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BUILDING PARTNERSHIPS

Wall Building
Technical Brief

Building Advisory Service and Information Network

Stone Walls in Mountainous Regions

Introduction

Stone is the natural walling material of mountainous regions. To haul up bricks or cement, often on human back, can take a few days. It makes more sense to bring the tools and the skill to the hills. Yet, unless traditional, the utilization of stone is limited, wasteful and also with little attention to environment. Stone foundations with a superstructure of other building materials are more common.

Local stone is cost-favourable as compared to transported building materials due to state-of-the-art technologies which have turned stone into a modern material which can provide local employment.

Stone is one of the few building materials applicable "as is" with hand tools: further processing or technological inputs are optional. Stone needs no warehousing for storage and packaging requirements are minimal.

In any pilot project within a sponsored model housing scheme a small pilot plant would encourage and facilitate the production of stone components like sills, lintels and paving elements.

It would also lead to the establishment of local stone supplies which, with quality control and transfer-of-experience potentials keep the wall building costs down.

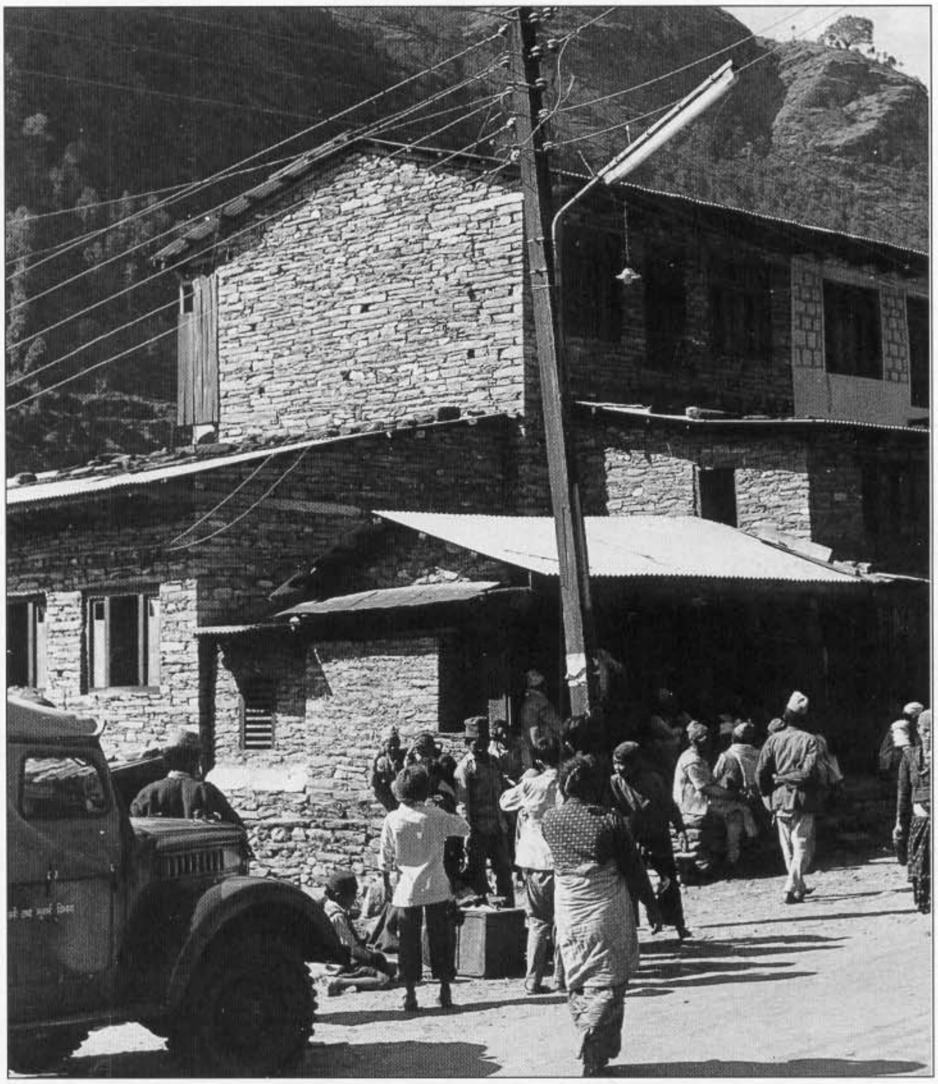

Figure 1: Stonehouses near Prithvi Rajmarg Highway in Nepal

Location profile

The more common, typically populated mountainous region is of a limestone type or contains rocks like basalt, sandstone, phyllites, schists, etc., usually overgrown with shrubs and with occasional trees on sparse topsoil. A limestone topography is more often than not strongly affected with karstic features, it has extensive terracing supported and enclosed by dry walling. Rainfall in most mountainous regions is seasonal, with notable exceptions.

