EXECUTIVE SUMMARY

Ferrocement is the name given to a composite material made from a high strength mortar cement mix reinforced with steel mesh and wire. It is distinct from reinforced concrete in the following ways:

i) no stone aggregate is used in the mix,
ii) the steel reinforcing consists of small diameter wires and mesh closely spaced, rather than larger diameter bars spaced further apart,
iii) minimum thicknesses of ferrocement elements are small, from as little as 10 mm,
iv) ferrocement is not poured between and moulded by shutters, but is worked by hand into the steel mesh reinforcement,
v) due to this construction method ferrocement can be moulded into any shape.

In its pure form ferrocement has a steel content of over 5%, which would be very high for reinforced concrete. The total steel content is, however, not necessarily higher because ferrocement structures are thin wall structures.

The first recorded use of steel in combination with cement is attributed to the Frenchman Joseph Louis Lambot, who in 1848 made a rowing boat using cement mortar reinforced with steel bars and wire mesh. Before long the new material had been used for items as diverse as flower pots and guard rails. The French called this new material “ferciment”. Soon after this an Englishman named Wilkinson realised the value of steel reinforced concrete beams in buildings, beginning a revolution in building design on which all modern structural concrete engineering is based. With this being the main commercial application and with steel rods being more easily available than steel mesh, the use of steel mesh in reinforcing thin shell structures was for a period forgotten.

Ferrocement, as distinct from reinforced concrete, was rediscovered by the Italian Pier Luigi Nervi in the 1940s. He used the material for moulded thin shell roof construction, and also built ocean-going boats from ferrocement, spawning the “concrete yacht” boat industry. It was not long before the value of ferrocement in the construction of water retaining structures was realised. With its high cement content and low cement-water ratio, the mortar used in the construction of ferrocement is significantly less permeable than ordinary concrete. Furthermore the thin shell nature of the construction means that less material is used than is the case for a reinforced concrete reservoir of similar size. SB Watt in his 1978 book *Ferrocement Water Tanks and their construction* describes ferrocement water tanks built since the 1950s in the United States, New Zealand, South East Asia and Southern Africa (specifically in Botswana and the then Rhodesia (now Zimbabwe).

While ferrocement boats were being built in South Africa from the 1960s, another two decades passed before the introduction of ferrocement for water tanks or reservoirs. Initially its use was restricted to small reservoirs (typically 5 000 litres) used in conjunction with spring protections and rain water harvesting by NGOs engaged with rural development work such as the Valley Trust and World Vision. The first known use of ferrocement for a larger reservoir in South Africa was by the CSIR (Council for Scientific and Industrial Research) who used it for two 40 kℓ reservoirs at KwaHlophe in the Ndwedwe District of KwaZulu-Natal in 1990. In 1992 the CSIR again used ferrocement construction for two 75 kℓ reservoirs at the neighbouring KwaNyuswa Water Project, as well as a number of smaller reservoirs. In 1993 the CSIR built a number of 100 kℓ ferrocement in Maphumulo, the neighbouring district.

The first CSIR ferrocement reservoirs were based on a design which had previously been used by Graham Simpson, then an engineer with the CSIR’s Building Research Division, when he had worked in the then Rhodesia. Simpson’s design incorporated a catenary shaped roof, which the CSIR changed for a fibreglass roof which was not a success. At kwaNyuswa a domed mortar roof design was used and this worked well. Since the early 90s several hundred ferrocement reservoirs in the size range 5 kℓ to 220 kℓ have been built in South Africa based essentially on the design first used by the CSIR at KwaNyuswa.

The largest ferrocement reservoirs built to date in South Africa were two 450 kℓ tanks built in 1995 at

Osindisweni, some 20 kilometres west of Verulam. These were designed by the consultants James

Crosswell and Associates and built by Exter Construction. Large ferrocement reservoirs have therefore been in use in South Africa since 1992. Based as they are on a thin shell design they are typically 40% cheaper to build than standard reinforced concrete. What most engineers want to know, however, is whether they can be trusted to stand up in the long term. One of the objectives of this study, therefore, was to carry out field evaluations of ferrocement reservoirs in practice to see how they had weathered in the field. A total of 41 reservoirs were visited and they were checked for signs of spalling, cracking or leakage. It was found that the reservoirs were in general performing well and that they had not undergone any discernible deterioration.
It is normal for ferrocement reservoirs to display a certain amount of microcracking. This is because ferrocement is thin walled and relatively flexible. Mostly these cracks are superficial and limited to the outside of the reservoir, but where they do seep or weep they generally seal through a process of calcification within a period of weeks or months. Calcification and streaking is common with all water retaining structures, up to the largest dams. For those who are not familiar with this material this cracking may be disconcerting. For this reason the application of two coats of a good quality PVA on the outside of the reservoir, refreshed every few years, greatly improves the reservoirs' outward appearance and is recommended.

Over the years the following design changes have been introduced:

- uPVC piping, which does not rust like galvanised steel piping, was used for all pipes cast into the base. [A watertight bond is achieved by scouring the outside pipe wall, or using PVC glue and sand]
- The shape of the roof shuttering (previously shaped by eye and therefore sometimes irregular) was regularized using a support system of telescopic poles and interlocking radial rings. This change straightened the roof slope somewhat so that the new roof design, though still convex, was more cone than dome shaped.
- More wire and mesh was added to certain sizes of reservoir to increase the design safety factor and reduce micro-cracking. In particular the importance of vertically oriented steel in the smaller reservoir sizes has been proven and this is now standard for all but the smallest (5 kℓ) reservoirs, where wire and fowl netting suffice.
- A bandage and sealant was specified as standard on the wall-floor joint.

Design parameters have been developed for the walls and the roofs, and these have been included with this report. A finite element analysis has been carried out to check the accuracy of the simplified method used for the analysis of the roof stresses, and this has proven the adequacy of the design method used.

A construction manual is also included with this report, and the key points have been highlighted. Like any craft ferrocement construction can be done well or badly and attention to detail is important.

Given their significantly lower cost and the evidence of their durability, there is no reason why ferrocement reservoirs cannot be used with confidence. They do not necessarily look as smart or professional as reinforced concrete reservoirs which have the cleaner and straighter off-shutter finish, but particularly in the agricultural and the rural sector, where cost is a greater consideration, they have their place. A further advantage in a country with South Africa's high unemployment levels, is that they are more labour-intensive than other types of reservoirs, and they do not require the importation of any expensive materials.