

STATIC AND DYNAMIC TESTING OF STEEL WIRE MESH FOR MINING APPLICATIONS OF ROCK SURFACE SUPPORT

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ABSTRACT

Wire mesh has been used for surface ground support in mining since the 1950s. Experimental studies have been conducted throughout the world. The response of the mesh is dependant on the sample size, the boundary restraint systems and the loading conditions.

The Western Australian School of Mines (WASM) has developed a facility for the static testing of ground support elements. The static facility consists of several stiff steel frames used to support the sample and a screw feed jack used to load the sample. The sample is restrained on all sides and displaced at a constant rate by a screw feed jack. Instrumentation measures the displacement and the load being applied.

The WASM dynamic test facility has been recently modified to enable the testing of surface support elements. Surface support element testing at the dynamic test facility will be conducted using sample sizes and boundary conditions similar to the static testing facility to enable the comparison of results between the two facilities.

Two testing programs have been undertaken to assess the static and dynamic performance of welded wire and chain link mesh. The results of the test programs are presented and comparisons are made for the performance of the two types of mesh.

1 INTRODUCTION

It has been recognised for many years that underground mining within Western Australia is progressing to greater depths and the influence of stress on the mining environment is becoming more pronounced. Seismicity, stress related rock mass degradation and the associated ground support problems are becoming more common. Accordingly it is becoming increasingly important to understand the response of ground support to both static and dynamic loading conditions.

Stress related rock mass damage impacts considerably on ground conditions within many West Australian mines. This increases the need for effective areal surface support between rock reinforcement elements. Wire mesh is currently the most popular surface support element used in Western Australia.

Wire mesh has been used as surface support in mining since the 1950s. Many forms of mesh are used including welded wire mesh, expanded metal mesh and woven (chain link) mesh. In the early 1980s, mesh research was undertaken in South Africa by Rand Mines limited (Ortlepp, 1983) and by the Ontario Ministry of Labour in Canada (Pakalnis and Ames, 1983).

In the 1990s, Ortlepp continued his work, progressing to dynamic testing. Tannant et al and Thompson et al both conducted large scale mesh tests to determine the force - displacement reaction properties of the given mesh being tested.

In 2002 the Western Australian school of Mines designed the dynamic test facility to test reinforcement elements (Player et al., 2004). Recent modifications to the test facility have been undertaken to enable testing of surface support elements.

In 2005, the Western Australian School of Mines designed and built a large scale static testing facility to complement the dynamic test facility (Morton et al., 2007).

Two test programs were undertaken to assess the static and dynamic properties of welded wire and chain link meshes.

The results from the test programs are presented and the static and dynamic performances of each of the mesh types are compared.

2 TEST FACILITIES

2.1 Static Test Facility

The WASM static test facility has been described by Morton et al. (2007) and is shown in Figure 1. The facility comprises two steel frames; a lower frame used to support the sample and an upper frame to provide loading reaction. The mesh sample is restrained within a stiff frame that rests on the support frame. The restraint system consists of high strength threaded bar, eye nuts and D shackles passing through a perimeter frame at allocated points (Figure 2).

