MODELLING AND OPTIMISING OF A LIGHT-WEIGHT ROCKFALL CATCH FENCE SYSTEM

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SUMMARY

Rockfall catch fence is a mechanical barrier system that is used at the foot of cliffs to stop and retain falling rocks from reaching nearby infrastructures. A typical system comprises of a high tensile strength wire mesh that is anchored to the ground by rigid posts and strengthened to the lateral and upslope sides by anchoring tension cables. Additional components, such as shock absorbers, might be added to improve the system capacity to dissipate energy. This multi-component system characterises by geometrical complexity and high nonlinear response to impact loads.

A light-weight catch fence system is a simple system that can be easily installed in a time efficient manner using manpower rather than heavy machinery, which makes it ideal for railways located in mountainous and difficult terrain regions where there is difficulty in accessing sites with limited workspaces and restricted installation times. However, this should be combined with a proper design to ensure that the system provides the required protection to impede falling rocks from reaching the train lines. In this paper, a parametric study based on finite element analysis is developed to optimise the design of a light-weight catch fence system that has an energy absorption capacity of up to 100 kJ.

1: Introduction

A finite element analysis study using Abaqus/Explicit is carried out on an existing design of a light-weight rockfall catch fence system to evaluate and optimise its capacity to dissipate impact energy under various loading conditions. A 3-dimeniosnal (3D) full-scale model is created using SolidWorks and Abaqus/CAE as shown in Figure 1a where a number of design parameters were chosen to perform a parametric optimisation study on the system. During the impact, wire mesh is the first component that comes into contact with the falling rocks, the wire mesh dissipates most of the rocks kinetic energy by plastic deformation of its wires and by friction contact between these wires. The remaining energy transfers to the tension cables and the posts which allow for a very small amount of plastic deformation to dissipate the energy. Therefore, it is crucial to accurately model and improve the dynamic response of the wire mesh prior to investigate the response of the whole system.

In the current analysis, a double twisted hexagonal mesh of 80x100mm dimensions,2.7/3.4mm wire/selvedge diameter is used. The wire mesh responds to a lateral impact loading by axial (tension) and bending deformation of its wires; thus the interaction between the axial and the bending responses is considered through the usage of 3D modelling approach of the full scale; the model is discretised by using beam elements as shown in Figure 1b.

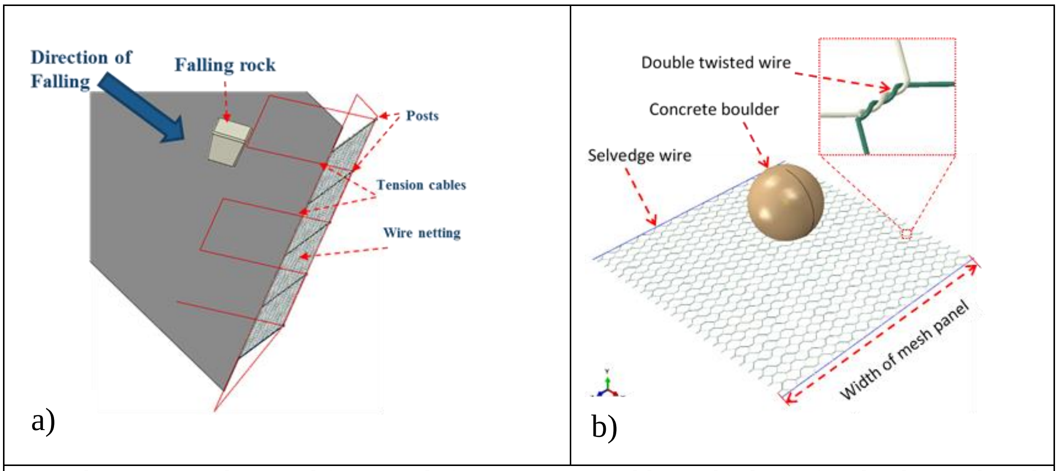

Figure 1: a) A rockfall catch fence system, b) Modelling of a double twisted mesh panel.

2: Constitutive behaviour of the wire net

The impact loading on the wire net develops an elastoplastic deformation at a high strain rate in the wires. In order to accurately model the mechanical behaviour of wires, an elastoplastic model that accounts for rate dependent effects is required. Classical metal plasticity models, such as Mises plasticity model, is able to describe the material behaviour within the strain rate limits provided by experimental data. For a single wire of 2.7mm diameter, it is difficult to obtain experimental data at high strain rates. Therefore, Jonson-Cook plasticity model is used which is an empirical formulation of Mises plasticity model that describes effective stress as a function of strain, strain rate and temperature effects. For adiabatic deformation, the temperature effect is neglected and the model can then be given by [1];

$$\sigma_Y = \left[A + B(\varepsilon^{p}_{eff})^{n}\right]\left(1 + C ln\frac{\dot{\varepsilon}}{\dot{\varepsilon}_o}\right) \qquad \text{Equation 1}$$

Where σ_Y is the effective stress, ε^{p}_{eff} is the effective plastic strain, $\dot{\varepsilon}$ is the strain rate, $\dot{\varepsilon}_o$ is the reference strain rate, and $A, B, C,$ and n are the model constants which need to be calculated. For this purpose, a number of uniaxial tensile tests on a single wire taken from the wire net are conducted at various strain rates, as shown in figure 2b, where the results are used to calculate the model constants. The suitability of the model to represent the plastic deformation of the wires is checked thorough a comparison between the experimental data and the model predictions of true stress-strain curves at various strain rates as shown in Figure 2b. It shows that the model is capable of capturing the stress-strain relation of a single wire at various strain rates.

