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Strengthening and/or Repairing of Existing Structures

Renforcement et/ou réparation de structures en béton armé

Verstärkung und/oder Reparatur von bestehenden Bauwerken

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SUMMARY

Three cases of reinforced concrete structures presenting unusual problems to the engineer are presented:

— strengthening of a loading dock to meet the requirements of a massive increase of live load
— reversal of the construction sequence of building when it was not possible to proceed in the normal manner: supporting columns poured after the slab
— repair of a severely damaged reinforced concrete column of an eight storey building.

RESUME

Trois cas de structures en béton armé présentant des problèmes peu communs sont présentés:

— renforcement d'un quai de garage pour quintupler la capacité portante
— inversion des étapes de construction par suite d'obstacles inattendus: des poteaux ont du être coulés après le plancher qu'ils devaient supporter
— réparation d'un poteau sévèrement endommagé d'un édifice de 8 étages.

ZUSAMMENFASSUNG

Drei Fälle von Stahlbetonbauwerken, die dem Ingenieur besondere Probleme stellen:

— Verstärkung einer Verladerampe für eine massive Erhöhung der Nutzlast
— Umkehrung der Reihenfolge im Bauablauf: Giessen der tragenden Stützen nach der Erstellung der Platte
— Reparatur einer stark geschädigten Stahlbetonstütze eines Gebäudes mit acht Stockwerken.

1. INTRODUCTION

The professional Engineer is often confronted with problems different from the usual one of conceiving and designing a new structure.

An outline is here presented of three such cases successfully solved:

- Increasing the load capacity of an existing structure;
- Reversal of the construction sequence of building when, due to special circumstances, it was not possible to proceed in the normal manner;
- The repair of a severely damaged reinforced concrete ground floor column of an eight storey building.

2. STRENGTHENING OF A REINFORCED CONCRETE STRUCTURE FOR MUCH HIGHER THAN DESIGN LOADS

2.1 Problem Description

On completion of a reinforced concrete structure for a loading dock, the management of the Company for which it had been designed and built, realised that the previously stipulated live load of 5 tonne trucks was far from sufficient. The owner decided that the loading dock should support the traffic of 25 tonne trucks.

The first impression was that such a massive increase in design load could only be met by demolition and reconstruction of the area in question. However this was ruled out due to excessive cost and the time factor.

2.2 Planning

Rankine and Hill was commissioned to produce a scheme for the strengthening of the recently finished structure in order to support the new live load.

The basic requirements to be met were:

- reasonable cost
- limited time for the execution of the works
- if possible, no propping to be used under the existing loading dock in order to allow other urgent activities in this area.

All these conditions were satisfied.

2.3 Existing Structure

The existing structure was a flat plate reinforced concrete floor with drop panels supported on concrete column, the slab thickness varying from 250mm to 400mm, to achieve falls to sumps. The structure was analysed by computer firstly for dead load only and then for live load. (Fig. 1). The live load consisted of trucks (D.M.R. H10 loading, equivalent to 10 tonne trucks) passing on the slab, two trucks to each dock. This loading pattern resulted in excessive overstress. However, the slab as constructed was adequate for trucks of up to 8 tonne (an acceptable overstress was indicated for this condition).

2.4 Design Procedure

The approach to the problem showed that it was necessary to keep a close correlation between design and execution in order to ensure that the design assumptions were effectively translated into practice.

To increase the capacity of the slab it was proposed to add 110mm of reinforced concrete on top of the existing slab, keyed to the existing slab by scabbling the contact surface and using a wet to dry epoxy. Special attention was given to this detail to insure a sufficient bond to resist the horizontal sliding shear (Fig. 2).