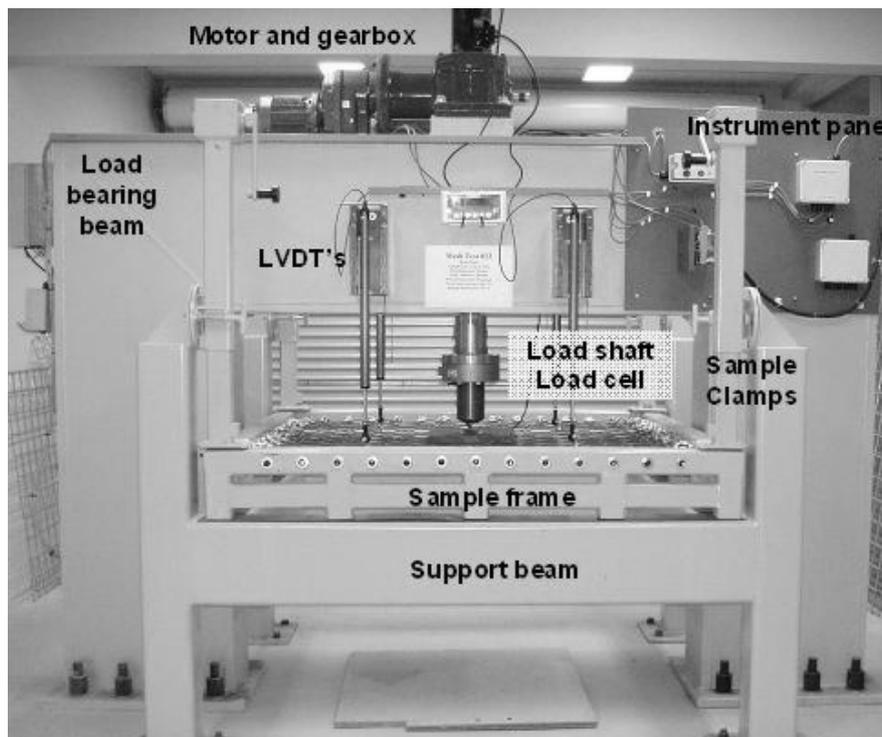


Figure 1: Static test facility

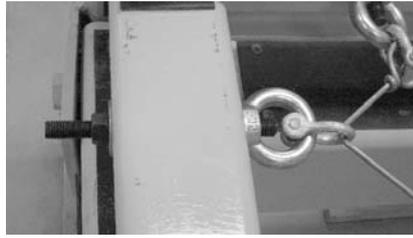


Figure 2: Boundary restraint system

A screw feed jack is mounted on the reaction frame. The screw feed jack is driven at a constant speed (4mm per minute) and allows large displacements to be imposed on the mesh. Load is applied to the mesh through a spherical seat, to a 300mm square, thick steel plate. The force is measured using a 50 tonne load cell mounted between the screw feed shaft and the spherical loading point. Data acquisition is undertaken at a rate of 2 samples per second. Testing of a sample can take up to an hour to complete.

2.2 Dynamic Test Facility

The dynamic test facility has been described in detail by Player et al. (2004) and is shown in Figure 3. The test facility consists of a drop beam positioned between four guide rails. Samples are loaded using the momentum transfer concept. A frame, to support the mesh, is bolted to the drop beam. The mesh is held in place using threaded bar, shackles and eye bolts in the same configuration as the standard static test arrangement. A loading mass is placed into the centre of the restrained mesh. The loading mass consists of a pyramid shaped bag filled with a known mass of steel balls (0.5 or 1 tonne). The loading area of the bag is 650mm x 650mm. A wooden prop is placed between the loading mass and the drop beam to prevent the mass “floating” during the initial free fall period. The drop beam and attached mesh frame assembly are dropped from a specific height to generate dynamic loading on the mesh sample.

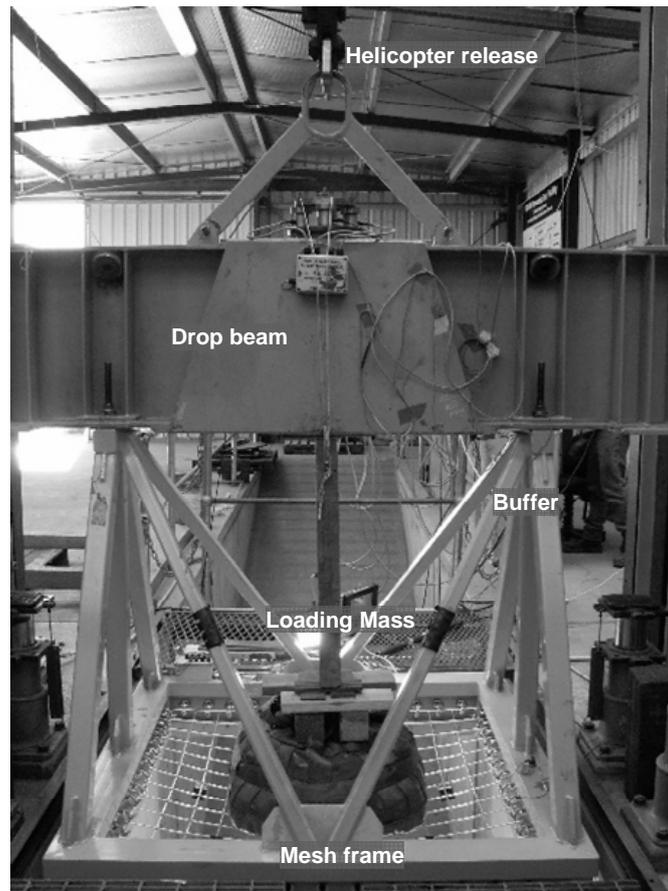


Figure 3: Dynamic test facility

Computer software, advanced instrumentation and a high speed video camera are used to record the test data. Data acquisition is undertaken at a rate of 25000 samples per second. Testing is completed in less than a second. Data processing is undertaken after the test to determine the dynamic performance of the test sample.

