STRENGTH OF GALVANISED WIRE-MESH WALL REINFORCEMENT

REINFORCEMENT OPTIONS FOR IMPROVED EARTHQUAKE RESISTANCE OF STONE MASONRY CONSTRUCTIONS

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INTRODUCTION

The Building and Construction Improvement Programme (BACIP), operating in the Northern Areas of Pakistan, is a project under the Aga Khan Planning and Building Services, Pakistan (AKPBS,P). The programme is financed by PAK-SID, a collaborative venture between the Canadian International Development Aid (CIDA) and the Aga Khan Development Network. The expenses of the Programme Director are financed by the Netherlands International Development Co-operation Programme (DGIS).

The western wing of the Karakoram Range of the Himalayas, comprising the Northern Areas and Chitral, is under influence of plate-tectonics that culminate under Afghanistan. Earthquake movements are frequently registered in the entire area and building to withstand these tremors is extremely important in saving human lives and minimising economic disaster.

Lack of natural resources have affected the building practices over the last generations. This aspect, combined with rapid population growth, has resulted in a severe deterioration of building quality, especially in areas where no alternatives to traditional stone constructions have be realised. The BACIP Programme has with the introduction of Galvanised Wire-Mesh Wall Reinforcement provided an economically feasible and technically sound method to reinforce traditional stone constructions in remote mountain villages.

Non-Engineered Constructions

In the present document it is explained how the galvanised wire-mesh reinforcement is applied in house construction. The methodology has been specifically designed to reinforce non-engineered stone masonry house constructions[1]. The BACIP recommendations are applicable for common housing, but the quality of the reinforcement effect depends on the quality of the masonry work.

Important

The wire-mesh wall reinforcement cannot be added to a completed building as it needs to be built into the construction during the masonry of the walls. If future storeys are to be added, the correct reinforcement must be applied from the beginning. It is therefore a better investment to spend a few thousand rupees extra to reinforce the lower floor, which allows for a future second floor, than to buy or use additional (agricultural) land for building another one-storey house.

Definitions

- One-storey house = ground floor only.
- Two-storey house = ground floor plus one additional floor.
- Three-storey house = ground floor plus two additional floors (maximum 30 ft.).

An overview of the wire-mesh manufacturing technique and its development are explained in detail in two separate documents entitled:

Galvanised Wire-Mesh Wall Reinforcement Methodology (December 1999)
The Development of the Wire-Mesh Knotting Equipment (December 1999).

[1] Non-engineered constructions are all constructions that are built on experience, without making special strength calculations. Nearly all housing in the Northern Areas is non-engineered. Currently many reinforced concrete constructions are also non-engineered as contractors place a "fair amount" of reinforcement in the floors and beams and hope it is enough. This leads to over-dimensioning and excessive use of concrete, adding to the weight and cost of the construction.

1. EARTHQUAKE REINFORCEMENT TECHNOLOGY

The methodology of reinforcing single, double or triple storey houses with galvanised wire-mesh wall reinforcement follows the same engineering principles as for reinforced masonry or reinforced concrete. The use of the BACIP galvanised wire-mesh reinforcement is particularly useful in the following circumstances:

A. For houses and buildings in stone or block masonry that are not higher than three storeys (ground floor plus two) or 30 ft. and have sufficient structural and supporting walls.

B. For all stone masonry wall constructions (18" two-stone) that are not masoned in strong cement mortar or do not have reinforced concrete layers or beams cast into the walls.

C. For all stone masonry that is to be built high up in the mountains and in which only little amounts of cement mortar can be used (for practical or cost reasons).

D. For the reinforcement of all low-quality cement block buildings (less than 100 psi), compacted earth block or adobe constructions.

E. For all house owners that do not have the funds for realising expensive and heavy[2] reinforced concrete constructions.

F. For persons that want to build additional storeys for housing accommodation on top of an existing concrete frame construction (without in-fill walls). The open frame construction comprising the ground floor is usually used to accommodate a store or workshop for commercial purposes.

