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THE DEVELOPMENT OF A TEST RIG FOR INPLANE DYNAMIC TESTING OF MASONRY PANELS IN A UNIAXIAL TESTING MACHINE.

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ABSTRACT

The purpose of this research program is to investigate the dynamic failure properties of an unreinforced masonry panel under controlled dynamic loading conditions. This rig design is based on the classic diamond loading pattern. It is designed to achieve a uniform stress over the central area of the panel. The aim of the measurements will be to measure the rate of damage evolution in an inital "square" of masonry in the centre of the overall panel. A test rig has been designed that is capable of applying a non- proportional quasi-static biaxial loading coupled with a dynamic shear force to a 1.2 metre square masonry panel. The uniaxial cyclic loading to develop the sinusoidal shear-loading pattern will be supplied by an Instron 250 kN UTM.

Masonry, when constructed from brick units and mortar, exhibits a wide scatter of experimental results even for an apparently consistant product. One's interest from the experimenter's viewpoint is thus focussed threefold to better understand the constitutive relationships of the material; firstly on the intrinsic material properties such as Young's Modulus, secondly by understanding the material's basic properties and providing a high quality control on the masonry so as to limit the number of tests undertaken experimentally because of the time and reducing the experimental scatter for a given unit and thirdly to provide a valid numerical model for the experimental results. This paper's objective is to outline in detail the design and construction aspects of interest for the development of the mechanical items for this test rig. The loading pattern and electronics will be dealt with in future papers.

INTRODUCTION

Research into the tensile properties of masonry has reached a stage where there is a substantive understanding of the physical characteristics of the finished product for given variations in the materials and methods of manufacture. How intrinsic material properties for masonry are affected by variations in the materials used and in the method of manufacture given a set of standard ingrediants has been investigated at the University of Newcastle (Sugo,1996). Results from this work would indicate that 'workability agents' such as 'detergent' are contra-indicated for a high quality mortar. The economic imperative for 'real world mortars' is an interesting although essentially falactious argument even in an intraplate seismic area for this type of research work.

This research work is predicated on the use of a single type of mortar that has previously produced a relatively high tensile and compressive strength masonry. It represents a philosphical break to clearly enumerate that these experiments have been completed without additives and using a high quality consistant research mortar and masonry (Nichols and Totoev,1997). That most testing is conducted with more variable real world mortars often containing varying quantities of additives is interesting but of little relevance to this research.

The test rig is based on the method suggested by Macchi(1982) at the Rome Masonry Conference and can be viewed as a thematic continuation of the in-plane static loading tests undertaken at this University by Page (1979).

The test rig is designed as two separate mechanisms.

The first mechanism is a compressive reaction frame to impart a uniform compressive stress along two orthonormal faces of the panel. The pinned reaction elements provide the counterbalancing force. This system provides a quasi-static non-proportional uniform loading to the masonry panel. It can provide equivalent loading to several stories of unreinforced masonry as a dead weight.

Th second mechanism uses the Instron and a shear yoke arrangement to impart a dynamic shearing load to two orthonormal edge strips. This mechanism is balanced by the lower shear yoke both of which are connected by friction grip bolts to the masonry panel. A 250 kN Instron UTM provides the cyclic loading.

The two mechanisms, when assembled on a panel, are supported with a standard Universal Column reaction frame located with in the University of Newcastle-Civil Engineering Laboratory. Masonry panels are constructed separately and are slid into the compression mechanism after curing. The shear yoke system is then installed.

The dynamic loading will be within the frequency range normally associated with seismic events and for URM buildings of 2 to 7 floors. This is in the range of 1 to 10 Hertz (Richter,1958).

This research has the purpose of measuring the changes in the constituent properties of masonry panels under dynamic in-plane loads. This measurement of the change in stiffness was eventually termed the damage mechanic defined from the seminal work by Kachinov(1958). His initial work was based on the inverse of the damage mechanic. Either metric measures the rate of change of stiffness of the material. Philosphically the damage mechanic is prefered to its inverse the continuity factor.

