SHEET PILE WALLS – A SPACE-SAVING AVALANCHE DEFENCE STRUCTURE

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ABSTRACT: Steel sheet piles, primarily used as retaining walls when excavating soft ground and for stabilizing fills, are introduced as flexible components for a variety of effective and space-saving avalanche defense structures.
Where ground conditions are favourable sheet piles can be arranged in any actual pattern and may have fixed spacing for any given snow depth and slope-angel. Both catching and deflecting dams and methods of energy dissipation, is presented. The design and layout, and choice of pile profile, dimension and quality of steel, are based on the dimensioning load and actual purpose of the measure.
Single and double steel sheet walls and barriers are space-saving and more flexible than alternative mitigative measures of comparable efficiency. They are also much faster and normally cheaper to construct than structures erected by concrete, stonewall, geo-textiles or steel fabrics given the actual ground conditions. Examples applied for protection of rural highways in Iceland are exhibited.

KEYWORDS: Avalanche mitigation, steel sheet piles, deflecting dam, catching dam, energy dissipation.

1. INTRODUCTION

Conventional avalanche defense structures like earth dams, consume large space in the runout zone especially where the terrain is steep. In a number of situations the space available for a defense structure in the runout zone is limited so alternative mitigative measures must be applied. Such structures can be made by reinforced earth material or some other rigid material like concrete, steel, rock or wood.

In 2002 the authors introduced space saving structures in the form of steel-silo, (Hestnes and Jónsson, 2002). This article describes optional structures that may save even more space than steel-silos.

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Steel sheet piles are usually designed to create a rigid barrier for earth and water. They are used for construction work such as retaining walls, temporary shoring, cofferdams, docks, etc. because of their strength, their ease of handling and construction, and their potential for reuse. Despite their multipurpose function they are barely used in snow avalanche engineering.

Steel sheet piles, interlocked at the edge, can form a continuous wall of any desired length and height up to 10 m or more depending on form of structure (Figure 1).

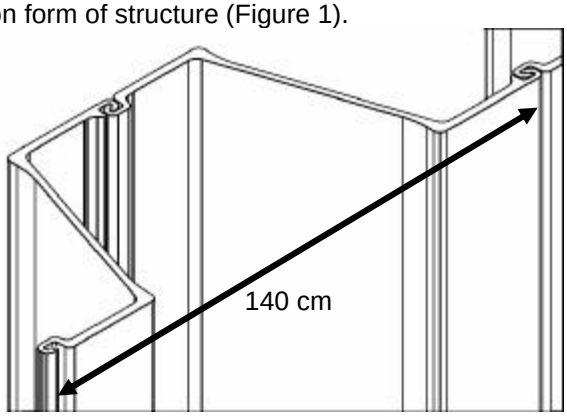


Figure 1: Numerous designs and locking systems of steel sheet piles exist. The depicted piles and locking system is manufactured by Arcelor, Luxembourg. The section is 140 cm across.

Defense structure made of steel sheet piles can be used to build a variety of space saving structures and structures that can dissipate avalanche energy. They can be used for direct protection of objects and as continuous deflecting- and catching dams. Such walls can also be combined with other constructions, for instance like earth dam. Steel baskets filled with stones are commonly used for the steep proximal part of earth dams in Iceland. Steel sheet piles can be an option to those baskets.

In Iceland the space is of concern both in small villages and along avalanche prone roads along fjords.

Figure 2. Steel sheet piles at Óshlíð in West fjords, Iceland. The wall is approx. 3 m high and is built to stop small avalanches and rocks before entering the road. Photo: Árni Jónsson 10/2005.

The Icelandic Road Authority (IRA) is concerned about the avalanche safety. Thus, space saving avalanche defense structures made of steel sheet piles and gabions have been used for road protection in the West fjords for some years now. Their aim is only to protect against small avalanches and boulders which were frequently hitting the road.

This article gives a variety of examples of how steel sheet piles can be used for avalanche protection along roads and above urban areas where space is limited.

2. ADVANTAGES OF STEEL SHEET PILES

One of the advantages of using steel sheet piles for avalanche protection is that time-consuming earthwork is reduced. Especially, compared to building earth dams with steep sides made of steel baskets, gabions or geocells. Handling and installation of sheet piles is also easy. However, they require cranes and other special equipments to install.

Environmental as well as aesthetic aspects is important in Iceland when protective measures are planned and designed. The piles will normally be coated to achieve an acceptable look instead of rusty steel-fabric (Arcelor, 2005). In urban atmosphere the steel might also need some protection or coating to slow down the corrosion. Detailed information can be found in brochures and web-sites belonging to wholesale dealers and manufacturer.