3 MESH SAMPLES

Testing has been undertaken on two different mesh types (Figure 4). The standard welded wire mesh used in Western Australian mines comprises 5.6mm diameter galvanised wires welded to form a 100mm square grid pattern.

The second type of mesh is 4mm diameter high strength steel wire chain link mesh provided by Geobruigg. Wires are shaped in a zigzag pattern and are then woven together to form a diamond grid pattern. The wires are joined at the ends using a specially designed process.

A 1.3m x 1.3m sample size is tested in both facilities. The welded wire mesh samples were cut from larger sheets provided by various sponsors. The chain link samples were specifically manufactured by Geobruigg to size for testing purposes.

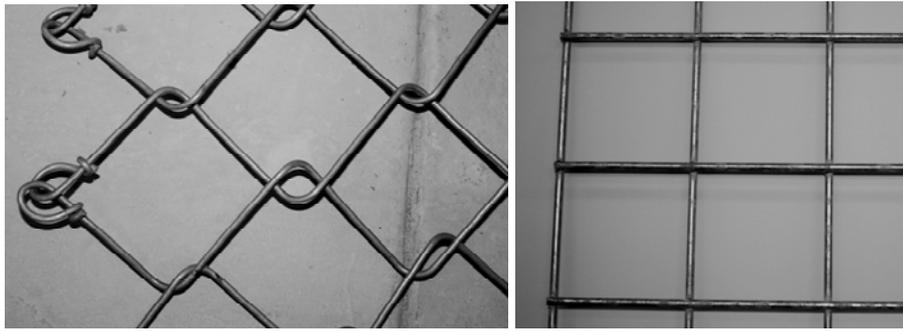


Figure 4: Chain link and welded wire mesh respectively

The welded wire mesh samples are cut from larger sheets (3m x 2.4m). The cross wires are marked so the sample can be placed within the mesh frame using a known configuration. All samples were positioned with the cross wires oriented across the frame and upwards, in contact with the loading plate.

The chain link samples were oriented with the direction of the stiff wires stretching across the frame.

4 RESULTS

In the assessment of any ground support system, the displacement, force and energy must be assessed in relation to the expected rock mass demand. Villaescusa et al. (2008) suggest that high energy absorption or large displacement capabilities may not necessarily be beneficial in controlling dynamic ground movement. The energy absorption is a function of force and displacement. Displacement is influenced, some times significantly, by the number of failures within the sample. For this reason, analysis of the mesh types has been undertaken at rupture. Rupture is defined as the point at which a part of the system breaks. Rupture may or may not correspond to the peak force achieved during the test. The variability of the sample response after rupture has occurred means detailed analysis cannot be achieved. Some post peak analyses have been attempted for both the static and dynamic data but are not presented.

4.1 Static Results

Typical static force - displacement response for welded wire mesh and chain link mesh are shown in Figure 5. A summary of all the static force - displacement results is shown in Figure 6.

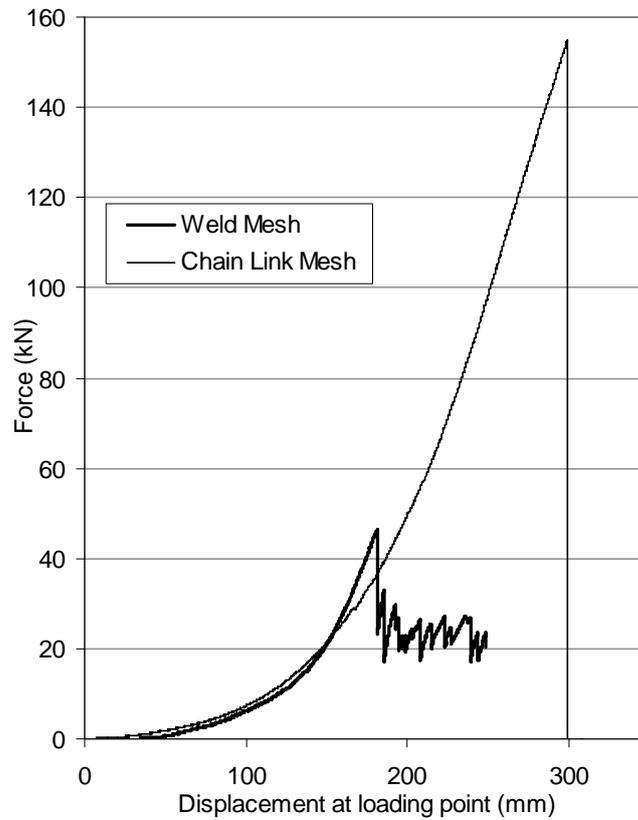


Figure 5: Typical static force – displacement response for welded wire mesh and chain link mesh

