Experimental Study on Structural Behaviour of Steel Wire Mesh under Impact Loading

Masakazu Sugimoto[1*], *Kanako* Koizumi[2], *Takeshi* Arita[1], and *Toshiyuki* Horiguchi[2]

[1]Tokyo Rope International, Shibusawa City Place Eitai, 2-37-28, Eitai, Koto-ku, Tokyo, 135-8306, Japan
[2]National Defence Academy of Japan, Dept. of Civil Engineering, 1-10-20 Hashirimizu, Yokosuka, 239-8686, Japan

Abstract. In view of application to debris flow/rockfall barrier system, several types of steel wire mesh were selected to verify their basic behaviour under impact load of free fall weight at the controlled testing environment at an in-house testing facility capable of dropping a heavy weight on approximately 1-meter square panel made of such steel wire mesh material. Out of the 3 types of wire mesh tested, high-performance chain link endured the highest impact load energy, while newly developed wire mesh showed a high potential of effectively absorbing the impact energy by its plastic deformation along the total length of wire components. Both of the above two types of wire mesh are expected to be applied in flexible type debris flow catchment system in combination with larger opening mesh such as ring net. The newly developed wire mesh consisting of spirally deformed steel wires behaved as energy-absorbing elements while transmitting the impact load to the supporting ropes by its own plastic deformation along the total wire length.

1 Background

Debris flow has long been one of the threatening causes of severe natural disasters in many parts of the world. Japan is no exception consisting of mountainous regions amounting to 70% of the whole area, together with abundant water and numerous typhoon attacks every year. There has been a tremendous effort to avoid such a disaster, and many types of debris flow catchment structures have been proposed, tested, and installed in many parts of debris flow prone areas. A recent trend is the adoption of a flexible system consisting of wire mesh, supporting rope, and anchorage, as opposed to a rigid steel structure system, fixed on a robust concrete foundation.

As for the type of wire mesh used in the large-scale flexible system, the adopted majority has been a so-called ring net composed of several inter-connected high-tensile steel wire rings. This type of net and its siblings have proven to perform very well under impact loading such as rock mass, debris flow substance mainly consisting of muddy liquid and fallen trees without detrimental damage. While effectively distributing the load to the support ropes, a large portion of the kinetic energy of falling substance still seems to be carried over to the supporting ropes, causing large rope tension, and finally requiring some sort of energy absorption system (brake system) at the rope fixture end or somewhere in the middle of the rope. The reason for a large portion of impact energy not being absorbed by the net itself can be explained by the fact that only a limited small portion of the still wire goes through plastic deformation and thus contributing to the energy absorption.

If the net itself is capable of mobilizing a larger portion of the wire component throughout the entire wire length to go through plastic deformation, larger energy can be absorbed by the net itself and the total structural system can be simplified with the decrease in the support rope strength or elimination of brake system.

The paper presents a chosen several types of wire mesh material commercially available together with some newly developed wire mesh materials to verify the basic nature of their energy absorption capacity, and provide some valuable information for the future application of these mesh materials.

2 Specimens of steel wire mesh

For a comparison among several wire mesh materials available for impact force/energy absorption for debris flow catchment systems, three types of wire mesh material were selected as shown in **Table 1**.

Table 1. Steel Wire Mesh Material.

Type of Wire Mesh	Wire Diameter	Wire Material Grade	Spacing
A) Normal Chain Link	4mm 5mm	JIS G 3547 SWMGS-3	50mm
B) High-Performance Chain Link	4mm	JIS G 3548 SWGF-4	50mm
C) Newly Developed Wire Mesh	4mm 5mm	JIS G 3547 SWMGS-3	55mm

* Corresponding author: sugimoto.masakazu@tokyorope.jp

A) Normal Chain Link is the most commonly used type of wire mesh material for many applications such as Rock fall barrier and catchment fence in Japan. Its required minimum tensile strength is 290 MPa.

B) High-performance chain link with high tensile strength wire (tensile strength of 1230 MPa) is applied to large energy absorption rock fall catchment fence.

C) Newly developed wire mesh is composed of spirally fabricated steel wire (made from the same steel wire grade as A)) and is capable of exerting large deformation with plastic deformation along the full length of wire in comparison to normal straight steel wire.

