Medical Staff Residence at Royal Liverpool Hospital

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SUMMARY
The ten storey Medical Staff Residence at Liverpool's Royal Teaching Hospital is one of the tallest half brick slender crosswall structures in Europe. The paper describes the development of the scheme from a series of low rise buildings to the multi-storey structure as constructed.

The masonry specification, construction techniques and provision against vertical movement in the external walls is discussed.

The robustness of the construction provides admirable resistance to progressive collapse through accidental damage and the construction methods optimised speed of erection and maximum continuity of work for the relatively small work force.

INTRODUCTION
The Medical Staff Residence at the Royal Liverpool Teaching Hospital comprised phase 4 of the 800 bed, multi-million pound hospital complex. It was completed at a cost of around £1.2 million in time for the official opening by Princess Alexandra, in October 1979 after a 22 month contract period and is one of the tallest half brick slender crosswall structures in Europe.

DEVELOPMENT OF THE PROJECT
The development of the project, up to completion on site, spanned virtually two decades with the first discussions taking place in the early 1960's. At that stage the proposal was to construct a series of low-rise units to house the medical staff and nurses. Preliminary schemes, using simple crosswall construction principles, were prepared and an investigation of the sub-soil ground conditions was instigated. The results of this ground investigation was to have serious financial implications on the proposed scheme in that it revealed the need for costly foundations.

The sub-soil conditions were fairly constant over the whole area of the development and showed loose demolition fill to a depth of approximately 3.0 metres overlying soft to stiff boulder clay of a further 3.0 metres depth and this overlying sandstone, weathered at its surface becoming sound and hard within 0.5 metre. Bored piled foundations were necessary to support reinforced concrete ground beams beneath the loadbearing walls and, owing to the loose and variable nature of the demolition fill, it was considered necessary to suspend the ground floor slab also. Needless to say, the cost implications of a fully suspended ground floor system over bored piles were extremely serious when related to a series of low rise structures - each requiring its own foundation and hence multiplying the cost penalty. A number of alternatives were considered, including the possibility of re-siting the same scheme on another site with preferential ground conditions, however the solution adopted was to stack the series of low rise hostel-type units one above another to produce the high rise solution which is the subject of this paper.

During the progress of the development to that stage, the nurses accommodation was separated from the Medical Staff accommodation and is now scheduled to become phase 5 of the complex at some date in the future. The structure under review contains the Medical Staff accommodation and its associated building services. Typical floor plans are shown in figures 1 and 2. Phase 5, the nurses accommodation, is expected to be even taller and, following the success of phase 4, there is every reason to believe that this also will be designed and constructed in the same structural form, i.e. slender crosswall construction.

DESIGN LIAISON WITH CONTRACTOR

The Medical Staff Residence was the final phase to commence before the official opening and consequently the design team were able to derive certain benefits from pre-contract discussions with the resident Contractor. The Contract itself was negotiated with the resident Contractor who involved himself usefully with the Design Team in the development of the working drawings to arrive at a scheme which optimised economy and speed of construction. As with all Contracts it was important for the Contractor to achieve continuity of work for his labour-force. The history of the earlier stages of the construction of the remainder of the complex had been dogged by labour troubles. It was therefore particularly important at the outset of the phase 4 Contract to eliminate any such sources of difficulties and the scheme adopted provided for this.

THE STRUCTURAL SCHEME

The basic scheme used half brick thick (102.5 mm) internal loadbearing walls throughout,(except where sound or fire regulations demanded walls of greater thickness such as around stairs and lift shafts). The external walls were all simple cavity walls employing half brick thick leaves both internally and externally. Floor slabs were solid reinforced concrete, 150 mm thick, and were partially precast to minimise shuttering operations on site. The floors comprised 65 mm thick prestressed concrete planks with 85 mm thick insitu concrete topping above. The planks which were generally 1200 mm wide, were laid between loadbearing walls and temporary propping was required, generally only at midspan and taken down through three lower floors, until the topping concrete had achieved its design strength. The plan of the building was divided, for construction purposes, into two halves and after the bricklayers had completed one half they moved into the other half while the concrete floors were constructed in the first half. In this manner full continuity of work was maintained at all times for the relatively small work force. The two staircases were also precast using similar techniques to those employed for the floors. The landings were cast separately to the flights and again utilised the two-layer method of precast slabs and insitu toppings. The flights were each provided with notches at top and bottom and were placed onto the precast landing sections before the landing toppings were poured. Continuity reinforcement projected from the flights for tying into the landing topping later and whole precast staircase system was made on site, using melamine-lined timber moulds, by the Contractor. Fine tolerances were necessary in both the precasting work and the construction of the walls and the good fit of the units into the work without problems being encountered was a credit to the Contractor. Typical details of the construction methods used for the floors and staircases are shown in figures 3 and 4 .