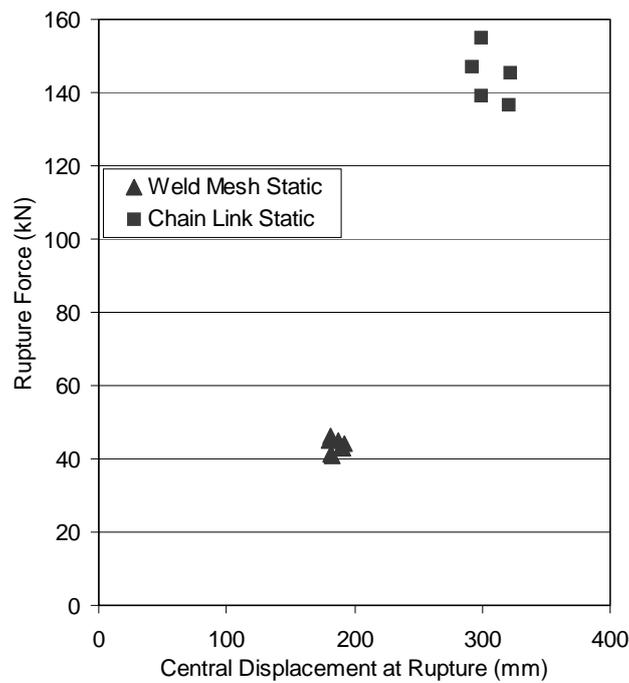


Figure 6: Summary of static force - displacement results for welded wire mesh and chain link mesh

The average static rupture displacement for welded wire mesh is 186mm whereas the average static rupture displacement of chain link mesh is 307mm.

Slight variations were observed in initial tension of the chain link mesh samples at the beginning of each test. This was taken into account by measuring the displacement of the mesh due to the placement of the loading plate before the commencement of a test. Highly tensioned sheets had minimal displacement whereas loose sheets displaced significantly as a result of the placement of the loading plate. The initial tension did not appear to have a significant effect on the overall force - displacement response of the mesh.

The average static rupture force for welded wire mesh is 44kN. The average static rupture force for chain link mesh is 145kN.

Significant differences were observed in the failure mechanisms and their locations between welded wire mesh and chain link mesh. The rupture of welded wire mesh always occurred at the boundary on a directly loaded wire. This is a function of the stiff boundary conditions used for testing. The failure mechanism of welded wire mesh, on the other hand, is a measure of the mesh quality. Three different welded wire mesh failure mechanisms were observed (Figure 7); tensile wire failure, weld failure and failure of the wire through the heat affected zone (HAZ). Tensile failure of the wire occurs when the weld strength is more than the strength of the wire.

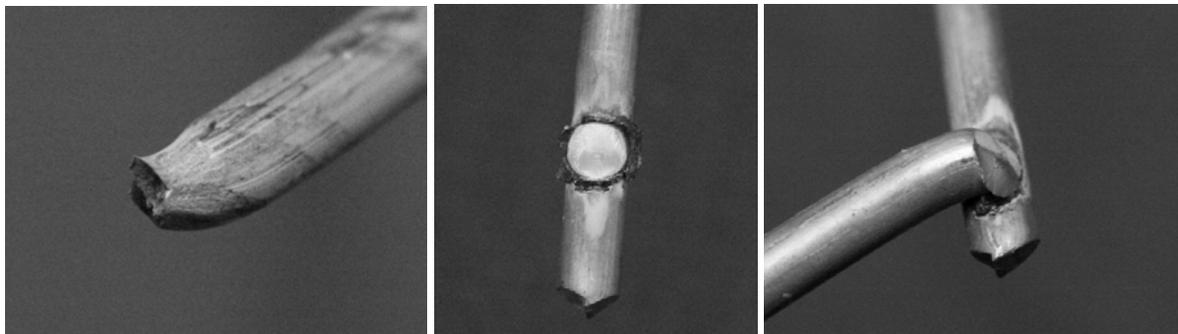


Figure 7: Welded wire mesh failure mechanisms; L – R tensile wire failure, weld failure and failure of the wire through the HAZ

Only one failure mechanism was observed for chain link mesh. The chain link mesh failed on the edge of the plate (Figure 8), either as a result of the plate cutting through the wires or as a result of the wires cutting each other at a “link”. This failure mechanism limits the direct applicability of the test and causes some variability in the results. Generally only one or two wires broke. The load dropped completely after the first rupture as a result of plate movement and the test was stopped. This was not considered complete destruction of the mesh.

