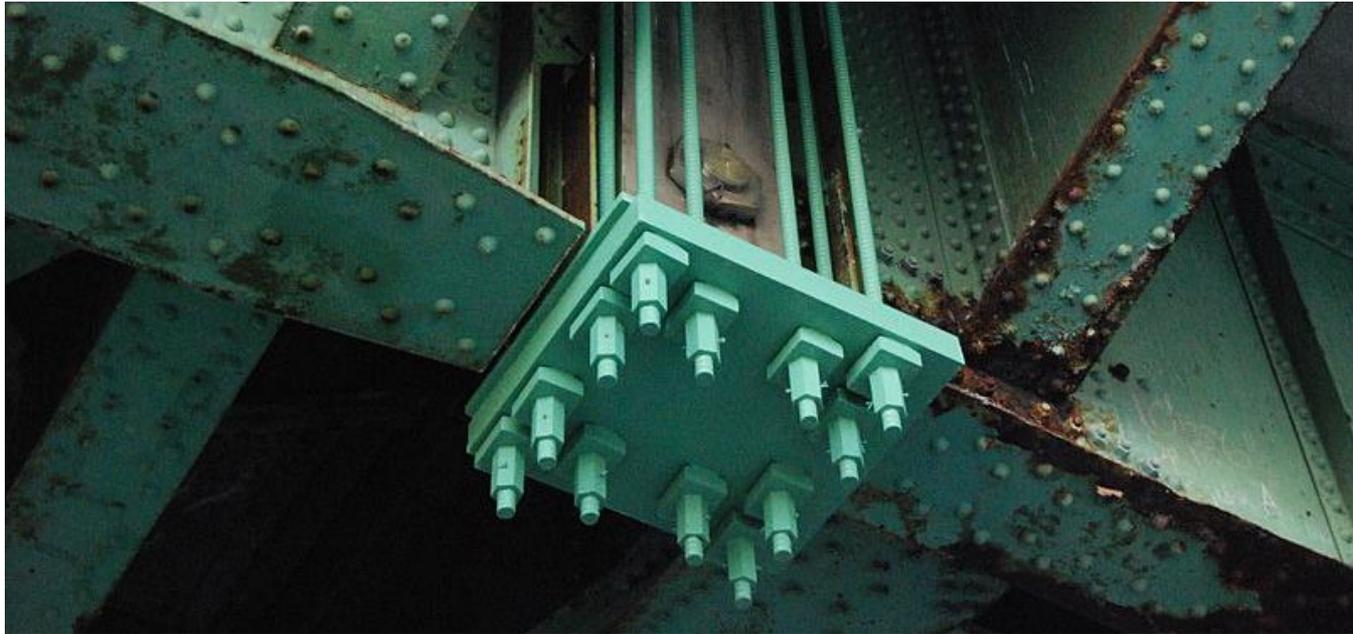


Activity



Statistical Analysis of Methods to Repair Steel

Civil Engineering Challenge

Perform a statistical analysis of the effectiveness of the different configurations of CFRP patching to rehabilitate steel structures, comparing the mean fatigue life of slightly cracked steel beams and mean fatigue life of slightly cracked steel beam reinforced with CFRP patches.



Data Analysis

CFRP Experimental Results

Construction and Building Materials 23 (2009) 1664–1677

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Strengthening of old metallic structures in fatigue with prestressed and non-prestressed CFRP laminates

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Experimental and numerical study of the fatigue behaviour of composite patch repaired cracked steel plates