The masonry panels are constructed from an Australian Pressed Bricks of nominal dimensions 225 by 110 by 75 millimetres. A standard Cement-1 : Lime-1 : Sand-6 mix by volumne is used for the panel construction. Additives are contra-indicated for this research quality mortar.

LITERATURE REVIEW

Work in the field of Damage Mechanics has identified two distinct types of failure mechanisms for ceramics. The failure mechanism of the first kind relates to failure on the weakest plane under static loading. Masonry research in the last three decades can be considered to have systematically studied the failure mechanism of the first kind only. Page(1979), Ganz and Thurlimann(1982), Ali (1987), and Dhanasekar's work (1985) all explicitly excluded a dynamic failure mechanism for masonry with their selected experimental method and analysis techniques.

Ceramics and other brittle material have been shown to have a greater fracture resistance to loading that causes a dynamic failure mechanism. A detailed explanation of the effect is provided in Freund (1990) §8.7. The failure mechanism of the second kind occurs "*during impulsive loading where multiple fractures on different planes can be nucleated and they grow to a significant size without arresting each other.*"

There have been several sets of experiments on the dynamic in-plane properties of masonry walls. Recent studies have been undertaken by Tercelj *et al.*(1969), Mann, *et al.*(1988), Tomazevic & Modena(1988), Tomazevic & Lutman (1988), Paulson & Abrams(1990), Shing, *et al.*(1990), Klopp(1996), Papa & Nappi (1995), Zhuge *et al.*(1996), Tena-Colungra and Abrams(1996), Tomazevic & Lutman (1996), Tomazevic, Lutman & Petrovic(1996) and Anand & Yalamanchilli(1996).

This body of research has demonstrated a potential difference between the failure mechanisms of the first and second kind. Tercelj *et al.*(1969) paper was the first to place a numerical estimate on the difference in horizontal capacity of a wall for a difference in loading regime in the range of quasi-static to 10 Hz loading patterns. The effect reduces with an increase in the frequency of the applied loading. This effect is within the normal range of natural frequencies of URM buildings of height from two to seven stories.

One of the difficulties in laying bricks either in the laboratory or the field is the millenium old problem of mortar workability. Improvements in workability generally come at a cost usually measured as a reduced bond strength. This reduction can be substantial across an order of magnitude in strength for nominally consistant units and mortar (Opperman and Rudert, 1983). This reduction contributes to the scatter of experimental results.

Recent laboratory work at the University of Newcastle has investigated improvements in workability using the lime element of the standard mix. A procedure of mixing lime putty or slurry using 1part lime to 1 part water by weight has been used based on anecdotal evidence from repairs in the Newcastle 1989 earthquake (Nichols 1990). The lime slurry is allowed to stand in excess of 24 hours in sealed containers to thicken.

This research work continues on from an extensive test program at the University of Newcastle based on measuement of the intrinsic masonry parameters (Sugo *et al.*, 1996) *and* Nichols and Totoev1997). The prefered mix from this research is a cement:lime:sand mix of proportions 1:1:6. The lime is supplied either as hydrated lime or lime slurry.

Sugo *et al.*,(1996) have shown the range of results that can be achieved in a simple tension test by varying the additives, whilst leaving the basic constituents constant. It is axiomatic that one changes the minimum number of variables in a well planned experiment. Whilst the use of additives does improve workability of mortar, it does so at the expense of the strength and bond properties in a manner that is unacceptable for research purposes.

Nichols and Totoev(1998) have provided details of a number of back ground issues related to the development of the test program. This work includes a consistent set of definitions for reporting the results.

DESIGN OF THE RIG

The concept for the rig can be attributed to Macchi(1982). The alternative rig types and their uses and limitations are documented in that state of the art paper. He suggested that a diagonal shear load application onto a square of masonry under simultaneous biaxial compression would provide a known uniform stress distribution. The conceptual basis for the rig is shown in Fig. 1.

A number of the existing rigs where details were available in the Literature were reviewed to consider the ease of design and construction. We needed to consider the turn around time for each experiment and had to make maximum use of existing equipment available at the University Laboratory.