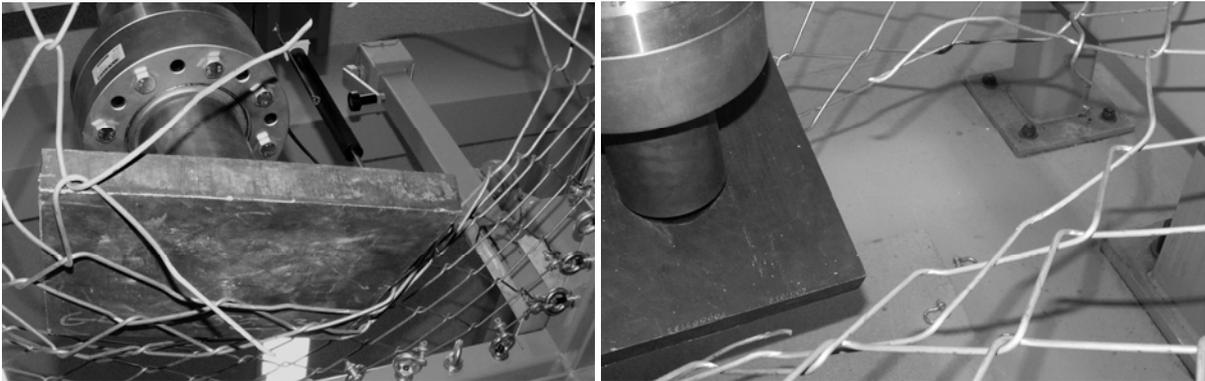


Figure 8: Chain link failure mechanism

4.2 Dynamic Results

Typical dynamic force - displacement reaction curves for welded wire mesh and chain link mesh are shown in Figure 9. A summary of all the dynamic force - displacement results is shown in Figure 10.

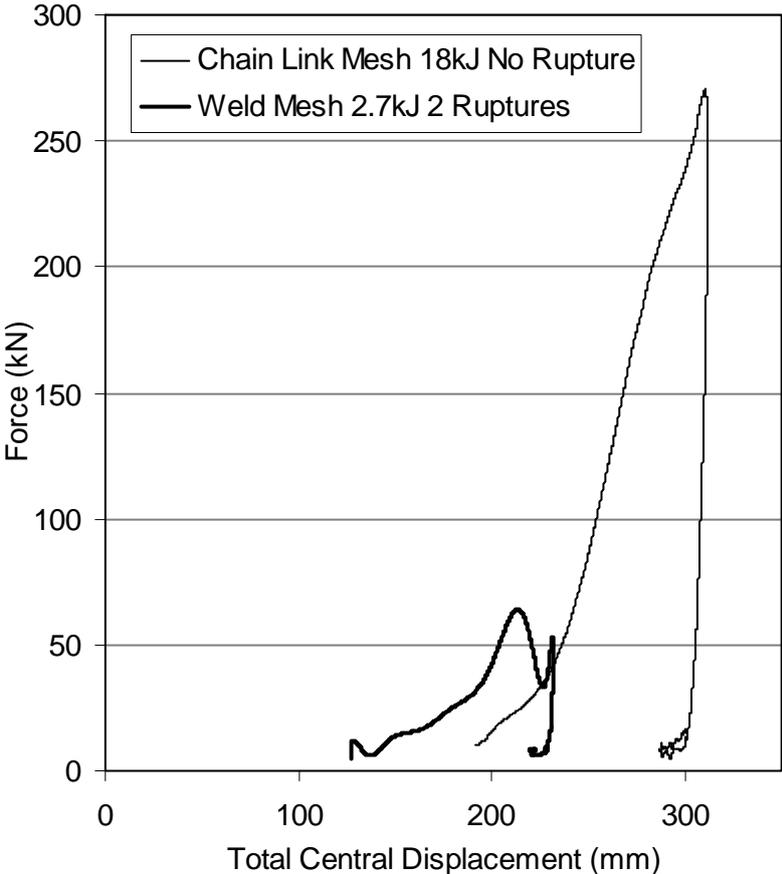


Figure 9: Typical dynamic force – displacement response for welded wire mesh and chain link mesh