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INFO ABSTRACT

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The use of adhesively bonded composite materials has led to great advances in repairing and strengthening cracked or aged metallic structures. However, less is known about the fatigue performance of the bonding between the composite and the metallic substrate, which is the deciding factor when designing the strengthening. In this study, a series of experiments is performed to investigate the effectiveness of the composite in preventing fatigue crack propagation and extending the fatigue life of steel plates. The composite material of CFRP sheets is adopted. Both single-sided and double-sided repairs are studied. Experimental results show that the application of composite patches substantially reduces crack growth rate and prolongs fatigue life. The double-sided repair scheme increased the fatigue life by 2.2–2.7 times over un-patched steel plates when normal modulus CFRP sheets were used, and by 4.7–7.9 times when high modulus CFRP sheets were used. The CFRP sheets with high modulus were found to be much more efficient. Bond width has considerable influence on the crack growth life. Two test findings were especially true for the double-sided repairs. The parameters of patch thickness, patch length and patch configuration, had an influence on fatigue life increase of over 20% for both single-sided and double-sided repairs, except that patch configuration had only a 6% influence on fatigue life increase for double-sided repairs. Furthermore these three parameters had slightly more influence on single-sided repairs than on double-sided repairs.

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NiTiNb –CFRP Experimental Results

Experimental study of fatigue crack growth behaviour in adhesively reinforced steel structures

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ABSTRACT

The use of adhesively bonded composite materials has led to great advances in repairing and strengthening cracked or aged metallic structures. However, less is known about the fatigue performance of the bonding between the composite and the metallic substrate, which is the deciding factor when designing the strengthening. In this study, a series of experiments is performed to investigate the effectiveness of the composite in preventing fatigue crack propagation and extending the fatigue life of steel plates. The composite material of CFRP sheets is adopted. Both single-sided and double-sided repairs are studied. Experimental results show that the application of composite patches substantially reduces crack growth rate and prolongs fatigue life. The double-sided repair scheme increased the fatigue life by 2.2–2.7 times over un-patched steel plates when normal modulus CFRP sheets were used, and by 4.7–7.9 times when high modulus CFRP sheets were used. The CFRP sheets with high modulus were found to be much more efficient. Bond width has considerable influence on the crack growth life. Two test findings were especially true for the double-sided repairs. The parameters of patch thickness, patch length and patch configuration, had an influence on fatigue life increase of over 20% for both single-sided and double-sided repairs, except that patch configuration had only a 6% influence on fatigue life increase for double-sided repairs. Furthermore these three parameters had slightly more influence on single-sided repairs than on double-sided repairs.

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1. Introduction

Examination of previous structural failures has revealed that many failures are due to fatigue fracture, which is the most significant failure behaviour for metal structures. Once fatigue cracks initiate, they may propagate at an increasing rate and lead to catastrophic failure. Therefore, it is very important to have the cracks repaired at an early stage. The methods of repair include repair welding, metal reinforcement, composite patches, single-patch overlays and fatigue crack arrest holes. Experimental studies [1–11] have shown that composite repair is an efficient and cost-effective means to reduce crack growth rate and extend service life. However studies in this area to date have been very limited and many issues remain unclear [12–15]. For example, most studies have focused on the behaviour of composite plates, even though composite sheets have been shown to have great advantages in the repair of structures with curves or complex shapes [14–17]. This paper reports on a series of experiments performed to investigate the effectiveness of composite in preventing fatigue crack propagation and extending the fatigue life of steel plates. Both single-sided and double-sided repairs were investigated. The crack

growth behaviour and fatigue life extension of the reinforced steel plates are discussed in relation to patch systems, patch thickness, patch bond length, bond width and patch configuration. During the fatigue tests the crack detection method of “beach marking” was adopted to record the crack propagation developing with fatigue cycles.

2. Materials and specimens

The experimental studies were performed at the Construction Laboratory of the School of Civil & Environmental Engineering, Nanyang Technological University of Singapore. In this testing program, a total of 21 specimens were designed, of which 11 specimens were patched on both sides and 10 specimens were patched only on one side. Different parameters were studied including patch system, patch thickness, patch bond length, bond width and patch configuration.

