Strength of Damaged Steel Sections

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Abstract

Steel structures are used extensively in the mining, steel and petroleum industries as well as in public infrastructure. Their damage and deterioration is a major concern for the operators and owners.

American sources estimate it will cost about $50 billion to upgrade all steel bridges in the United States to an adequate standard. In Australia, it is estimated that the cost of repairs to an existing structure can be up to ten times the cost of a similar item in a new structure.

The main causes of deterioration for steel structures include corrosion, metal fatigue, excessive load, poor design, poor workmanship and changed conditions. Some of the signs of these causes include surface rust, pitting, loss of section, cracking, excessive deflection and excessive vibration. Table 1 presents a description of some forms of damage, possible causes and some recommended actions. It must be emphasised that the causes and recommendations cover the majority of cases we have encountered but are not necessarily exhaustive.

The load carrying capacity of these damaged or deteriorated steel sections is reduced and they may no longer be fit for their purpose. Even though the structure may appear to be intact, the ability to resist earthquake loads, wind loads and other abnormal loads is severely reduced and catastrophic failure may result without warning.

Guidelines are available in the engineering literature for the assessment of the strength of damaged or deteriorated steel sections. In this article two main causes of damage are discussed – deterioration due to corrosion and damage due to local dents and buckles.

1. Corrosion

Typical patterns of corrosion are shown in Figure 1. Common areas where corrosion can be more severe include column bases, beam webs near connections of beams to columns, top flanges of beams in splash zones and any areas where corrosive material can accumulate.

The load carrying capacity of a beam or column is directly related to the cross-sectional area. Failure of a beam or column is generally defined as when the cross- section has totally yielded. Figure 2 shows a plot of the loss of strength due to corrosion. Three curves are presented – corrosion on the web of a column, corrosion on the top flange of a beam and corrosion on both flanges of a column. The corrosion depth is the average depth of corrosion over the whole section.

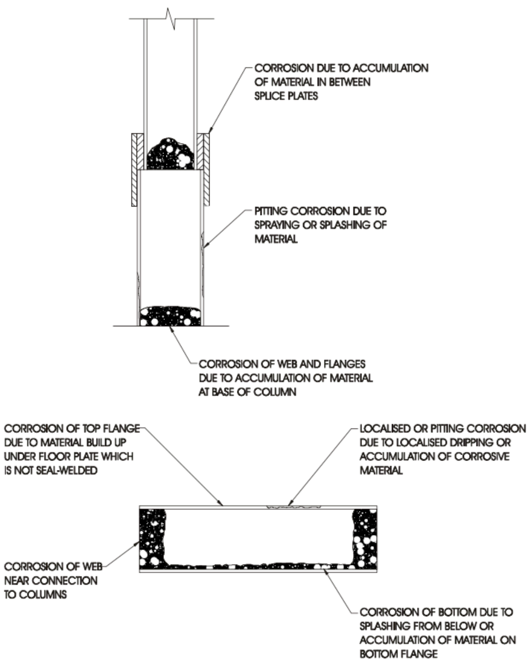

Figure 1. Typical patterns of corrosion.

Table 1. Types of damage in steel structures.

Description	Possible causes	Investigation suggested
General corrosion of structural steel sections	Environmental attack Presence of moisture Failure of protective coating Stress/galvanic corrosion	Ascertain type of corrosion Identify sources of moisture Check section sizes for residual capacity Check protective coatings
Corrosion of bolts	Environmental attack Presence of moisture Failure of protective coating	Ascertain type of corrosion Identify sources of moisture Check bolt sizes for residual capacity Check protective coatings
Missing fasteners; open holes	Badly fitting fasteners Fasteners not installed Defective fasteners Defective bolting Vibration	Replace missing fasteners Check adequacy of fasteners Check for building sway and vibration Check design and detailing
Loose bolts, nuts, rivets	Badly fitting fasteners Misaligned/misplaced holes Defective bolting Vibration	Check adequacy of fasteners Check for building sway and vibration Check hole accuracy Check design and detailing
Distorted fasteners Uneven head/nut seating	Badly fitting fasteners Misaligned/misplaced holes Defective fasteners	Check adequacy of fasteners Check hole accuracy Check design and detailing
Cracking of welds	Poor welding Fatigue Brittle fracture	Check weld quality by NDT Specialist investigation
Missing welds	Oversight	Replace missing weld
Welds with poor appearance	Unsatisfactory welding	Check weld quality by NDT
Excessive deformations	Out of plumb columns Poor fabrication or erection Overloading Design fault Accidental collision Inadequate bracing or lateral support Poor fit, slip or failure of support/connections	Check safety Check design and detailing Check construction against design Check connections for lack of bolts, inadequate bolt tightening, poor welding Check for accidental damage
Broken steel sections	Overloading Design fault Accidental collision Inadequate bracing or lateral support	Check safety Check design and detailing Check construction against design Check for accidental damage
Missing steel sections	Removal of key members	Identify structural system
Part of a steel section missing	Poor fabrication or erection Overloading Design fault Accidental collision Inadequate bracing or lateral support Removal of section on site	Check safety Check design and detailing Check construction against design Check for accidental damage
Unacceptable flexibility / vibration of structure or structural members	Wind or out of balance machinery Vortex shedding on circular structures Design fault	Check performance of structure in absence of wind or operating machinery Check adequacy of anti-vibration mountings Relate natural frequency of structure to that of exciting forces Specialist investigation

If the reduction in cross-sectional area is localised (less than span/10), we have found that up to 25% loss in cross-sectional area may be acceptable – the stresses in the localised area will re-distribute. However if the reduction in cross-sectional area is greater than 10% and extends over a distance greater than span/10, the corrosion should be regarded as severe. Repairs will be necessary forthwith unless further investigation is undertaken.

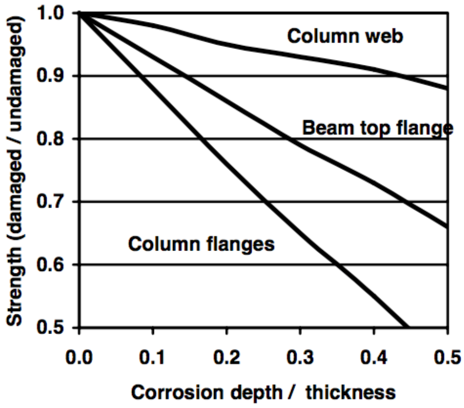

Figure 2. Reduction in strength for beams and columns with corrosion.

2. Dents

Local dents in columns are typically caused by vehicle collisions or impacts due to materials carried by cranes. Figure 3 shows the reduction in compressive strength for a circular tube. As can be seen, if the dent size is greater than the wall thickness then the strength of the section is severely reduced.

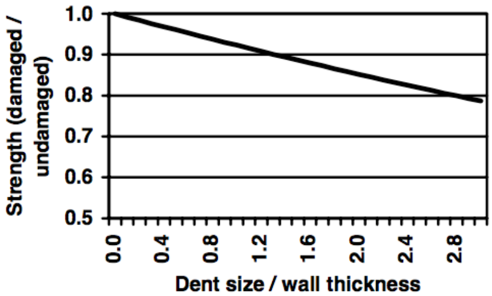

Figure 3. Reduction in strength for tubular sections with local dents.

Care should be taken when using the curves presented in Figures 2 and 3. They are meant to give an indication of the reduced strength and should not take the place of sound engineering analysis and design.