The limitation of steel sheet piles is related to the ground conditions. For cantilever piles the depth to the rock surface is a vital factor. A rule of thumb says that 1/3rd should be above the surface while 2/3rd in the ground. This will often be hard to achieve along roads in mountainous terrain where rock surface is here and there in the open. Another draw back is if the stratum is packed with boulders that hinder the installation.

However, a wall made by steel sheet piles can be anchored to the ground to overcome a depth problem. Alternative designs may as well be applied.

3. PRINCIPLE DESIGN

3.1 Basic forms of steel sheet pile structures

In avalanche mitigation steel sheet piles can be used in a variety of layouts and combinations depending on the purpose of the structure. Figure 3 shows three different examples.

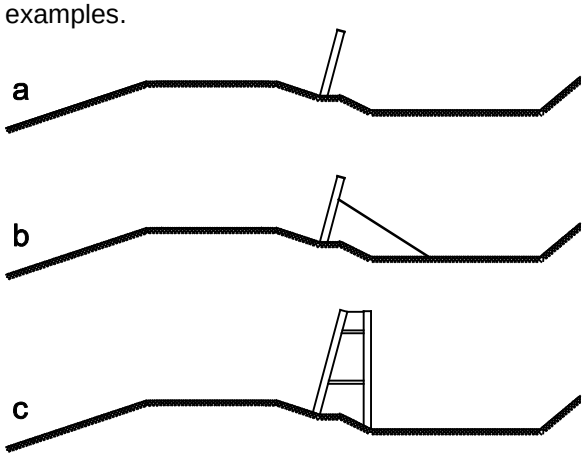


Figure 3. Some optional layouts of walls, here illustrated along road.
a) Single wall for small avalanches (cf. Figure 2).
b) Single wall strengthened by anchor for larger

avalanches.
c) Double wall strengthened by girders and infill. The width, size and layout of the ditch on the right hand side of the wall are important for the effect of the measure and effective removal of the snow when needed.

Cantilever steel sheet piles can be used for protection, given the ground conditions are favorable (Figure 3a). If ground conditions are not favorable or the forces are higher than the structure or the ground can withstand, methods sketched in Figure 3b-c can be applied. The structure in Figure 3c is filled with in situ or other suitable material to increase the strength of the structure and resistance against tilting and deformation. These structures may as well be erected on top of embankments to increase the effective height of protective measures.

The basic design and layout of steel sheet piles are shown in Figure 3 and Figure 6.

Steel sheet piles can also be used on very steep slopes, as inclination does not affect the effect of such vertical measures. They may as well be combined with deflecting and catching dams in this context (Figure 4). Such combined measures may be cost efficient on steep terrain.

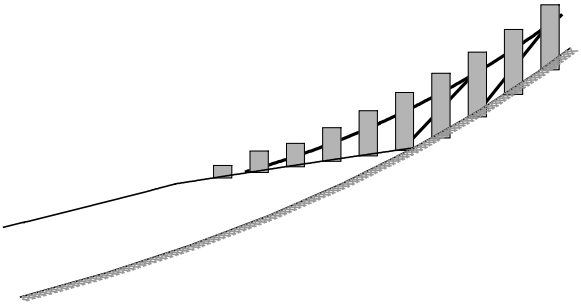


Figure 4: Combination of deflecting wall and dam. Steel sheet piles in the upper part are gradually taken over by earth dam in the flatter area.

3.2 Application

Many of the avalanche prone roads in Iceland are low-traffic roads. Permanent protection by expensive measures like galleries is not realistic.

For a new road section avalanche experts and engineers strive to avoid avalanche terrain. Where this intention fails precautions are normally taken to secure the traffic against avalanches running more frequent than every 10 to 20 years.

Due to the limited space along roads in hazardous zones, space-saving measures are usually needed to meet the safety requirements at the actual locations. Steel sheet pile structures are flexible solutions that normally fulfill these requirements.

Safety structures along roads should be continuous without openings. They may be located on the side-slope of the road embankment, but not on the shoulder. Where the terrain allows measures to be located away from the road minor openings between piles or sections could be advantageous.

The layout and design of the protection will depend on the local topography, possibility for terrain modification, size and velocity of the *design avalanche* etc. (Figure 5).