2.1. Material properties

The specimens were made of CFRP sheets bonded to cracked steel plates by epoxy adhesive. The steel plates had uniform dimensions of 200 × 200 × 10 mm. They were all machined with a

currently existing problem. Composite material patching is a very promising method for repairing and/or reinforcing steel structure. Composite patches prevent crack growth and extend the lifetime of the repaired structure. Composite patch repair and/or reinforcement overcome many, if not all the aforementioned disadvantages of the traditional steel repair methods. They do not involve hot works in any way and, therefore, existing deadweight loading or proximity to explosive environments has no particular consequences. Thus, they can be completed faster, they exhibit good fatigue resistance, they do not cause stress concentrations and they result in low added weight. All these innovations reduce significantly the cost and the time of the repair or reinforcement. Composite patch reinforcing technology is today dominated by applications in aluminium aircraft structures. Reinforcing old bridges and other civil engineer applications follow, with marine applications being very few. Aircraft applications of composite patch reinforcements are known from the late 1970s [1]. Among the key recent works in this field is that by Beach and Graf [2], where the test results showed a life extension of approximately 20 times with respect to the unpatched defect specimens and four times with respect to the unpatched specimens with no defects. An effort towards an analytical calculation of the Stress Intensity Factor (SIF) was the work of Ting et al. [3], who, based on the Rose model, developed a mathematical model for calculating the maximum SIF value of a patched cracked plate. Other related works are those of Lam et al. [4], Baker [5] and Okazaki et al. [6]. Wang and Pridemore [7] describe a series of experimental tensile and fatigue tests in V-notched aluminium specimens repaired with bono fibre pre-preg patches which showed that the life of the

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Data Analysis

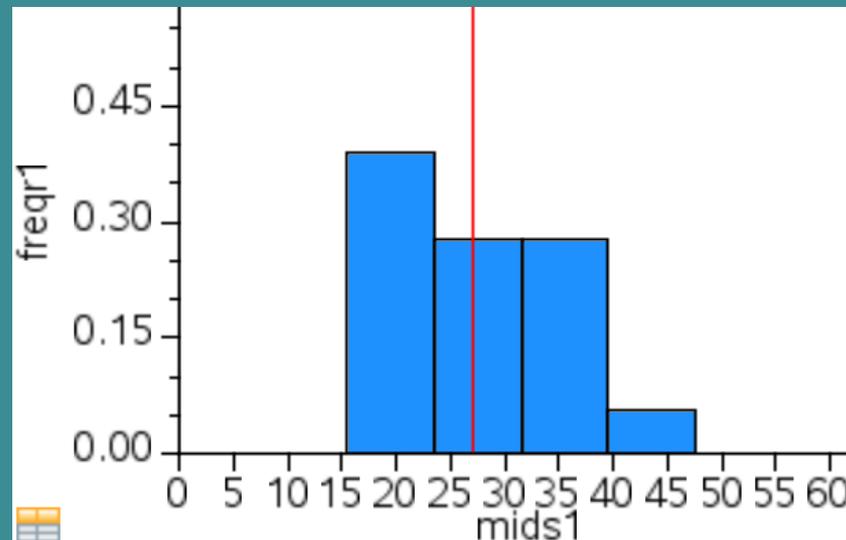
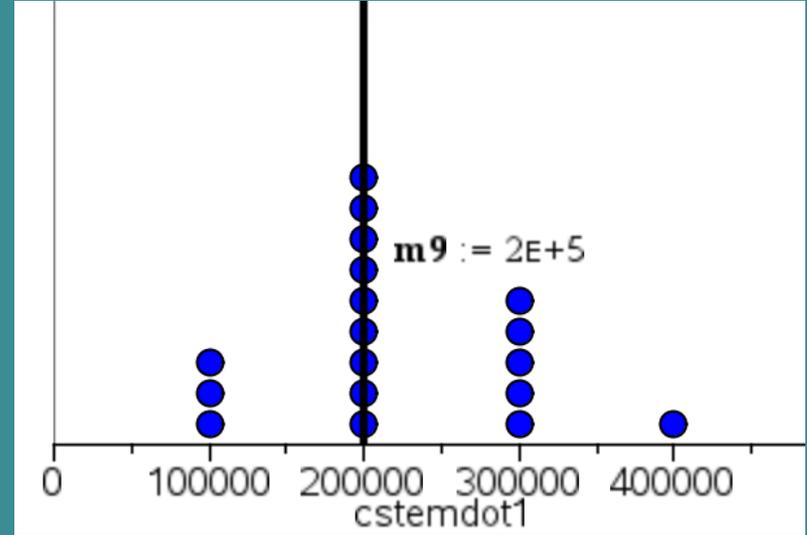
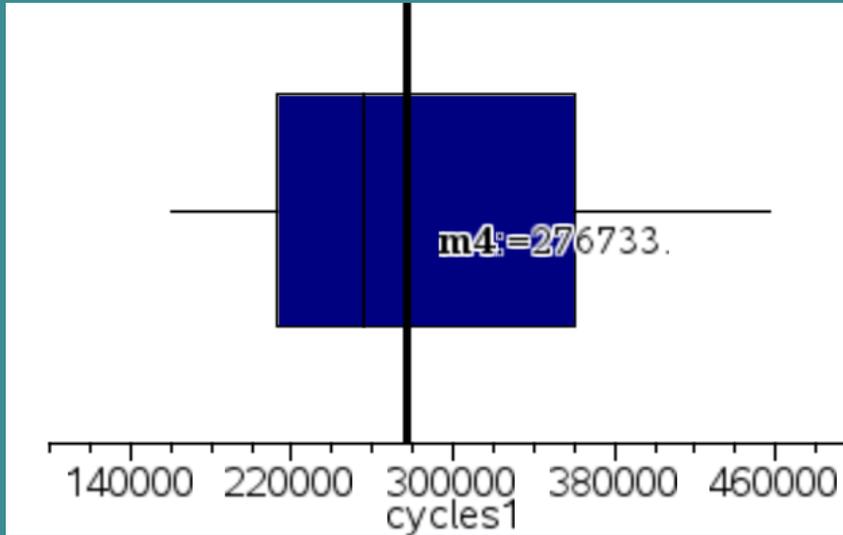
Five-Number Summary