ACCIDENTAL DAMAGE DESIGN

Owing to the height of the building, progressive collapse under accidental loading was an important consideration in the design. The mono-lithic construction achieved with the insitu topping was of great benefit to this

aspect of the design and certainly afforded the two-directional tying of the floor zones which is essential to prevent spread of the collapse. The floors were also provided with reinforcement placed in the topping concrete and designed to span in both directions onto all walls such that, in the event of one wall being removed, the remaining walls are able to provide the required support. It is generally necessary to provide this alternative means of support with a reduced factor of safety. The logic being to permit the safe evacuation of the building. It is believed that, with the construction form employed on this structure, sufficient robustness is available to maintain the structure in a serviceable condition even in the event of accidental forces removing certain supports. In such a situation therefore the building would be unlikely to require demolition after its evacuation; an important factor which other forms of construction or materials cannot readily offer. The stringent requirements, of the Building Regulations, to prevent progressive collapse of multi-storey structures arose from the disaster at Ronan Point in May 1968 which highlighted construction methods which had no provision to prevent the 'house of cards' type collapse associated with some slenderly tied precast concrete wall forms of construction, of which, Ronan Point was one. Had structural brickwork been employed for the construction of the Ronan Point project, it is doubted whether such a disaster would have occurred. Indeed, had the construction used for the Medical Staff Residence been employed this extent of collapse would have been virtually impossible. The two-way spanning capacity of the floors is available throughout the height of the building, however, it was calculated that, with at least seven floors of loading above any of the loadbearing walls they would have sufficient precompression to be capable of withstanding a reasonable horizontal accidental loading. The magnitude of this 'reasonable accidental force' is assessed, for the purpose of the Building Regulations, as $34kN/m^2$. The loadbearing walls, with seven storeys of precompression, are able to withstand the bending stresses resulting from a horizontal force of $34kN/m^2$. Hence the tying facility provided by the mono-lithic slab and the two-way spanning capacity of those floors is a bonus to the minimum stipulated requirements. The construction method certainly provides robust resistance to such accidental forces with minimal additional cost.

MASONRY SPECIFICATION

The full height of the building incorporates 9 storeys of Medical Staff accommodation with a ground floor of boiler room, fuel store etc and in addition a roof-top plant room which houses water tanks and lift motor room equipment. The external elevations are predominantly white concrete brickwork to harmonise with the fair faced reinforced concrete expressed on the elevations of the earlier phases of the complex. Internally, red clay fairfaced bricks were employed throughout and, in relation to traditional low rise construction the building might be considered to have been constructed inside-out. Elevations of the building are shown in figures 5, 6 and 7.

The maximum designed masonry strength, in the lowest storey, required bricks with a crushing strength of $50N/mm^2$ (7500 psi) set in a designation (ii) mortar (1:½:4½), and the same masonry specification was maintained throughout the two lowest storeys. To achieve a satisfactory compromise between economy and unnecessary and counter-productive confusion for the Contractor the masonry specification was reduced at 3 levels in the height of the structure (see figure 8).

STABILITY WITHIN LOWEST STOREY

As is quite common in multi-storey hostel-type structures the ground floor plan layout differed from those above, owing to the change in use of that floor to house some of the building services. As a result certain load-bearing walls were omitted from this, the lowest, storey and concrete beams, heavily reinforced, were designed to replace the missing support. In these areas the lateral stability from wind loading was also impaired by the loss of these stiffening walls and the reinforced concrete beams were cast into reinforced concrete columns either side of each span and each was designed as a stiff portal frame to accommodate both the vertical and lateral loading. The sizes necessary for these replacement supports compared with the slender crosswalls adjacent is indicative of the efficiency of structural masonry in such situations.

