# Rock-masonry Dams for Remote Areas

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Sept 2003

## Summary

A method of building small to medium sized dams using 'rock-masonry' (rocks, river sand, cement and water) is outlined. The rocks and the river sand are respectively sourced from the river-bed or immediate surrounds, so that only the cement is trucked in (about 7% of the total dam). The rocks are packed in as closely as possible, with mortar filling the voids. Most of the labour is supplied by the resident community. Because the operation is labour intensive, minimal mechanical equipment is required.

Experience shows that, overall, cost savings of 30% are achievable.

As the dam is made from locally sourced rocks, the structures blend in with the environment. A minimum of noise is generated at the time of construction.

The rationale for using this type of building system increases as:

- the scale of the dam decreases. Clearly the cost of establishing plant and equipment (e.g. crushers, cranes, batching plants) becomes dis-proportionately high for small structures
- the accessibility of the site decreases
- the cost of labour decreases
- suitable rocks and river sand are near at hand

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# Backgound

Earth embankment dams are often more cost effective than any other type. This is particularly so where suitable ground is available for the embankment, including clay for the core of the dam. They are also well suited to large long dams, since this makes the use of huge efficient earth moving/spreading/compacting machines cost effective.

On the other hand, in a moderately narrow gorge where a relatively small dam is to be built, or where suitable materials are unavailable for the construction of an embankment dam, other forms of construction are able to compete.

# Rock-masonry

A cost effective method of building relatively small dams that is well suited to rural Africa is a simple gravity or arch-dam made from ‘rock-masonry’. Providing that the dam is founded onto rock, and that measures are taken to ensure that the energy of the water is adequately dissipated (e.g. an apron in front of the dam, also from rock-masonry, as shown in figure 2), ‘rock-masonry’ dams perform very satisfactorily. Typically the full length of the wall acts as a spillway, thus reducing the impact of the over-flow water on the apron.

‘Rock-masonry’ consists of rocks that are small enough to be lifted and carried by one person, and placed in a matrix of river sand and cement (see figure 1). If the rocks are not freely available in the river bed, they may be obtained by blasting the upstream riverbed or flanks. Alternatively they are simply picked up from the surrounding countryside and heaped into convenient piles by a team from the local population. This allows a tractor with a trailer to visit the various collection points, where the rocks may be loaded on relatively quickly. This done the tractor/trailer departs to the dam site, offloads, and returns for the next pile. The sand required for the concrete is generally on hand in the riverbed. Thus the only ingredient that is imported is the cement, which amounts to about 7% of all the material making up the dam. Thus the only cost component attached to the ‘aggregate’ is labour.

Generally only *one* skilled bricklayer is required for setting out work. The rest of the ‘rock-work’ can be placed by local labour following some elementary training. An example of a typical rock-masonry dam being built is shown in figure 1.

Capital investment is limited to a diesel driven drum mixer for the mortar and a tractor and trailer combination (which may be hired from a local farmer) if the rocks are not available in the river bed. A front end loader may be required in higher dams to assist with the lifting of materials.

Experience has shown that this system of construction, although labour intensive, results in structures that are typically 30% cheaper than conventional concrete dams. Establishment costs are significantly reduced (no crusher plants, sophisticated batching plants, cranes etc.)

# Advantages of Rock-masonry Dams

The advantages of building small to medium 'rock-masonry dams' may be summarised as follows:

1. Cost effective: The savings in materials and equipment make this form of construction affordable where other methods are too costly. The materials are easily built into relatively thin arch type structures (see figure 1) that do not require reinforcing steel. No shuttering is required.
2. Labour intensive: The process of collecting the rocks, and packing them into the dam by hand provides substantial employment for the resident community for the duration of the construction phase. Those involved have a sense of ownership and refer to it as 'the dam that I built'.
3. Low Maintenance: The dam may be designed to be maintenance free and has all the durable characteristics associated with concrete.
4. Skills development: The participants will learn valuable skills in making mortar, and in rock masonry. Once the dam is completed, the acquired skill of *rock masonry* can be used to build houses, both walls and floors. As was the case for the dam, the rocks may be obtained from the veld, and built up with mortar.
5. Proven system: A number of these dams have already been built and are performing most satisfactorily. Typical examples are shown in figs 2 through 4.
6. Aesthetics and Environment: These dams blend in well with their surrounds, being made from the local materials (rocks and sand). The downstream side resembles a cliff face, providing a refuge for baboons/monkeys from predators (as in the Bakubung dam in the Pilanesberg nature reserve). Noise generation is minimal owing to the absence of large mechanical crushers or earth moving equipment.
7. Socio-economic benefits: The economies associated with a rock dam may be the difference between a dam and no dam. With a dam, the community will benefit from all the usual benefits that a dam affords such as: (1) a reliable source of healthy drinking water, although if animals have access to the water some form of purification will be necessary (2) development of agriculture with its associated employment opportunities, wealth creation and social upliftment.

   If many of these dams can be built, however small they may be, their collective contribution to the well being of the nation may be very substantial. Figure 5 illustrates how dams in rural areas can stem the tide of urban migration and reduce crime in the cities. It also shows how dams can reduce costs in a number of governmental departments such as police, courts, prisons, health, and education. Clearly this will positively impact on the national budget.