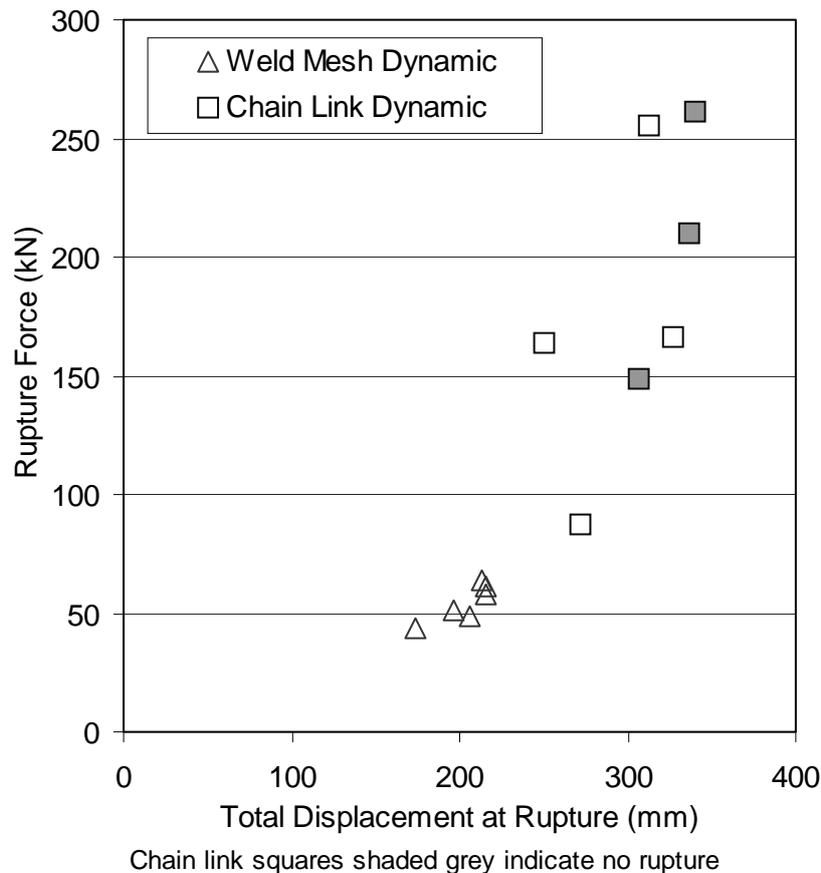


Figure 10: Summary of force - displacement results for welded wire mesh and chain link mesh

The average dynamic rupture displacement for welded wire mesh is 203mm where as the average dynamic rupture displacement of chain link mesh is 306mm.

The average dynamic rupture force for welded wire mesh is 55kN. The average static rupture force for chain link mesh is 185kN.

The average dynamic rupture energy for welded wire mesh is 2kJ. The average dynamic rupture energy for chain link mesh is 9kJ. The energy and displacement results are shown in Figure 11.

As with the static testing, differences were observed in the dynamic failure mechanisms of welded wire mesh and chain link mesh. The failure mechanisms for welded wire mesh under dynamic loading conditions were the same as in the static tests; namely tensile wire failure, weld failure and failure of the wire through the heat affected zone (HAZ). Due to the rapid nature of the testing, the location of rupture was difficult to determine in all tests. In general, rupture occurs at the centre of a boundary of the sample and progresses towards a corner.