RESTRAINT OF EXTERNAL WALLS

It was considered necessary, owing to the height of the structure, to introduce supports, at every third storey height, for the outer leaf of the external cavity walls. Differential movement between the two leaves of cavity walls, resulting from natural growth of clay brickwork and shrinkage of concrete brickwork as well as the moisture and thermal movements, can cause loosening of wall ties and eventual instability. This phenomenon is likely to be more serious with the more conventional arrangement of clay bricks externally and concrete bricks or blocks internally, however it was considered in this instance to be a potential problem and a support detail, shown in figure 9 was devised. The floor slab also projects through the cavity to support the outer leaf and, as the Architect was not happy to show a band of concrete, brick slips, 25 mm thick were adhered to the face of the slab to maintain the all-brick elevations. It is vital to ensure a complete separation of the panels of brickwork above and below these supports to prevent transfer of movement from one panel to the next through the adhered brick slips. Such stresses would be likely to cause the brick slips to become dislodged and fall to the ground. The Authors have on occasions been retained to advise independantly on such problems and figure 10 indicates one possible consequence. The design and detailing of such crosswall structures is examined in detail together with worked design examples in the references listed below.

REFERENCES

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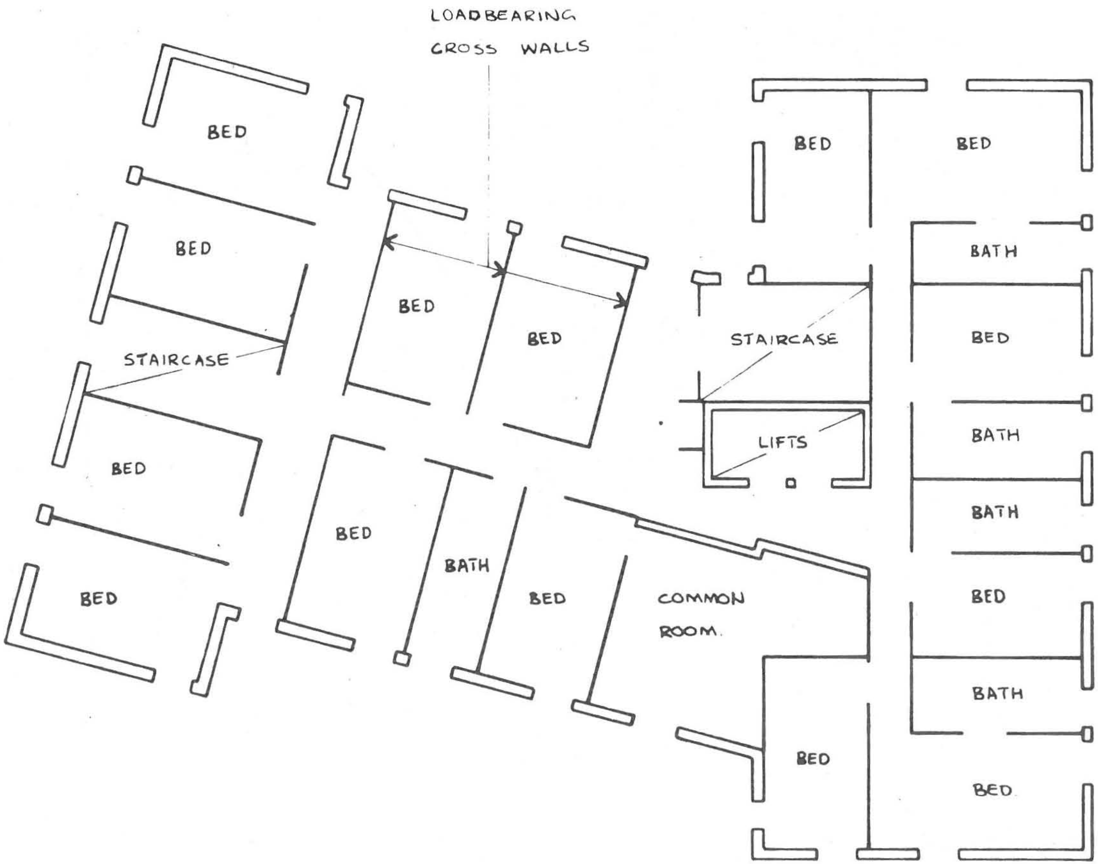

