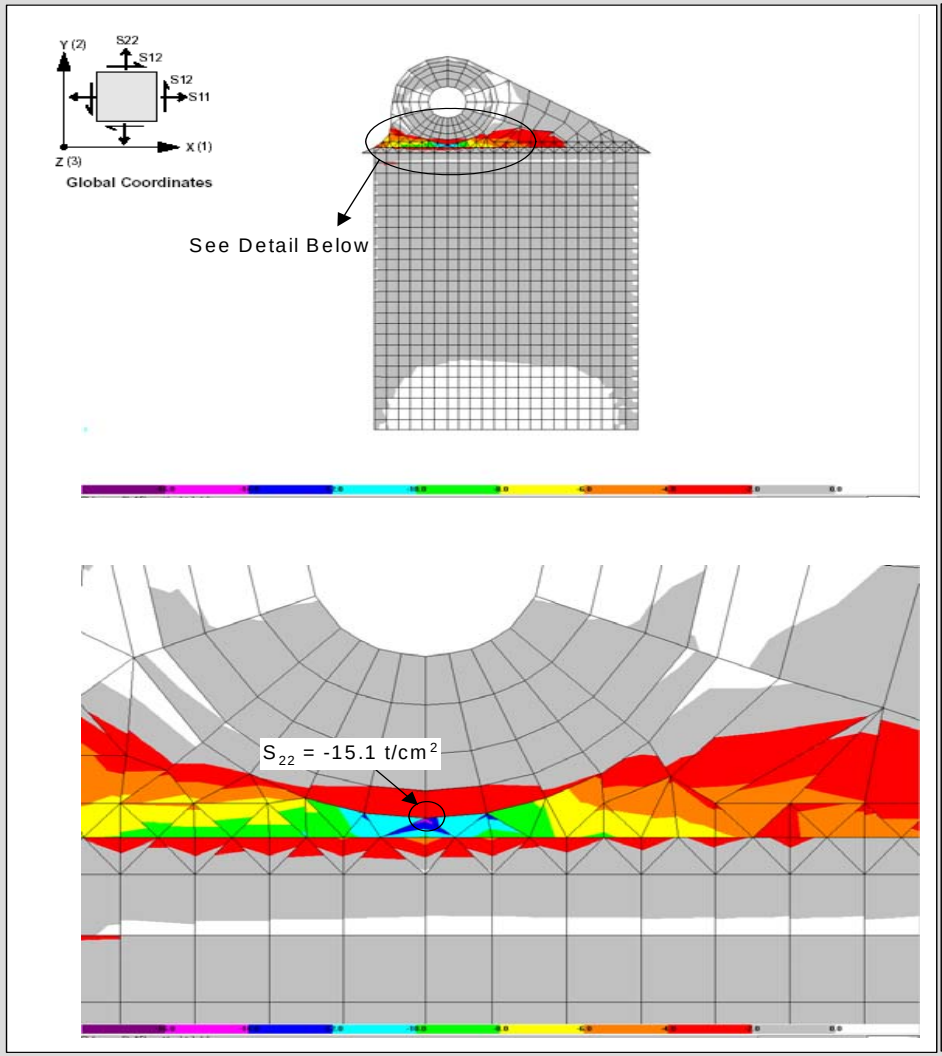
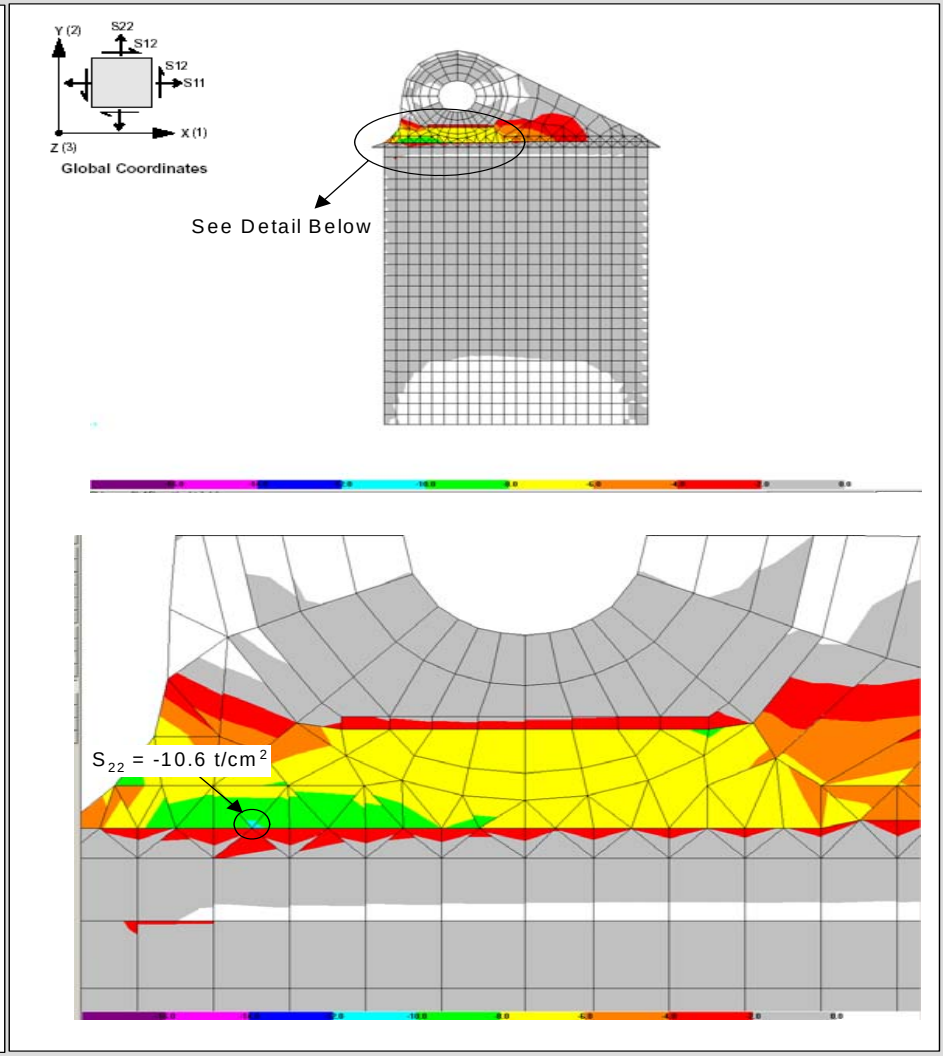
Modified Detail: Stress Analysis