- minimum
- Q1
- median (Q2)
- Q3
- maximum

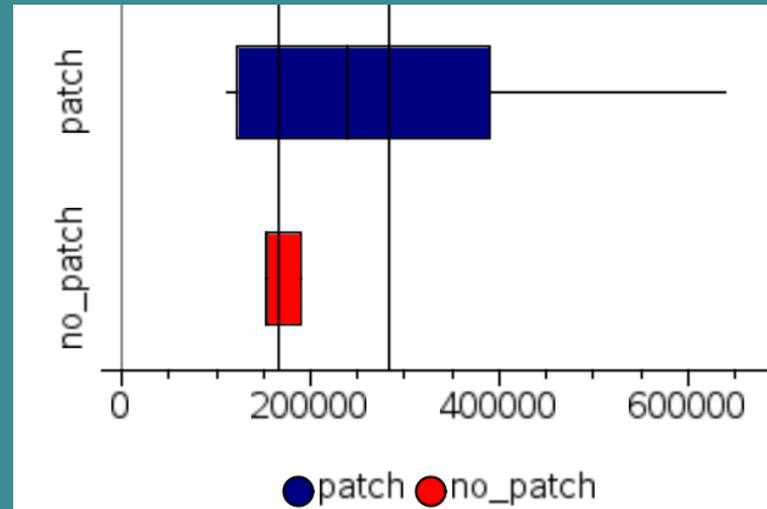
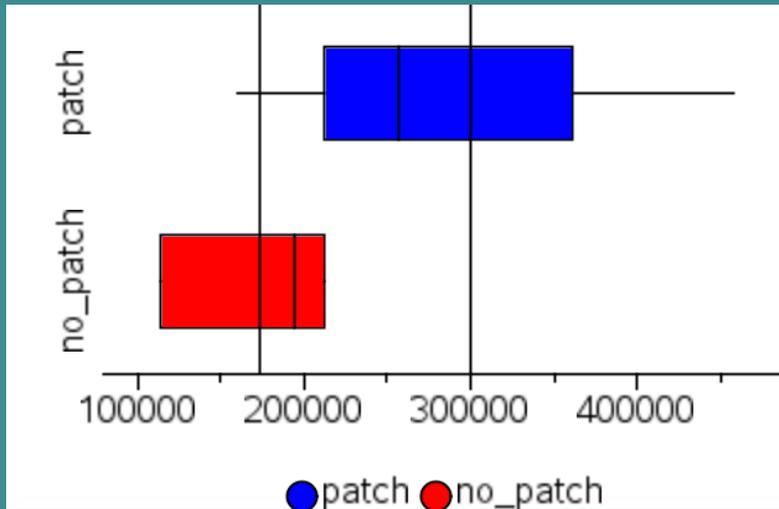
Central Tendency