A failure criterion is incorporated into the model to simulate the onset of material failure under loading; in this analysis, Johnson-Cook dynamic failure model that accounts for the effect of strain rate is considered. The model constants of the same material is considered from another reference because it is difficult to experimentally extract these parameters for a single wire [2].

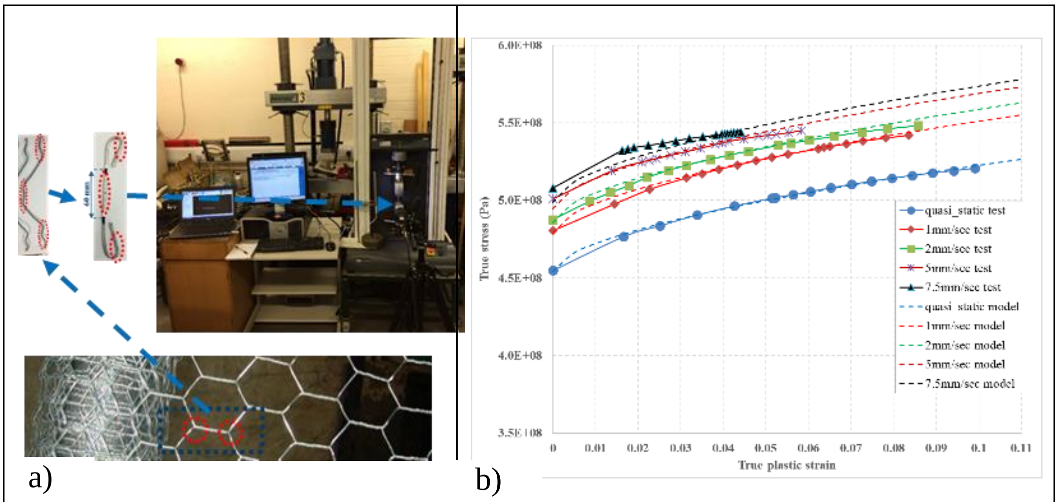

Figure 2: a) Experimental tensile tests, b) Comparison between tests data and model calculations of true-stress strain curves at various strain rates.

3: Results and conclusions:

The developed model of the wire net is calibrated by simulating of a quasi-static punching tests where the test data is provided by the manufacturer of the wire net [3, 4].

The proposed energy dissipation capacity for the current design is 100kJ with a maximum weight of the falling boulder of 2 tonnes. Thus, the maximum impact velocity is 10m/s. In order to predict the nonlinear behaviour of the wire net, a wire net panel of 2m length and various widths (2, 4, and 6m) is subjected to an impact loading by dropping boulders with various weights (100,200, 500 and 2000kg) at 10m/s impact velocity.

It is found that improving system flexibility, by increasing the width of the panel, will increase the time of contact between the net and the boulder which lead to transfer and spread of the impact load over a wider area of the wire net and thus smoothing the energy dissipation. Thus, improving system flexibility, by increasing the post spacing, will improve the energy dissipation capacity and reduce the costs and time of installation works by reducing the number of required posts for a certain length. In addition, the modifications improved the maintenance process by providing a wider accessible area on the top side of the fence which is necessary to clear the fence from trapped rocks and vegetation.

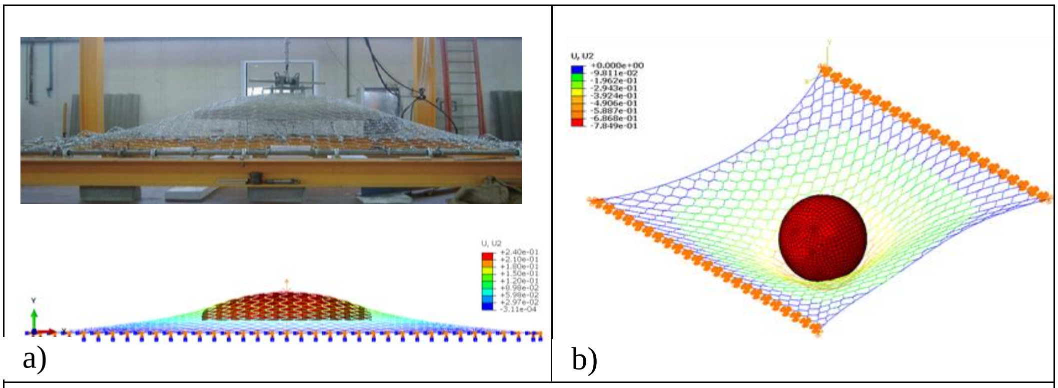

Figure 3: a) Modelling of punching test [3], b) Deformation of the mesh panel under impact load.

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