Original



Modified

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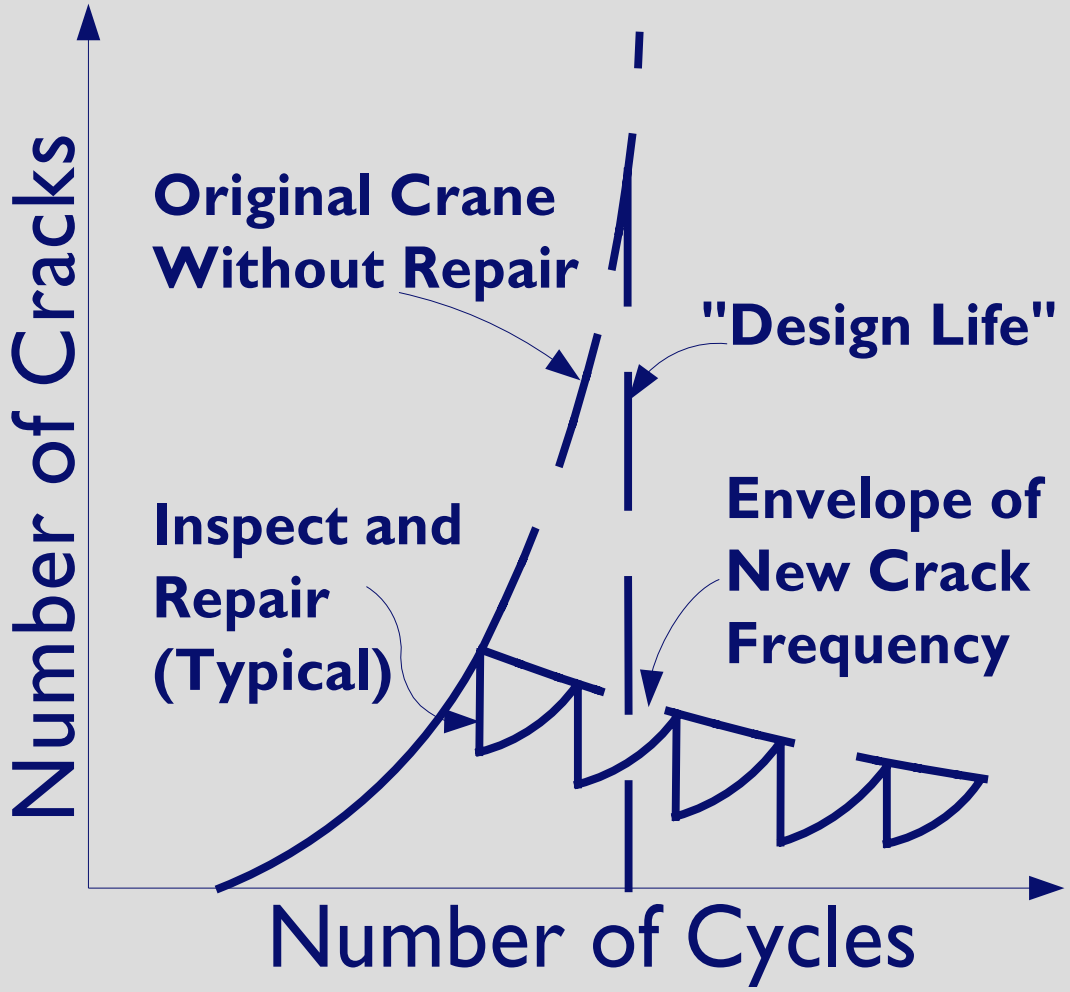
Crack Occurrence and Maintenance



