Loading on plate with different tension-compression strength

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Abstract. Whilst superseded by other materials, there are many instances of engineering structures in use today that are formed of grey cast iron. These aging assets need to be assessed for their abilities to continue to function, and to predict performance in the event of engineering works being carried out on the asset, or nearby. Grey cast iron does not exhibit an obvious elastic regime when loaded in tension and is often classified in terms of minimum guaranteed tensile strength. Grey cast irons typically fail in brittle cleavage with a strain limit of <1%, therefore an elastic based assessment is often applied despite the hardening properties exhibited. Tensile properties were extracted from dataset, compared to elastic assumption of different and same tension-compressive modulus using a plate model with distributed pressure. Different boundary conditions were applied to simulate potential constraint on a sewer penstock. It was found that the elastic models gave good estimation of the dataset models at lower stress levels, higher on higher stress levels, where increasing hardening is experience.

Introduction

Grey cast iron was one of the most prominent structural material in the early-mid 19th century, thanks to the lower melting point compared with pure iron, and the ability to produce a near nett cast product [1, 2]. There is a high carbon content in grey cast iron (2.5-4% wt), which stabilises into graphite flakes when the molten metal solidifies [3]. However, grey cast irons exhibit relatively low tensile strength, (although good compressive strength) and typically fail in brittle cleavage [2, 4, 5]. The material shows hardening properties without an obvious elastic loading regime and is often classified based on the minimum guaranteed tensile strength [6, 7]. It is common for grey cast iron to be assessed in a linear elastic manner, possibly due to the lack of material for testing [8, 9]. There are a number extensive assets (large in terms of size, inventory, or both) that are formed of grey cast iron components, and which are still in operation today. Some such assets are found to be in critical locations with respect to enabling works for 21st Century projects, and it is necessary to assess the residual capacity of the asset [10]. Such activities highlight the lack of materials knowledge that can compromise even the most elegant finite element analysis (FEA) [11, 12].

Following on from a physical experimental approach, which used ASM Class 40 data for reference [13], the current work investigates the reliability of an elastic approach for grey cast iron. Additionally, plate with pressure loading was simulated in FEA to investigate complex loading condition in the material. This setup was motivated by the ageing grey cast iron penstocks in the water industry. It was found that it is important to account for different tension-compressive strength, whilst the linearized elastic assumption can be used for conservative analysis given the correct failure assumption was applied.

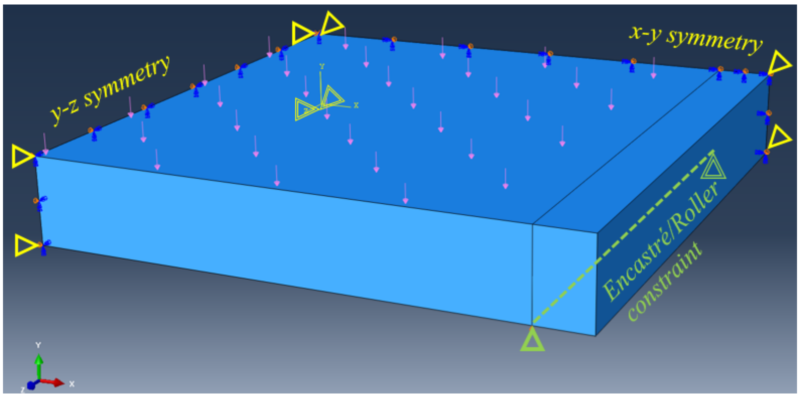

Figure 1 Quarter model of plate with distributed pressure loading.

Material property and FEA

Three different material properties were investigated: - I) dataset values, II) elastic with $E_{tension}$= 110GPa and $E_{compression}$=140GPa, and III) elastic assumption with E=110GPa. Material properties were converted to true stress-strain using the calibration function in Abaqus, and cast iron plasticity setting for the dataset values.

A quarter model was simulated using Abaqus 6.20 to investigate the effects of different material stress-strain assumptions in a plate loading test (Figure 1). Two different boundary conditions were specified on the pin line, Encastré ($U_{1,2,3}$=$UR_{1,2,3}$=0) and Roller (U_2=0). Distributed pressure was applied on the opposite of the pin line, leading to a general bending stress distribution across the plate cross section.

The Encastré models gave lower estimation of principal stresses and displacement compared to the Roller models. The bending axis from the dataset models tend to shift towards the compression region, whilst the elastic models showed consistent values. The model shown a maximum displacement of approximately 1.5% of the plate thickness (Figure 2), which confirmed that a Roller BC would be more suiting for the assessment of penstocks in the sewers.

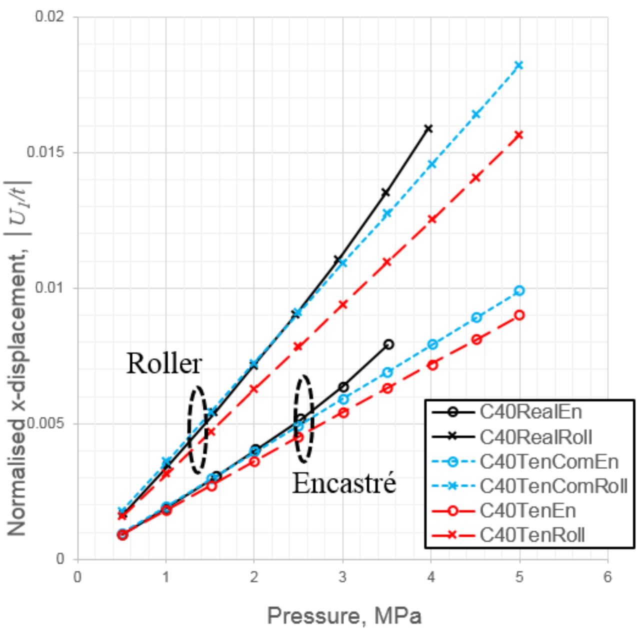

Figure 2 Displacement around the plate edges normalised to the plate thickness

Conclusion

It is important that the input data for assessment is applied as accurately as possible. The linear elastic assumptions gives good estimations of the actual dataset model at lower stress levels, conservative at the hardening stress region.

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