Stone resources

The stone resources on the slopes are easiest to extract when outcropping in hill ledges or from previous excavations or riverbeds, terraces or abandoned quarries. They vary from fine grained to coarse grained with various degrees of crystallinity, various tonalities and textures or ornamentations. As a start stone outcrops situated near the construction sites could be used. The larger waste heaps from previous quarrying enables proper grading and selection on a wider scale.

Stone Identification

General guidelines

Stone as a local material is usable practically without complicated further processing other than ornamental. Being a mono-technology, the material itself needs no transformation; what one has to know about stone is concerned with its extraction, selection and shaping:

The bedding and layering of stone at the source has to be checked for the required

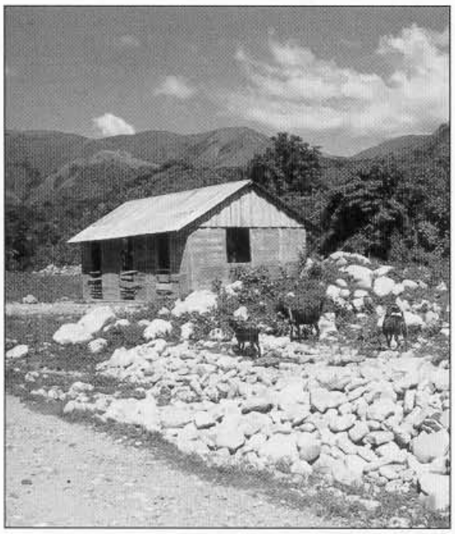

Figure 2: Stones resources in the Dominian Republic

thickness. Already applying a hammer or a crowbar gives much information about cohesion, hardness, soundness and/ or breakability.

If the stone "rings true"and reverberates, then flaws are unlikely. These are indicated by a dull sound, as in striking a cracked clay vessel or flowerpot. Therefore clayey, marly and the softer chalky stone varieties should be avoided. Scratching the stone, soaking it in water for a few days will also give much information about hardness, coherence and porosity. Highly porous stones will increase in weight; even hard marls and clays, which look stone-like when dry, and can disintegrate during soaking. Limestone rocks are either hard or chalky limestones, or clay and marly varieties.

Cleavability and jointing are important for a good workability. A chisel-pointed hammer, mason's hammer, or a chisel will indicate breaking directions. Weathering changes can be observed by comparing the natural "skin" of the stone with a freshly broken surface.

In a regional investigation a prime resource target are slabby limestone layers; these are easy to trim on the sides, the top and bottom being naturally flat.

Applications

The preparation and construction of the foundations and the stability of the walls, are basic in planning.