## Existing Structures

Examples of complete dams built on this basis are illustrated by figures 2 and 3 and 4. The structures are generally designed as cantilever arches or buttressed multiple cantilever arches, or mass gravity structures in the case of smaller structures. Providing that (1) the structures are designed by a professional engineer with specialised dam engineering qualifications, and (2) the construction work is adequately supervised; and (3) the project is efficiently managed, experience has shown that these dams perform very well. They may be built to a height of 20m.

## Conclusion

There are many rural communities that would greatly benefit by having a dam, for drinking purposes and for agriculture. Given the correct topographical and founding conditions, small dams made from 'rock-masonry' can provide a most cost effective and satisfactory solution.

## References

Shaw, Q, 2001. Photographs for Figures 1 though 4, personal correspondence, ARQ Consulting Engineers.


**Figure 1** Example of a dam being constructed with rock-masonry. The tools are simple and the process is labour intensive with minimum noise generation.

**Figure 2** Example of an arch dam made from rock-masonry, Hogs back.

**Figure 3** Buttressed multiple arch-dam made from rock-masonry, Pilanesberg Nature Reserve

**Figure 1-4** A cantilever-arch dam made from rock-masonry. The wall is 17m high with a 28 m radius.

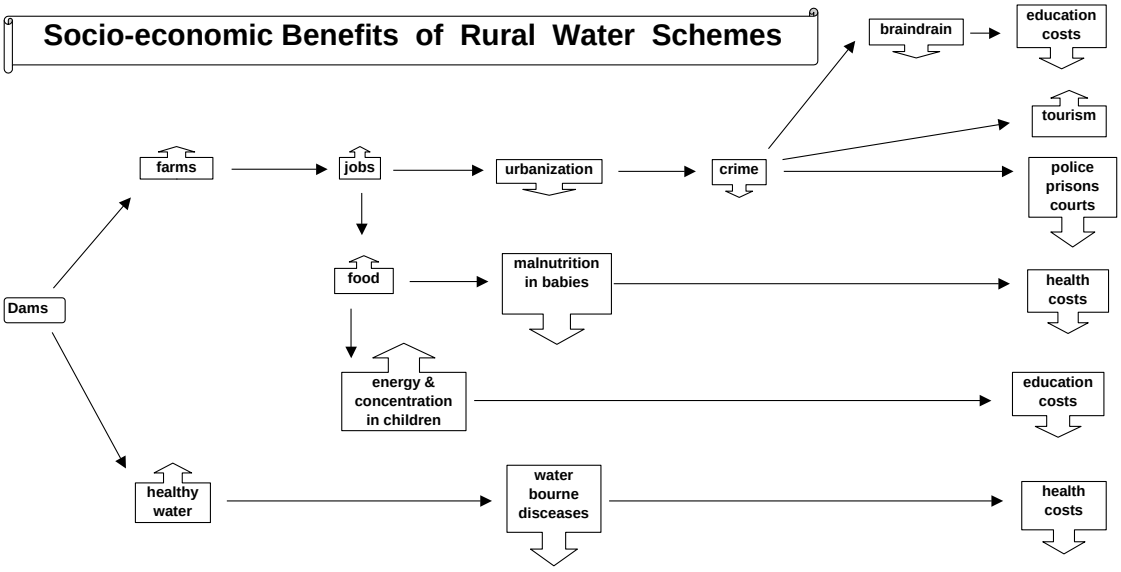


**Figure 1-5** Socio-economic benefits of 'rock-masonry' dams

# About Dams for Africa

**Dams for Africa** (Pty) Ltd designs/constructs/rehabilitates water related infrastructure to empower communities in remote rural areas. Typical projects include the construction & rehabilitation of dams, canals, weirs, reservoirs and installation of pipelines and irrigation systems.

DFA recognises the need to be flexible and will tailor its involvement according to each need, from consultations to turnkey projects.

DFA's contribution to a typical project may take the form of an initial consultation, feasibility study, business plan, design, construction/installation.

Whenever practical labour intensive methods will be used in the construction process, sourced from local community.

DFA is also in a position to provide the necessary hydrological, topographical, geological, ecological and social impact studies, and attend to the technicalities and legalities associated with water related infrastructure.

Dams for Africa fully appreciates the need to network and co-operate with partners such as:

1. *Community based organizations* that are in touch with the needs of the resident population.

DFA is aware of the importance of *community involvement* and is, if required, prepared to participate in all stages of this process. This would include a response-to-need request as the first step, assistance with visualization, participation in negotiations, recruitment and training of local residents for the construction stage, facilitation of training in subsequent agriculture and irrigation, and ongoing mentoring as may be required.

2. *Donors/funders* including government and financial institutions.

DFA is prepared to participate in *fundraising* for worthwhile projects, and in the production of 'bankable' documentation.

3. *Training organizations* who teach on farming methods, marketing of produce, and who know the value of ongoing mentoring.

DFA would like to know that its engineering contribution is placed in the hands of a motivated community that has been *equipped* with the necessary skills to put the water infrastructure to good use for many years to come.

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