- Poor initial details repaired
- More attention during repair
- Threshold stress range

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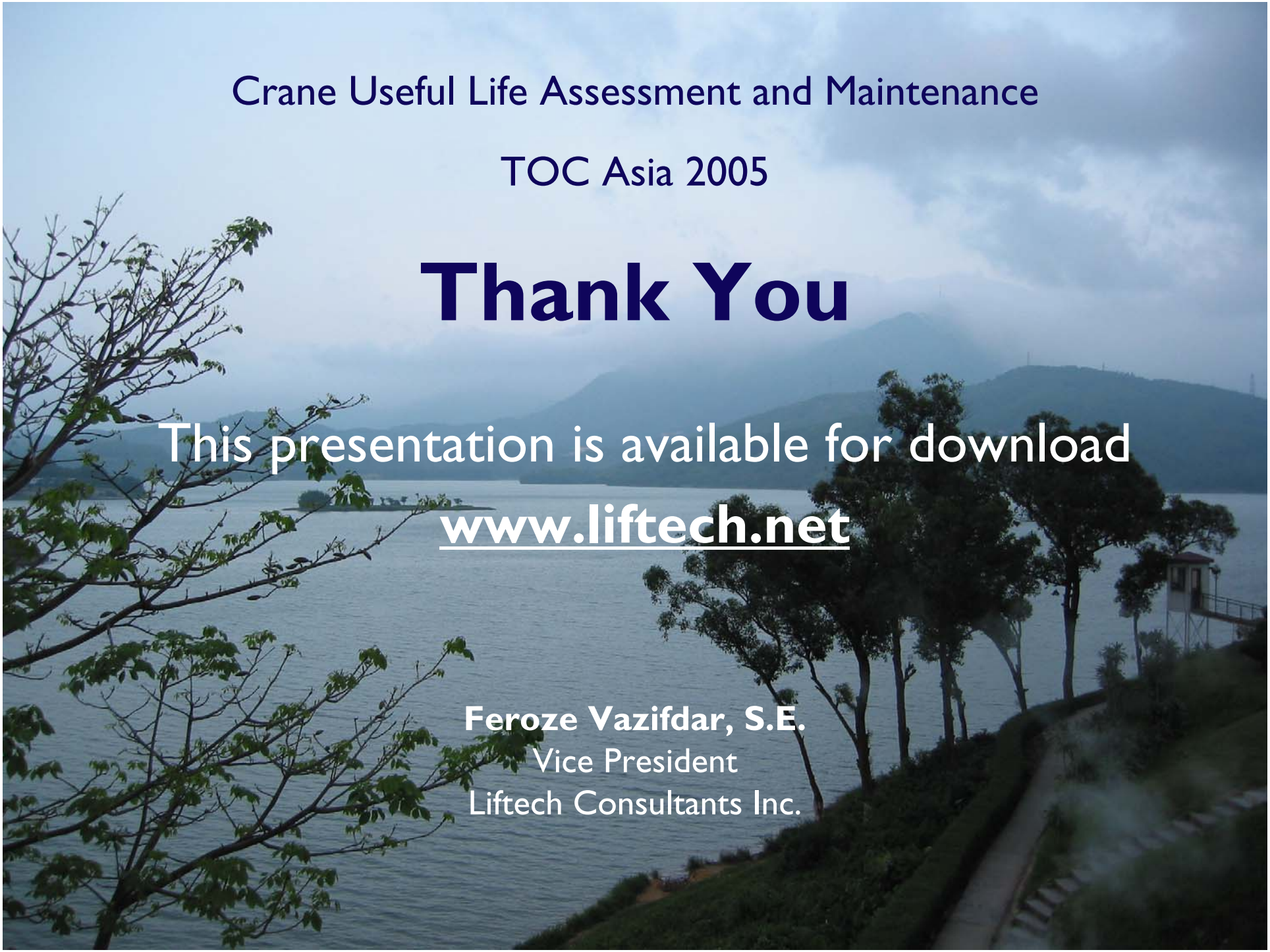
Summary

Fatigue cracks will occur and can be catastrophic if not repaired

Cracking can be controlled with proper design, workmanship, quality control, and a proper structural maintenance program

Crack repairs are inexpensive

Useful life analysis can be used to predict future cracking so the owner can decide the best course of action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