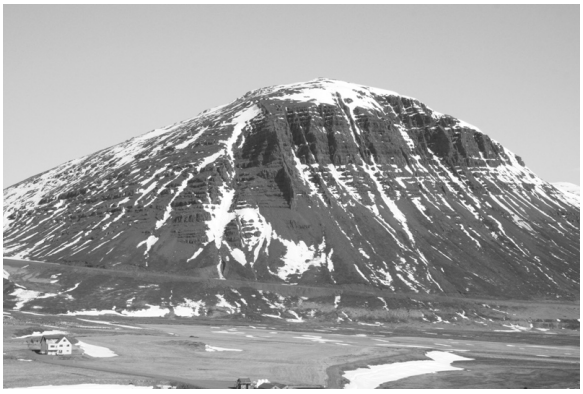


Figure 5. Grænafell mountain in East Iceland. A road-cut can be seen in the lower part of the mountain-slope. The road is hit by avalanches every year. Space for protective measures is limited along the road due to the steepness of the mountain side. Photo: Árni Jónsson, 28/4 2006.

Steel sheet structures of limited height may be vertical (cf. Figure 2). Larger constructions located along roads should be inclined to minimize the negative effect of an overwhelming wall and for aesthetic purposes. An inclination of 10^{o}-15^{o} is recommended (cf. Figure 3a-c).

It is important that maintenance equipment can clear snow from the backside of such mitigative structures to maintain the accumulation capacity.

Earth dams, either deflecting or catching dams, are the most frequent protective measure in urban areas in Iceland. The height ranges

from 15-20 m and a 22 m high catching dam is planned.

Avalanche experts are discussing what happens when a large avalanche of high velocity are hitting high dams. A primary question is if air can be locked under the front of the avalanche causing an uplift of the front.

The potential problem can probably be reduced by using a partly open steel sheet pile structure which can be located either on prepared terrain or on an embankment or dam (Figure 6). The combined dam in Figure 4 is an example of the latter. The optimal design of such air and energy dissipating measures will, however, depend on the site-specific problems to be solved.

Figure 6-1

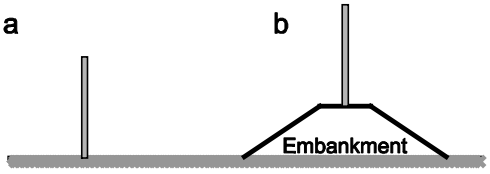
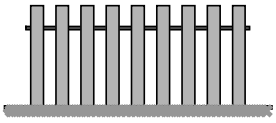


Figure 6-1: Principle cross sections here shown on level ground.
They may as well be located on inclined ground.

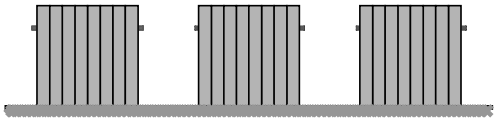
Figure 6-2

a



Proximal side.
Open form, every second sheet pile is left out, for energy dissipation.
Usage:
- On level or inclined ground
- On top of embankment or dam

b



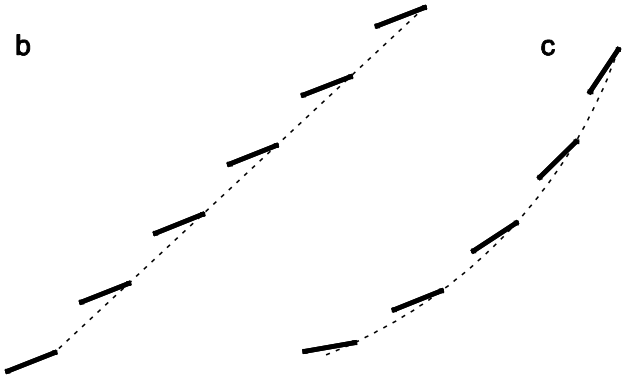
Proximal side.
Open form, section of sheet piles with opening in between the sections.
Purpose of opening is energy dissipation.
Usage:
- On level or inclined ground
- On top of embankment or dam

Figure 6-3

a

Catching dam or embankment

b



c

Deflecting dam or plough

Open form: every second sheet pile or sections of sheet piles on ground or embankment.

Figure 6. Basic forms of steel sheet piles.

The combined deflecting dam in Figure 4 will dampen and dissipate energy and air in the upper part where part of the avalanche mass will flow through the sheet pile structures. The design and layout should be adjusted so that the mass passing through stops before reaching any object being protected by the measure due to lack of momentum.

As previously mentioned steel sheet pile structures alone can not stop large avalanches with high velocities. However, placed on top of a dam such structures will reduce the volume and space needed for dam construction. A vertical steel structure is also more effective in dissipating energy than a dam with sloping sides so the total height can as well be reduced.

Depending on the impact angle the steel sheet piles may need to be strengthened to minimize the risk of rotation and buckling. Anchoring or supporting may inevitably be needed for the higher structures in protection of urban areas, but when protecting roads it may not be necessary in some cases given the ground conditions are favorable.

4. ACKNOWLEDGEMENT

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