The limitations set by the design of the laboratory are that the strong floor is designed only for vertical loads, the existing UC frame holding the Instron had a height clearance limitation of about 3 metres and the Instron has a maximum capacity of 0,25 MN. Eight--fifty tonne RC256 Enerpac jacks with a stroke of 150 mm were available to provide the compressive loading.' Hydralic power is supplied separately to each bank of four rams.

The available space would suit a maximum panel size of 1.2 metres. This length is equivalent to 5 by 14 bricks for the nominated brick. A number of bricks considered for the experiments were discarded because of size variation problems. A 10 mm thick mortar joint was selected. Panels were constructed in a square frame to achieve the required level of accuracy on the dimensions of the panels. All holes required in masonry units were precored prior to construction.

The uniform compressive loading mechanism

The design of the mechanism to supply the uniform compressive non-proportional bi-axial load was based on the development of a mechanisms using four separate rams on each face to supply a "uniform" pressure. Two alternatives were considered the use of external rods or the use of the rams directly. The ram design was selected for ease of use and it was considered to be capable of imparting a more "uniform" compressive loading. Although this should be considered as a subjective opinion.

Page's(1979) work included a set of special needle plattens that provided an effective zero Poisson's Ratio for the plattens. This type of arrangement would have been impractical for this work so the use of four indepent rams provided a compromise solution to a single solid platten. PFC 300 mm back to back provide the main beam element of the mechanism. A typical view of the ram plate is shown in the Fig 2. The ram plate is designed to be stiff. The maximum applied stress on the face of the brickwork is 15 MPa in two orthonormal directions. The pins are 100 mm 350 MPa grade steel rods.

A typical plan and cross section through the rig is shown in Fig. 2.

The Shear Yoke Arrangement

Finite element analysis using Strand 6.16(G+D,1995)provided details on the estimated variations in stress patterns in fitting a shear yoke to the rig. The main issue was providing a uniform shear in the panel. Four alternative arrangements were modelled for the shear yoke. These variations were based on the method of load transfer to the yoke arms. The system consists of two shear loading yokes. Each consists of two opposing arms being made from twin 75x40 mild steel flats separated from the masonry panel by 12.5 - 25 mm of plywood sheeting. Each group of two flats are bolted togehtor through the masonry panel.

The load per yoke group is 250 kN as an absolute maximum under a sinusoidal loading regime. Four bolts per yoke arm provide a compression onto the brickwork to provide a shear transfer mechanism. A pin pulls through the centre point of each yoke arm to transfer the dynamic loading. The selected arrangement is shown in Fig. 3.

General Arrangement

The general arrangement plan for the rig is shown in Fig. 4.

Page(1979) constructed the panels for the equivalent static tests using half scale sawn pavers. A jig was constructed and the panels laid on the horizontal. This procedure was trialed for this series of experiments. The IRA of the selected bricks and the size variation precluded the use of this method. A frame was developed for the construction of the panels. This frame is shown in Figure 5. Panel construction is undertaken with two batches of identical mix comprising Cement Type A : Lime Putty : Sand in a mix of 1:1:6 by volume. This mix has been shown to have sound mechanical properties in the critical interface areas.

CONCLUSION

This paper has presented an overview of the issues related to and the design for a rig capable of meeting the concept proposed by Macchi(1982) at the Rome Conference on Masonry for the inplane dynamic testing of masonry panels.

The rig has been designed within the constraints of the Universities Laboratory equipment and the available resources.

It is proposed to load and monitor to failure 20 single skin unreinforced masonry panels. Each panel is to be 1.2 metres on side, being 5 bricks by 14 bricks. A uniform non-proportional compressive loading is applied using a reaction frame mechanism. The load is applied using 8 fifty 50 tonne rams on two separate arms of the reaction frame. A shear yoke system applies a dynamic load to the masonry panel to simulate an equivalent seismic type loading. The loading will increase in intensity with time to a maximum amplitude of 0.25 MN.

The change in stiffness of a central portion of the masonry panel will be used to assess the dynamic failure mechanism and the evolution of the damage mechanic.