The use of the BACIP galvanised wire-mesh reinforcement is NOT useful in the following circumstances:

- When the stone masonry is going to be made of very poor quality and the stones do not join well together. In this case the wire-mesh reinforcement will not be properly squeezed (locked) in between the stones, and adherence to the construction is insufficient. This means that the wire-mesh is not a solution for poor quality dry-stone masonry work. The better the dry-stone masonry work, the better the wire-mesh will reinforce the walls.

- For building constructions that are made higher than three storeys or 30 ft. Although it is possible to reinforce higher buildings using the wire-mesh reinforcement technology, calculations need to be made to assure that the right amount of reinforcement is applied in relation to openings and bearing walls. In this case it is no longer a non-engineered construction.

- If buildings are initially built with sufficient walls at the ground floor level (with frame construction), but where it can be expected that in the future the ground floor will be converted into a large workshop, store or other open floor construction for which the wall constructions are to be removed[3]. In this case the wall constructions cannot function as bearing or shear walls.

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[2] As the force of an earthquake is directly related to the weight of the construction, it is important to reduce the weight of the construction as much as possible. Reinforced concrete may be strong, but is also heavy.
[3] This is often the case in urbanised areas where occupants start a business on the ground floor and add living quarters above. Even if it is a reinforced concrete construction, this can cause dangerous situations.

The galvanised wire-mesh wall reinforcement has been especially developed and the manufacturing technique designed for three categories of house builders in the mountainous areas of the Himalayas, namely:

◊ House builders living high up in the mountains where the making of reinforced concrete is very expensive due to costly transport of cement and lack of aggregates and/or sand. The use of the galvanised wire-mesh wall reinforcement avoids to a large extent the use of these expensive materials. It is possible to reinforce the house without cement mortar.

◊ House builders that are constructing their houses in the beginning or the end of the winter period when the night-time temperatures drop below zero degrees Celsius. Under these circumstances no good quality cement or concrete mortar can be made. This point is important as the building season is limited to the period when the agricultural land cannot be worked. At the moment the ground thaws, all attention and time must be given to the preparation of the land as food production is the livelihood of the people.

◊ House builders that want to reinforce their houses but are only accustomed to building in dry-stone masonry, using clay-soil as a filler material between the joints. Depending on the width of the walls and the intersections between the walls, two to three storeys can be constructed. The top floor should then be of a light construction material, such as double insulating wattle panels with soil-lime plaster. This kind of construction requires a little more maintenance than constructions in which cement mortar is used, but the building costs are considerably lower, the insulation value is increased and maintenance can be done by the house owners themselves.

Winter Table

The following table is an approximation based on information from local builders. Local contractors will try to continue for two more weeks into the first night frost period, producing poor cement quality.

In the table, a "+" indicates the weeks that cement can be used and a "-" indicates when it is too cold (less than +5° Celsius at night). Overnight evaporation of water will additionally cool down fresh masonry in the higher altitudes.

The table indicates that the building season (with cement mortar) in the winter is rather short for most of the mountain villages, especially those over 7000 ft.

Village	Altitude	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April - August
Gilgit	5000 ft.	++++	++++	++ - -	- - - -	- - - -	- - - -	++++	++++
Hunza	6000 ft.	++++	++++	+ - - -	- - - -	- - - -	- - - -	- +++	++++
Hopper	7500 ft.	++++	++++	- - - -	- - - -	- - - -	- - - -	- - ++	++++
Sost	8000 ft.	++++	+++ -	- - - -	- - - -	- - - -	- - - -	- - -+	++++
Phundar	8500 ft.	++++	++ - -	- - - -	- - - -	- - - -	- - - -	- - - -	++++

A minimum of four hours of daily sunshine has been considered. When buildings are located in the shadow-side of the mountain (in the winter the sun is considerably lower than during the summer), one additional month of winter time needs to be added to the above table.