

CHAPTER 1

INTRODUCTION

1.1 General

Dry-stack masonry construction refers to a method of building masonry walls, in which most of the masonry units are laid without mortar in the joints. The units are usually stacked in a stretcher bond. The masonry units may be of brick or block proportions and may be solid or hollow. The shape of the units usually incorporates geometry that provides an interlock between units when laid in a specified bond. Dry stacking relies on mechanical interlocking features in the units to provide stability and assist alignment and levelling during construction.

In modern construction dry stacking is a relatively new mortarless technology, but it is however based on the ancient construction technique. The technique of dry stacking masonry units in construction has existed in Africa for thousands of years. The Egyptians pyramids, which were constructed about 5000 yrs ago, and the Zimbabwe ruins, a capital of Shona Kingdom, which the construction was said to have started in 400 AD, are the typical living examples of dry stacking. For example the pyramid "Khufu" which stands 137 m above the ground with base area of 13 square acres is made of 2.3 millions dry stacked blocks of stones with average weight of between 2.5 tons for the smallest to 9 tons for the largest blocks (Khufu, 2002). Zimbabwe ruins, a dry-stack stone masonry wall of height varying from 1m to 12 m and thickness of 0.5 to 0.8 m, housed an estimated population of about 20,000 people (Walker *et al*, 1991; Uzoegbo, 2000).

Of late, dry stacking or mortarless technology is increasingly becoming popular. A study by Vanderwerf (1999) states that conventional masonry is losing projects to dry-stacking technology. The customers are swayed by the advantages they often perceive in these new systems: lower installed costs, shorter site time and

dependence on a small pool of highly skilled labour. Comparatively conventional masonry requires more labour hours by more highly skilled (and highly paid) workers. As the history of innovation consistently shows, a successful innovation starts in the market niche. Innovative mortarless systems have improved with time since mid 1980's and are now more competitive in many more market segments than before.

This technology is not yet regulated by code of practice. Several countries are now involved in the development of this technology; however the emphasis so far has been on the development of the geometrical properties of the dry-stack masonry units with very little attention on the analytical investigation. This is likely due to the fact that the development of interlocking dry-stack masonry units requires continuous extensive modifications through experimental investigations before satisfactory geometry is achieved. There is a great diversity among the existing dry-stack masonry systems because of the unique nature of the interlocking mechanism of the units. Each interlocking system is unique with regard to structural behaviour.

1.2 Problem Statement

In conventional masonry, mortar is used for bonding the units. In mortarless technology dry stacking relies on mechanical interlocking features of the units to assist alignment and levelling. The "HYDRAFORM system" investigated utilises interlocking compressed soil-cement blocks normally stacked in a stretcher bond. The units feature "tongued and grooved" type of interlock on both bed and head joints. The system was initially developed and patented by Hydraform Africa (Pty) Ltd of South Africa and was further improved following research at the University of the Witwatersrand.

In recent years since mid 1980s, there has been a renewed interest in the dry-stack form of masonry construction for small buildings, mainly residential and

institutional, largely due to the convenience and speed of erection possible with this form of construction. Structural engineers must respond to this challenge to ensure safe buildings. The structural performance of the HYDRAFORM system under action of load is not fully understood and hence the purpose of this study.

1.3 Objectives and Scope

This study was conducted in two Phases as follows: -

Phase one: The main objective of the study in phase one was to investigate the general structural performance of the Hydraform dry-stack masonry wall systems under static load and ultimately to develop load prediction models for the system.

The following are the major variables in the investigations:

- Units strength
- Depth of the interlocking mechanism of the units
- Plaster
- Span of the wall
- Bonding materials such as Everbond
- Flexural strength
- Conventional masonry for the comparison of the load capacity.

Phase Two: In the second phase the main objective of the study was to investigate the structural performance of the Hydraform system under simulated seismic load. The investigations involved testing of full-scale one-roomed structures on a shaking table. Two types of structures were tested. The first test structure was constructed using normal Hydraform blocks, plain dry stacked (without reinforcements) and the second test structure was a conventional masonry of similar parameters constructed and tested in a similar manner for comparison. The test structures were subjected to seismic motions of different intensity, and monitored for peak displacements, peak acceleration, natural frequency, and mode of failure. Finally recommendations for further strengthening of the system were given.

It is the opinion of the author that this research will be considered as a preliminary approach towards development of standards for the structural design of dry-stack masonry system.

1.4 Outline of Thesis

The thesis consists of eight chapters; namely introduction, literature review, development of load prediction model for dry-stack wall panel under static in-plane loading, empirical studies of dry-stack wall systems under lateral loading, empirical studies of flexural strength of dry-stack masonry, development of load prediction model for laterally loaded dry-stack masonry, investigations of seismic blocks and a shaking table study of a single story dry-stack masonry houses. Detailed calculations and summary of test results are given in appendices.

The first chapter describes the background of this investigation, the objectives and an outline of the work covered in this thesis.

Chapter 2 reports the evaluation of the existing mortarless or dry-stack masonry systems made based on the available collected information up to the present time. Twenty-three different systems have been evaluated and the information has been collected worldwide from various sources.

Chapter 3 discusses the development of an empirical model for the prediction of the load capacity of dry-stack masonry system under axial compression. Series of full scale wall panels were tested under concentric loading, supplemented by tests on wall prisms to establish the relationship between wall panel capacity and masonry unit strength, relationship between the strength of masonry unit, prism and wall panel. Discussion on a full-scale conventional masonry wall panel tested for comparison is also presented.

Chapter 4 reports the empirical studies of the lateral strength of dry-stack masonry wall systems with emphasis on effect of span, effect of unit strength, effect of the depth of the interlocking mechanism of the units, effect of Everbond, a thin layer

bonding agent and effect of plaster. A comparison with conventional masonry is also presented and discussed.

Chapter 5 describes the empirical studies of flexural strength for dry-stack masonry. Flexural tests of specimens under vertical and horizontal bending is discussed, the major variables in the investigation includes units strength, dry-stack specimens and mortar bonded specimens. The flexural strength in both orthogonal directions is reported and finally the orthogonal ratio of the system is also reported.

Chapter 6 presents the development of an analytical model for load capacity prediction for laterally loaded dry-stack masonry based on test results from series of full-scale dry-stack wall panels of different spans tested under lateral load.

Chapter 7 investigates a new masonry block with conduit for reinforcement.

Chapter 8 describes the shaking table tests for two, single-story masonry houses. The first house was unreinforced dry-stack masonry (UDRM) and the second house was a conventional masonry of similar parameters constructed on a shaking table and tested in a similar manner for comparison. The discussions report the general structural behaviour and performance of the test structures in terms of failure load, mode of failure, peak displacement, peak acceleration and natural frequency. Finally recommendations for further improvement of the dry-stack masonry system are given.