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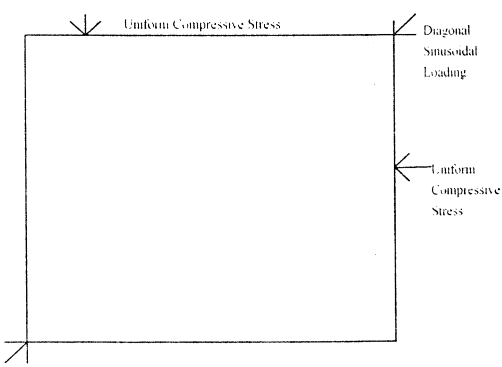

Figure 1 Conceptual Basis for the Rig.

Compressive Reaction Frame Mechanism

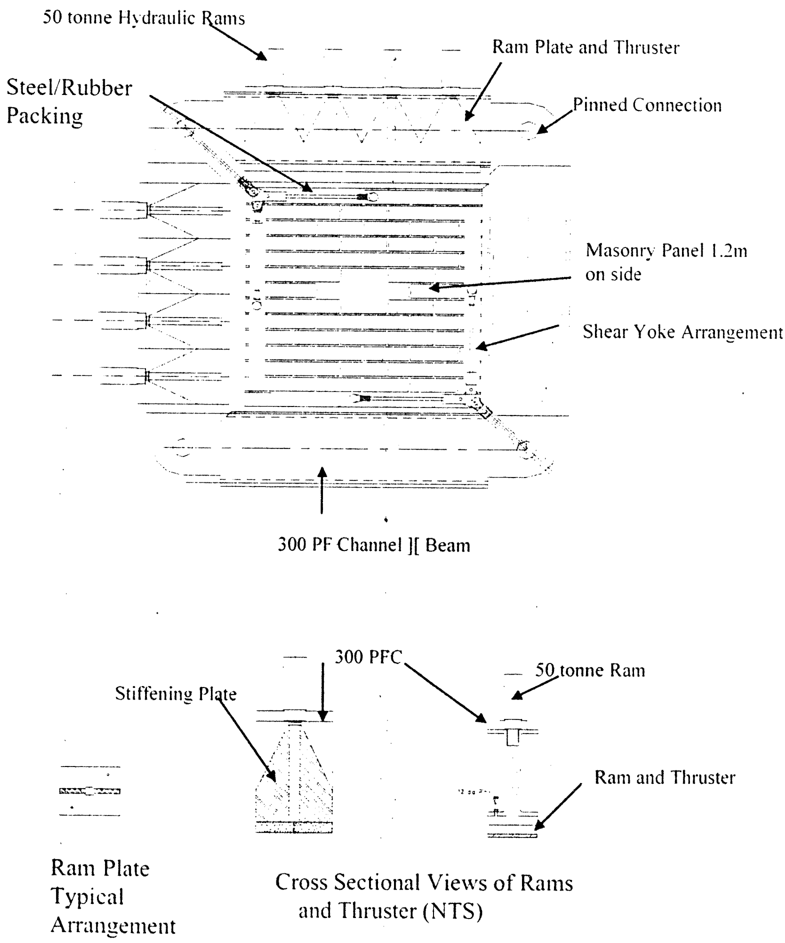

Figure 2 Typical Compressive Rig Plan and Cross-sectional Views