- sample mean
- sample standard deviation

Data Analysis: Graphs



Data Analysis: Graphs

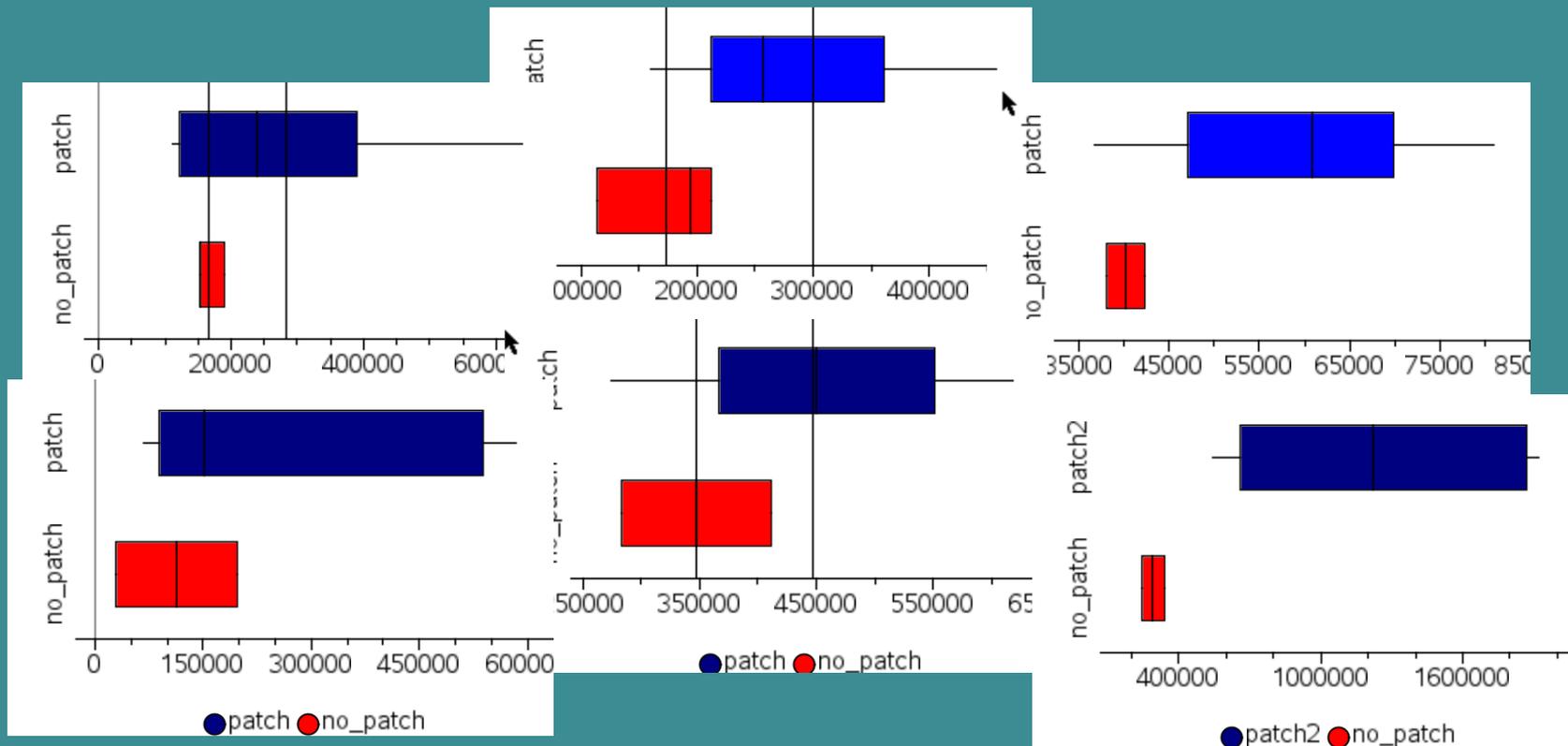


Patched vs. Unpatched Fatigue Life Comparison

Interpretation of the graphs

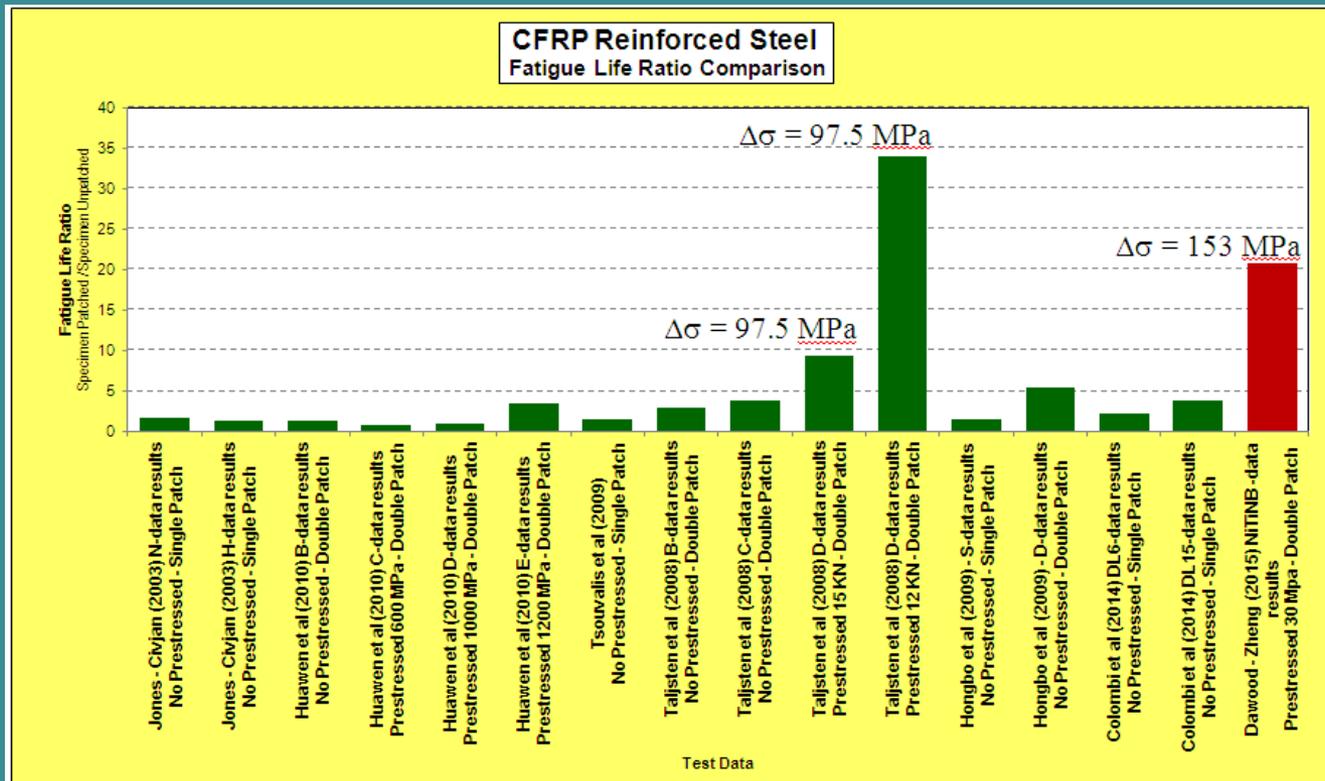