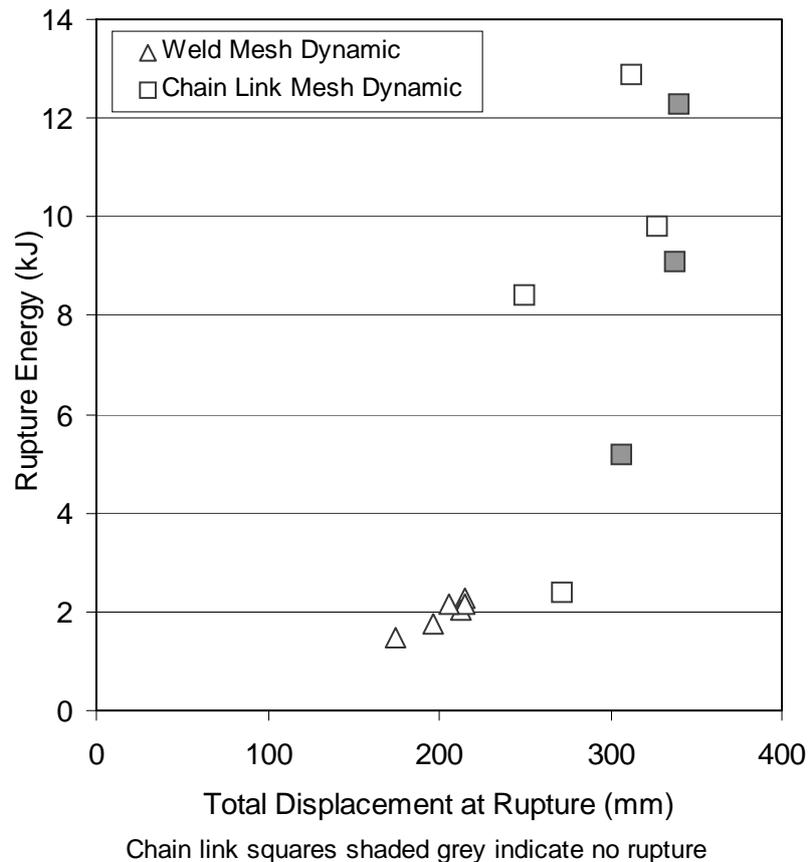


Figure 11: Rupture energy results for welded wire mesh and chain link mesh

The dynamic failure mechanism for chain link mesh was different from those observed during the static tests. Generally the mesh failed at the “link” between two wires. The location of the failure varied, with some tests failing close to the boundary of the sheet and some samples failing on the edge of the loading mass.

5 COMPARISON OF STATIC AND DYNAMIC RESULTS

5.1 Welded wire mesh

There is a good correlation between the static and dynamic performance of welded wire mesh. Less than 10% variation occurred in the average rupture displacement characteristics between the two facilities. A comparison of typical force - displacement reaction curves for welded wire mesh under static and dynamic conditions is shown in Figure 12. A summary of all the static and dynamic results for welded wire mesh is shown in Figure 13. The results indicate that slightly higher forces are achieved under dynamic loading. This may be a result of the larger loading area being used for dynamic testing which causes more wires to be directly loaded.

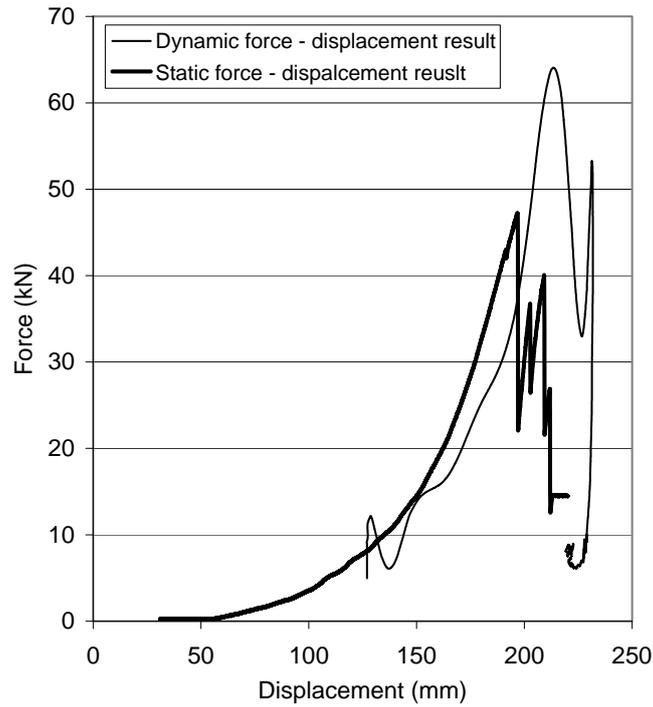


Figure 12: Static and dynamic force – displacement response for welded wire mesh

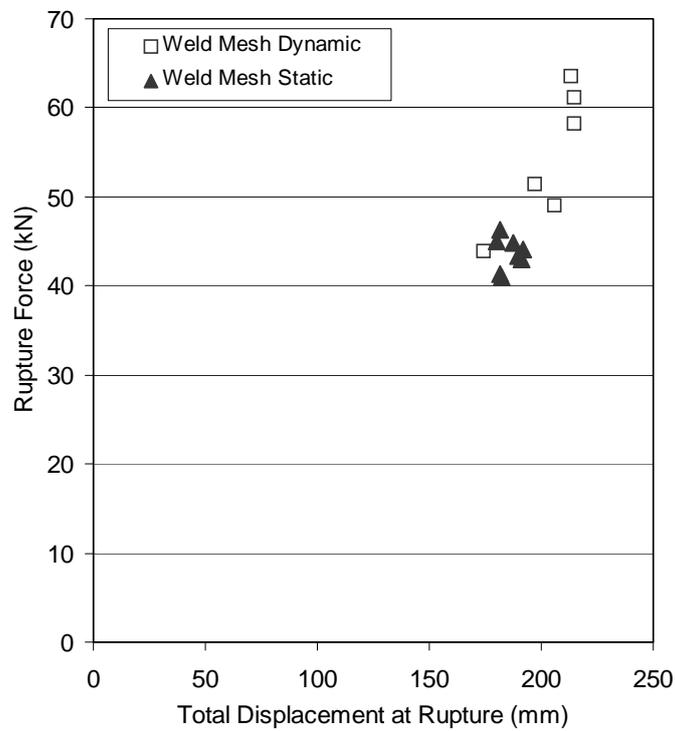


Figure 13: Comparison of static and dynamic force and displacement properties for welded wire mesh

