ABSTRACT

The economic and environmental benefits associated with earth brick shells strongly endorse their adoption as an affordable housing alternative. However, there is a dearth of information regarding their performance, durability and livability - particularly in South African conditions. Earth masonry is characteristically weak in tension and flexure; hence, there is a need to eliminate tension forces when designing and building with these materials. This can be accomplished by using optimal shell forms, such as catenary domes and vaults. In South Africa, numerous masonry shells have been built with profiles that do not engender structural efficiency, but many shells experienced cracking damage in their masonry and/or surface renders. Cracking is a concern because it provides a pathway for moisture ingress, which can lead to materials saturation, localised erosion, and strength degradation of earth-based building materials. Concerns also exist regarding the thermal performance of thin masonry shells built in South Africa, some of which comprise only a single-leaf brick section.

Several investigations regarding the design and performance of earth brick shell structures in South Africa are presented in this thesis. Design recommendations are presented, based on case study investigations, experimentation, experiences gained through the design and construction of masonry shells, and by comprehensive assessment of the literature. Measures to improve the durability performance of earth brick shells are reviewed and important design features highlighted. An original numerical method is presented for the shape optimisation of vaulted structures, i.e., to develop tensionless forms. Several loading considerations are discussed, and a significant finding being the criticalness of wind loading for the design of vaulted masonry shells with steep profiles. Wind design recommendations are also developed for catenary shells. The source of cracking in unreinforced shells is examined, and it is presented that elements such as gable walls and window frames tend to cause cracking if they restrain movement (contraction and expansion). Furthermore, shrinkage of mortar may also lead to cracking, if restraint is generated during construction. Finally, the long-term thermal monitoring of a compressed stabilised earth brick (CSEB) shell house is discussed highlighting some deficiencies with uninsulated masonry shells, and several passive design strategies are presented to improve the performance of such structures.