Data Analysis: Graphs

How to compare all the available data when coming from different experimental setups?



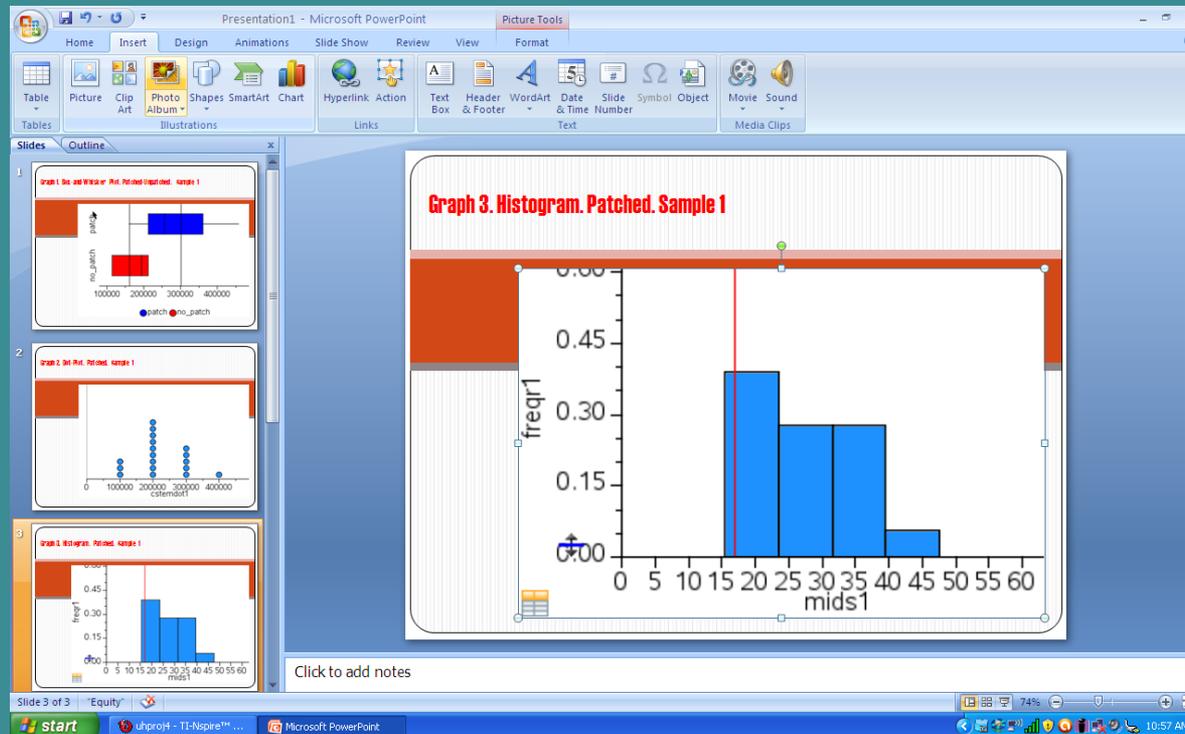
Data Analysis: Graphs

Using the fatigue life ratio: $\frac{\text{patched specimen mean fatigue life}}{\text{unpatched specimen mean fatigue life}}$



Student Results Presentations

PowerPoint + in-class presentation—or video (wmv, mp4)



- Background
- Procedure
- Data
- Graphs
- Stat analysis
- Conclusions