3 Test setup and measured parameters

The impact test was performed at the impact loading test facility capable of dropping up to approximately 350 kg spherical weight from around 3.5 meter maximum height. The 1 meter square specimens supported on 4 sides by both-end-hinge-fixed ropes (**Fig.1**) were fixed to a square shape steel frame jig. Parameters such as rope tension, elevation, and acceleration of the weight was detected throughout the fall/bounce process by use of strain gauges attached to rope end sockets, a razer beam displacement meter fixed on the steel frame jig, an accelerometer attached to the free fall steel member (red coloured object in **Fig. 1**).

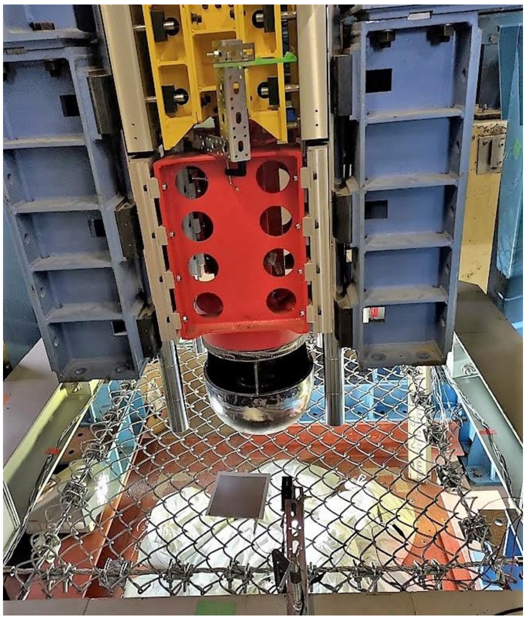

Fig. 1. Impact test setup.

4 Test result summary

In each round of impact testing, the behaviour of the freefalling weight and the wire mesh was carefully monitored (**Fig.2**).

After some 50 rounds of test cases, the approximate maximum kinetic energy with successful weight capturing has been deduced for each type of wire mesh. The results for typical wire mesh cases are summarized in **Table 2**.

Table 2. Maximum Energy absorption capacity.

Type of Wire Mesh	Wire Diameter	Weight	Max. Drop height	Max. Vertical Deformation	Approx. Max. Energy
A) Normal Chain Link	4mm	349kg	2 m	530 mm	6,800 kJ
B) High-Performance Chain Link	4mm	349kg	3 m	260 mm	10,300 kJ over
C) Newly Developed Wire Mesh	4mm	399kg	1.7 m	310 mm	6,700 kJ

In the above summary, a strictly fair comparison between wire mesh types cannot be made here, due to the difference in weight value of the weight (which could not be equalized due to the complexity and difficulty of changing the weight during the execution of several test cases. Also, due to the limitation in maximum drop height under the in-house testing facility condition, the maximum energy case for B) could not be performed in this test. However, it is fair to presume that A) and C) had nearly equal energy handling capacity while B) was able to handle more than 50 % larger energy under the test condition.

Normal chain link (4mm wire dia.) was able to capture around 6,800 kJ of kinetic energy with large resultant deformation and displacement as shown in **Fig. 2** and **Fig. 3**.

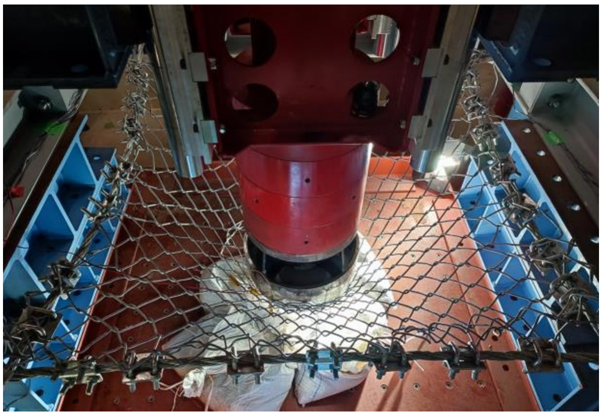

Fig. 2. Successful capture by normal chain link.

Fig.3. Large displacement of normal chain link.

High-Performance Chain Link was able to capture up to 10,300 kJ, and was expected to withstand even higher energy. But the test setup limitation allowed no further testing and the test had to be stopped at this level. Its basic behaviour under impact loading was similar to that of normal chain link as shown in **Fig. 4**.