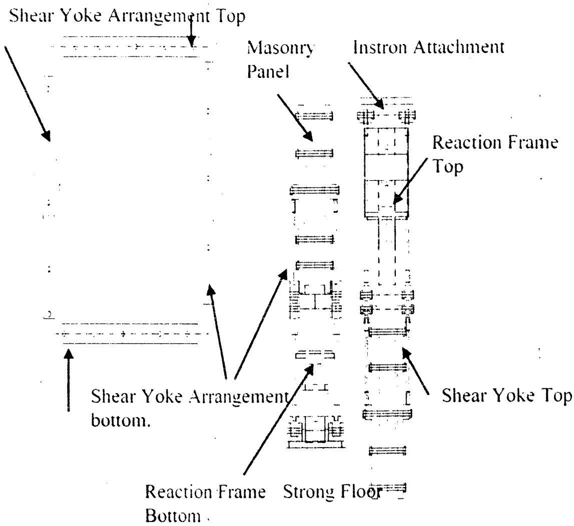

Figure 3 Shear Yoke Arrangement

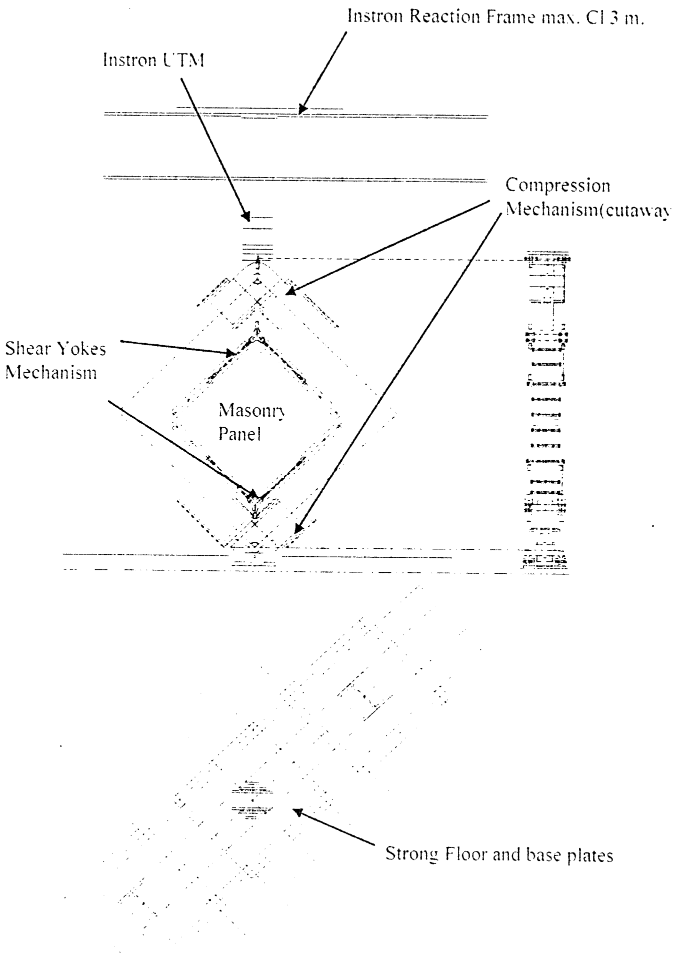

Figure 4 General Arrangement

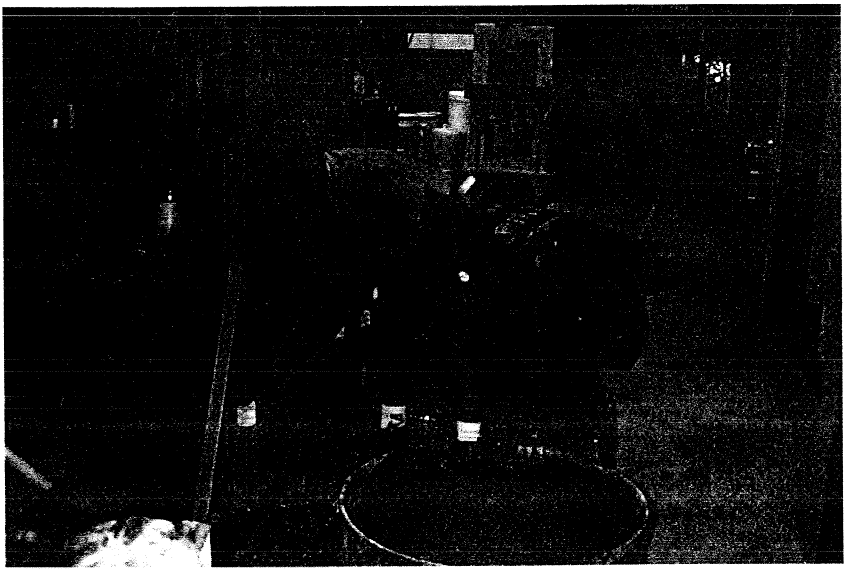

Figure 5 Panel Construction Frame.