Figure 1: Typical Upper Floor Plan

Figure 2: Floor Plan During Construction

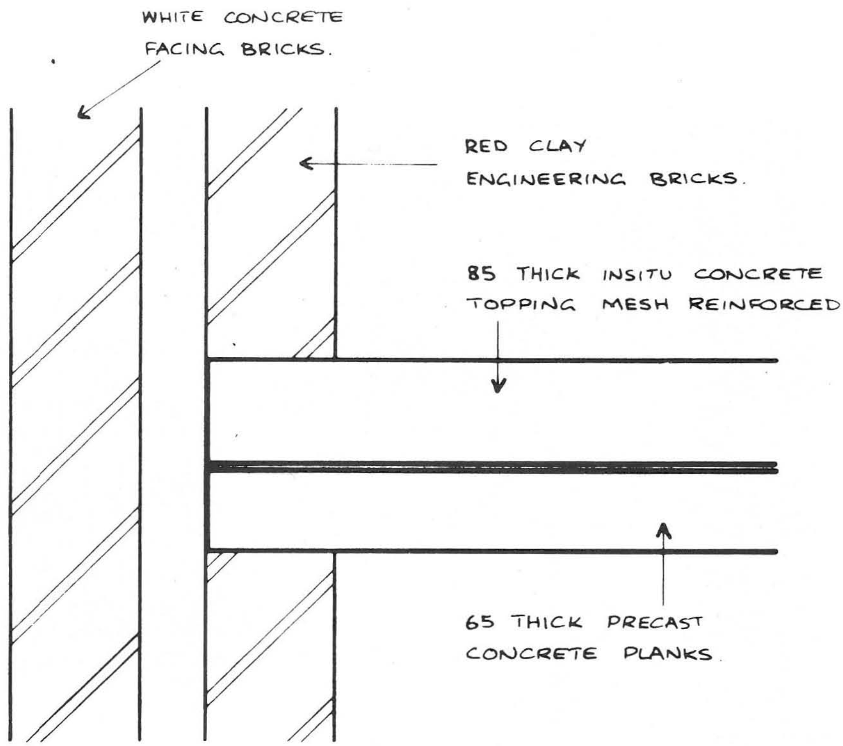

Figure 3: Typical External Wall Section

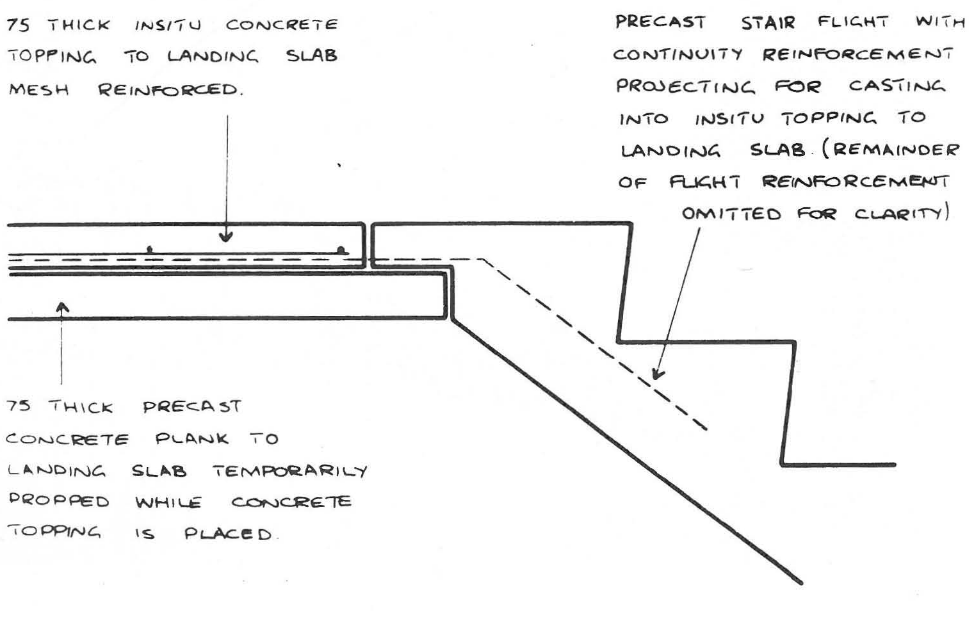

Figure 4: Typical Detail of Precast Staircase

Figure 5: Typical Elevation