5.2 Chain link mesh

The chain link mesh results did not have as good a correlation between the static and dynamic performance as welded wire mesh. Figure 14 shows the typical static and dynamic force – displacement responses of chain link mesh. The results indicate a difference in the stiffness performance of the mesh between the two facilities. This effect may be a result of the differing loading areas between the two facilities. Figure 15 presents a summary of the force displacement results from the two facilities. The results show that the static test facility has more consistent force – displacement results but underestimates the maximum potential force. This is likely to be due to the influence of the failure mechanism under static test conditions. Further testing is required to improve the static test loading configuration.

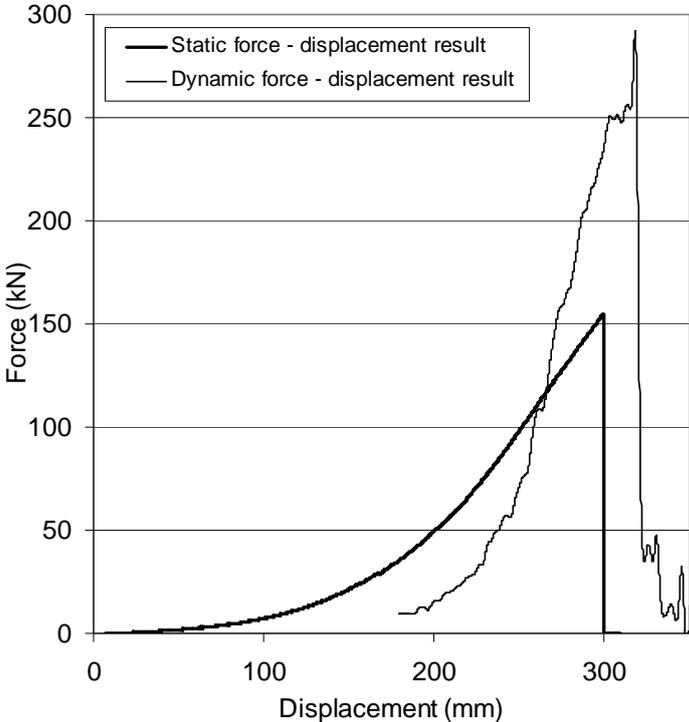


Figure 14: Static and dynamic force – displacement reaction curves for chain link mesh

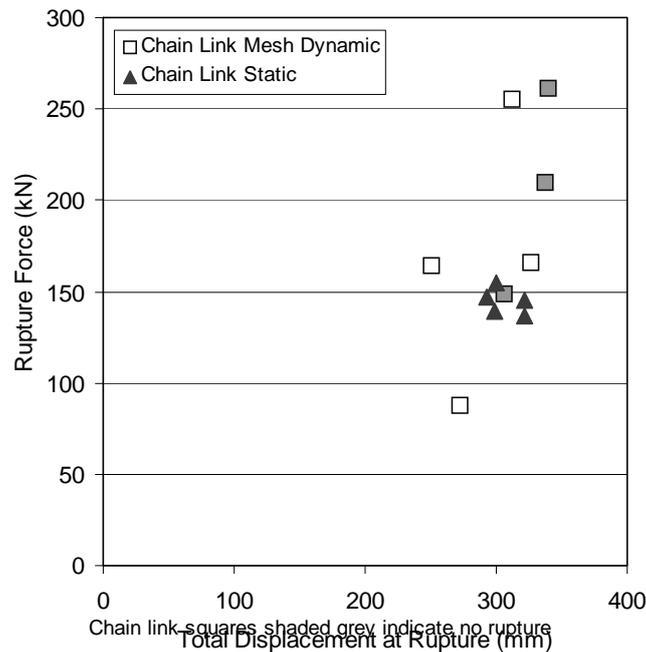


Figure 15: Comparison of static and dynamic force and displacement properties for chain link mesh

6 CONCLUDING REMARKS

Static and dynamic testing using the WASM test method has provided good comparisons for various mesh types. A comparison of static and dynamic test results has shown a good correlation between the two facilities. High tensile 4mm diameter chain link mesh has much higher force, displacement and energy capabilities than standard welded wire mesh currently used in Western Australian mines.

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