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Fig. 4. Displacement of high-performance chain link after weight removal.

The newly developed wire mesh captured the weight with less vertical deformation in comparison with normal chain link (**Fig. 5, Table 2**). On the other hand, uniform plastic deformation of the 2 sets of 3 wires close to the mesh center was observed as indicated in **Fig. 6**. This indicates the effectiveness of energy absorption by spirally preformed wire. Since the size of the weight tip of 300 mm diameter hemispherical head was too small in relation to the mesh opening size, only three wires placed close to the mesh center were mobilized for energy absorption. It is expected to have more numbers of wires to be mobilized if the size of the weight tip is large enough.

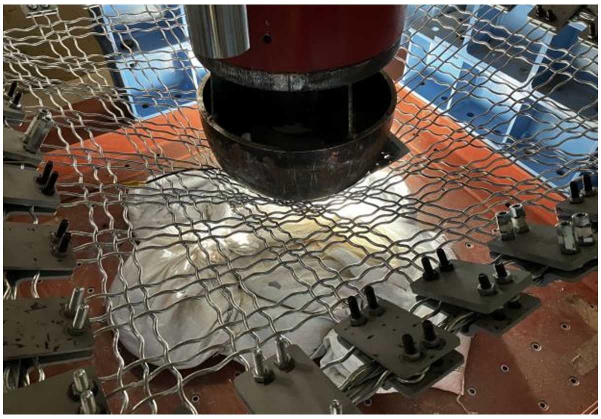

Fig. 5. Successful capture by newly developed mesh.

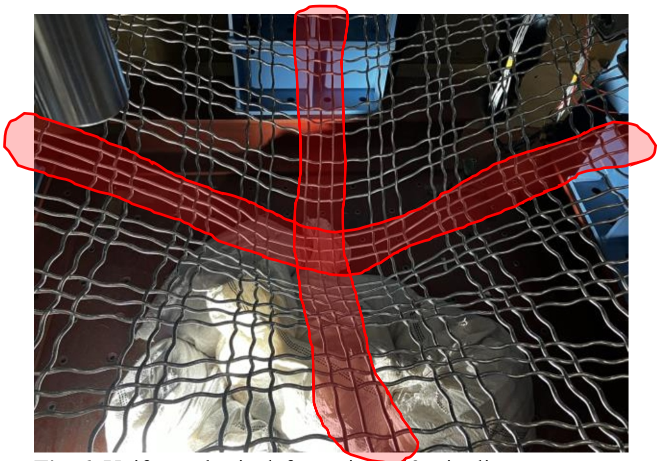

Fig. 6. Uniform plastic deformation of 3 wire lines.

Given the available space in the laboratory setup, the mesh panel size had to be limited to 1 meter square, and the tip of the falling weight had to be limited to 300 mm diameter hemispherical shape as previously mentioned with a maximum drop height of 3 meter. Under this condition, a set of impact loading tests provided meaningful data implicating that High-Performance Chain Link is more suitable for impact load absorption than normal chain link, and can function as the primary energy absorbing member in a flexible type debris flow catchment system.

A more detailed analysis of the experiment including the time history of supporting rope counterforce or weight movement during the impact loading is underway and will be reported at the conference.

5 Future tasks

The series of tests were performed as a first-hand approach to examine the basic behaviour of wire mesh exposed to impact loading, and to obtain several properties of the material so that they will provide useful information to fine-tune and upgrade the wire mesh materials in hand. It is scheduled to expand the scale of the test to replicate the behaviour of these materials under more realistic setting.
As for the newly developed wire mesh consisting of spiral wires,

Another area of the future task is to conduct an impact loading test of selected wire mesh materials in combination with commercially available ring nets or their siblings to demonstrate its total performance under severe impact loading.

In addition, it is also useful to apply numerical dynamic response analysis such as DEM to simulate and verify the behaviour or these mesh system [1, 2], and utilize the analysis method for the design of debris flow catchment system.

6 Conclusions

The paper presented an impact loading test of several types of wire mesh material commercially available together with some newly developed wire mesh materials to verify their energy absorption capacity.

Further research will be carried out on the advantages of the newly developed wire mesh with regard to load transfer and energy absorption mechanisms.

References

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