Figure 6: Typical Elevation

Figure 7: Typical Elevation

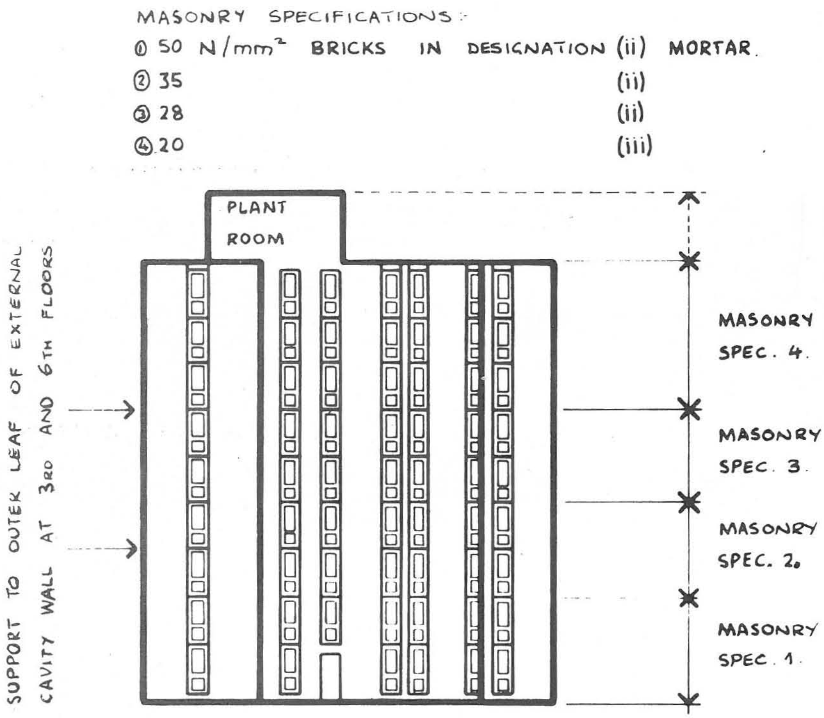

Figure 8: Reducing Masonry Specification

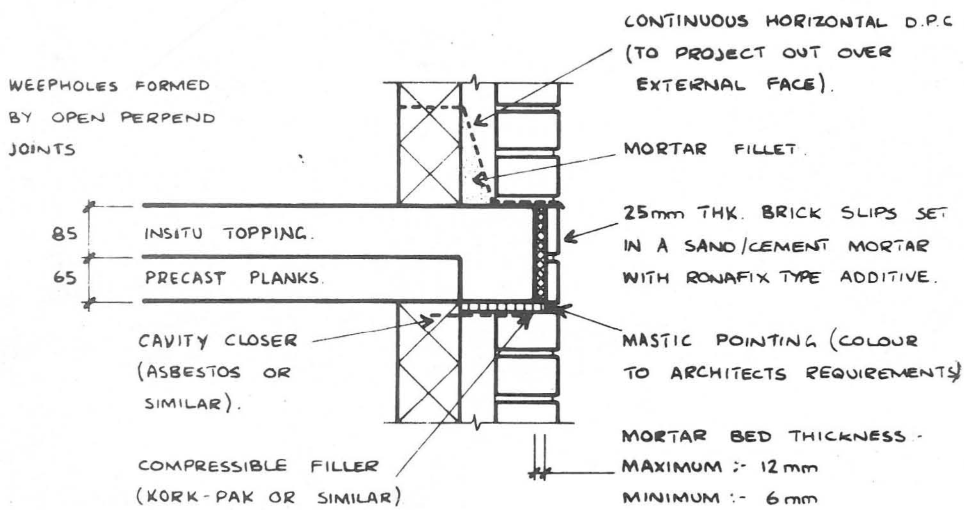

Figure 9: Support Detail - External Leaf of Cavity Wall

Figure 10: Brick Slips Failure