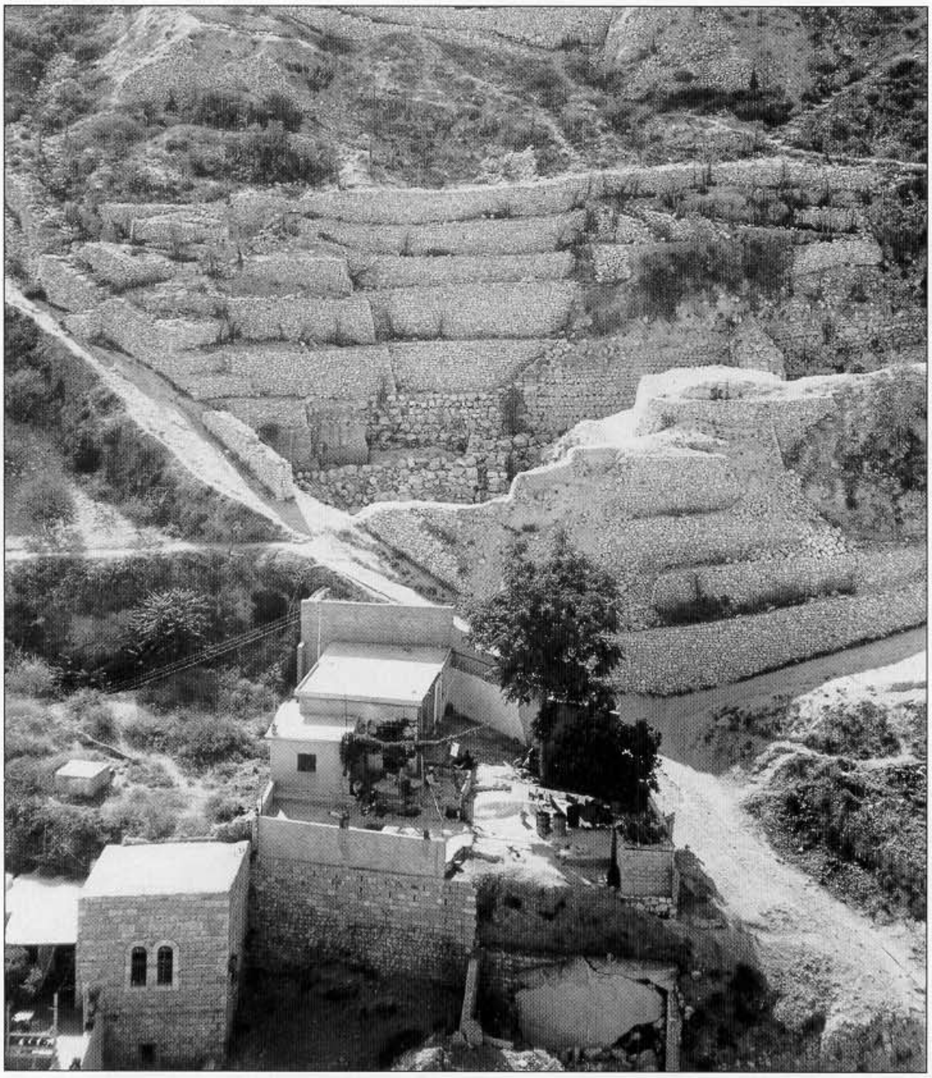

Figure 3: Retaining walls and houses built with stone in Jerusalem, Israel

Stone Foundations

A trench is dug in the shape of he house, tamped down, and then filled in by systematically laying boulders of large stones, possibly topped by an insitu cast reinforced concrete ring beam and/ or some courses laid with shaped stones in a preselected pattern. The foundation wall above the foundation seating could also be of poured concrete together with any stone material. Strength of the foundation is increased by selecting and stacking the stones with a minimum of concrete or mortar and applying the principles of drywall building. A slight inward angle of the stones toward the centre causes the outer layers of the structure to lean in against themselves, increasing stability. Good drainage channels should be built around the house and filled with small gravel to allow rain water to drain off.

Any structure above ground must be of the same quality as its substructure, the foundation and foundation wall. It is also necessary to always examine the subsoil and ground water level to avoid differential settlement and also to ensure the stability of the subsoil which e.g. should not be affected by a close-by river in a surrounding hill site. Backfill on the building site may require pre-consolidation. Any performance records of neighbouring foundations are important to note.

The depth of the foundation strip and thickness of the foundation wall depend on the resistance of soil or rock, and on the need for protection from harmful climatic effects due to variations in seasonal humidity. Foundation walls resting straight on the ground with variable strength often fracture, due to their unequal settlement, the more so in walls with irregular masses, even on uniformly yielding soil. Failure can be prevented by extending the base of foundation walls for an equal weight distribution of the structure over the substratum. Poor resistance of soil/rock is another cause of unequal settlement, since nearly all soils, unlike solid rock and gravel, are compressible under pressure.

Settlement causes no problem if uniform and of shallow depth, with the relative position of the parts of the structure remaining unaltered. The bases of the structure are invariably made wider than the superincumbent mass to increase the stability by distributing the load over an area sufficiently large for safely withstanding the pressure and for counteracting failure, especially where foundations do not reach the bedrock.

In stony ground, the building is usually put up onto rock . If the bedrock is not sound and insitu, it has to be treated like a soil base. If sound and uniform, the lowest stone course acts as an initial base directly on the foundation footing, preferably with squared slabs.

To use locally quarried stone is most economical. The design of foundation walls and above ground walls should take advantage of available stone shapes and sizes. As mentioned above in some cases a concrete footing or a reinforced ring beam on top of the foundation wall may be more expedient than trying to match random shaped stones.

Basic Types of Foundations

- Foundation in trenches: 30-80 cm in depth and wider than the planned walls above are sufficient where the unit load is less than the practical resistance of the soil.
- Foundations with footings: these should always be wider than the wall above so that the load can be spread over a larger area.

The base of the trench, the weight of the incumbent structure and environmental factors determine the need for concrete. For a compacted base of clayey soil, or clay, with or without stone, a footing course is sufficient for a one to two storey building. Stone courses below ground level are part of the wall and require as much attention as visible courses; they determine the level of the structure and carry more weight than any other course.

To complete the foundation, it is levelled with long stone slabs of about 30cms thickness. As such slabs are not always available, or complicated to square with basic tools (few hand guillotines can tackle lengths of more than 70 cms), a continuous concrete belt, 20 to 30 cms thick, is cast to take the lowest stone course.

This is especially important and should always be considered in earthquakeprone areas. A damp-proof course above ground level is also recommended.

Wall construction

- Retaining walls: these serve to keep back earth, soil, infill, or are used for terracing. They can also preserve contour levels for road cuttings or control erosion, with only one face exposed. Such walls usually do not exceed 1 meter in height. If built dry (without mortar) they usually have a thickness of about 45-50 cms. Retaining walls can be built with fieldstones.
- Free-standing wall: these are walls which have both faces exposed. The construction of the first course required for ashlar, slabby or squared stones is fairly straight forward. Random rubble requires "course-in" with quoins (corner stones).

Continuing on the floor slab, the footing of a wall is set in a bed of mortar brought to level. Stones with vertical faces on the outside, set at fairly regular intervals, form the pattern of the wall and fix the courses. Big stones in the first course prevent settling problems which occur when larger stones are used higher up and are put onto smaller stones, especially of irregular shapes as with random rubble. For solid walls the building work goes on from one side of the wall. If the two faces consist of stone "cladding" and fill, one face is worked at a time. Filling in between the faces is gradual as the structure rises. Infill just consists of packing material, it does not hold the wall together, but rather it tends to push the faces apart. It is therefore necessary to "bind "the wall together. This is achieved by using long narrow stones, which are set aside during sorting, when also stones for the finish are dressed. These "binding" stones are necessary in every other course. They are essential for the wall's stability. Care during sorting ensures that stone sizes are proportioned to the wall dimensions. Low walls require small and narrow stones. Larger stones should be used for higher walls.

Whether to use small odd-shaped stones for the foundation and to save the bigger flat stones for the wall courses is debatable. The foundation is critical and settlement may lead to cracks in the incumbent courses. Depending on the nature of the soil under the foundation, irregular shapes provides better anchoring than a flat underside. Wall courses require a stronger mortar to ensure that stones stay on top of each other.

Composite walls may contain several materials across their width; e.g. stone and concrete, various stone materials such as pebbles and broken slabs laid in a sand and lime mortar bed. The method used is a variation of the "banked stone system": rough or cut blocks or slabs of stone are used as "form boards" in place of shuttering on the outer side of the exposed wall face. This is common in the Middle East.

Stability of walls

Walls tend to support each other, especially when enclosing a space. The minimum thickness, required for their stability, increases with the wall length. The smaller the space in between walls, the greater the strength of the connecting wall. Various tying or bonding devices compensate for inadequacies in stonework, increase stress resistance and im-

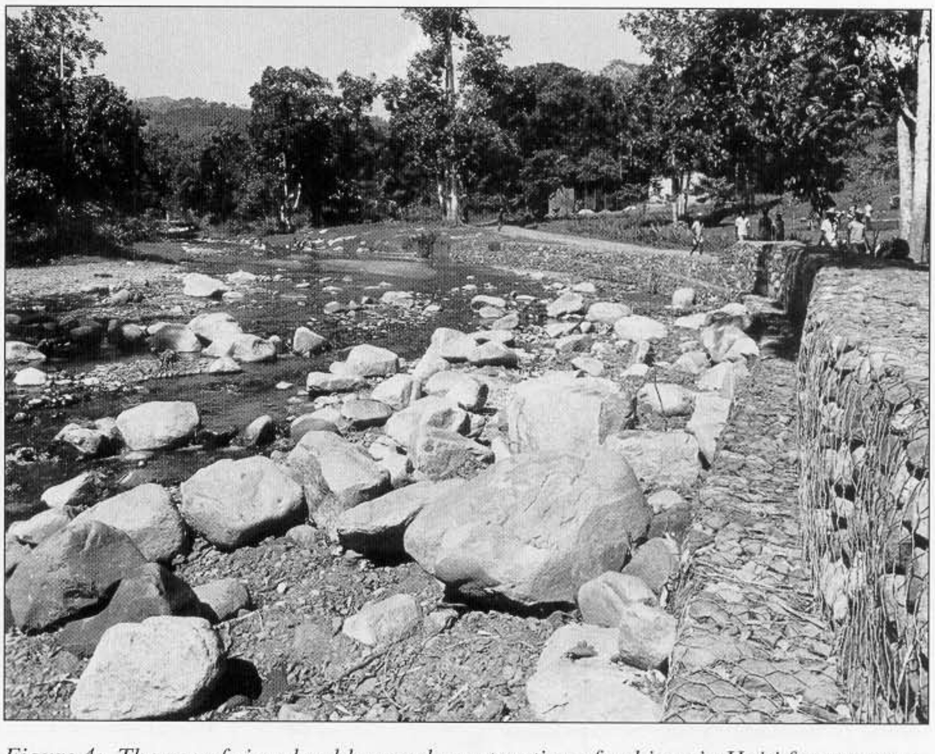

Figure 4: The use of river boulders and construction of gabions in Haiti for conservation of river banks and to prevent erosion during flooding