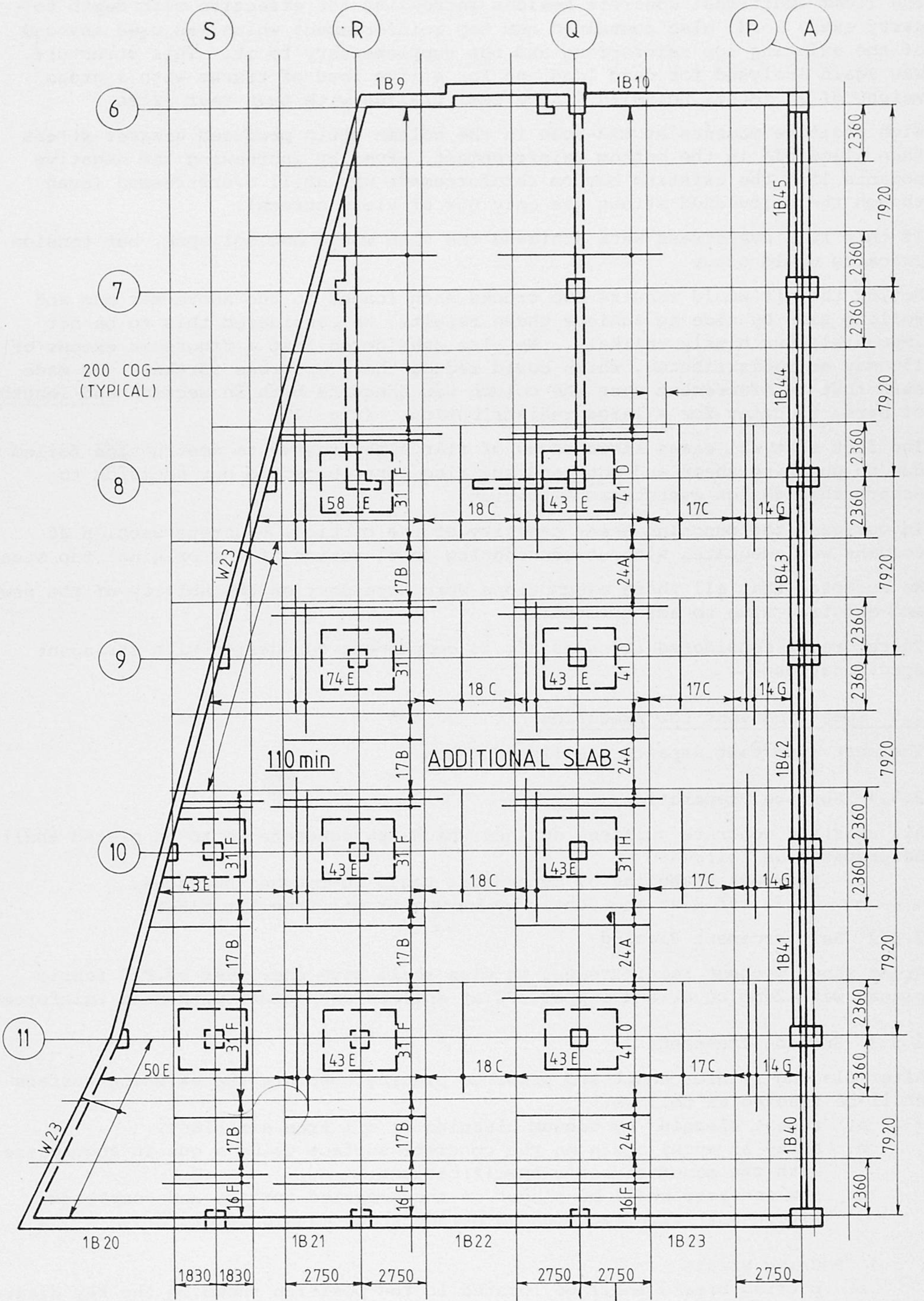

Fig 1

LOADING DOCK PLAN

The 110mm additional concrete besides increasing the effective slab depth to carry extra load, also contained new top reinforcement which was used instead of the existing top reinforcing and not supplementary to it. This structure was again analysed for dead load and for a live load of trucks with a gross weight of 25 tonnes being an H type semi trailer with twin rear axles.

High positive moments at mid-span in the column strip produced greater stress than allowable in the bottom reinforcement. Even by increasing the negative moments 15%, the existing bottom reinforcement was still overstressed (even though the calculated stress was only 65% of yield stress).

If this full overstress were achieved the slab would not collapse, but tension cracking would occur.

Noting that it would require two trucks each loaded to the above maximum and rolling side by side to achieve these results, we considered this to be not impossible but highly unlikely. We also considered that a figure in excess of 15% may be redistributed, which could reduce the overstress further. We made sure that reinforcement over the column was adequate both in section and length of bars, to cater for a large redistribution. (Fig. 1).

The fact that all cases known to us of flat slabs tested to destruction failed due to punching shear and not bending, also contributed to our decision to accept this design overstress situation.

In our case the punching shear capacity of the critical concrete section at columns was adequate, without considering dowel action of the original top steel.

We accepted that all these assumptions were dependent on the ability of the new and existing slab to act together.

Therefore we considered it necessary to complement our design with stringent specifications.

2.5 Specifications for Execution

The most important aspects are listed below.

2.5.1 Surface Preparation

All existing concrete surfaces against which new concrete is to be placed shall be prepared as follows:

a. thorough scabbling by mechanical tools to roughen surfaces.
b. clean off dust and debris by vacuum or oil free air blast.

2.5.2 Reinforcement Placing

Areas shown without reinforcement on plan shall have one layer of F72 fabric placed with 25mm cover and lapped 300 at splices and joints with main reinforcement.

2.5.3 Surface Treatment

After placing reinforcement and prior to placing concrete the existing surface shall be treated as follows:

a. repeat cleaning by vacuum cleaning or oil free air blast.
b. spray an epoxy resin on the concrete surface using a gun in accordance with the manufacturer's specifications.
c. new concrete shall be placed on the prepared surface and completed within work time recommended by the epoxy manufacturer.

2.5.4 Pouring Breaks

a. pouring breaks shall be located in the position shown on the key diagram [Fig. 3].
b. reinforcement shall be continuous through the joint. Joint surfaces shall be prepared and treated as specified above.

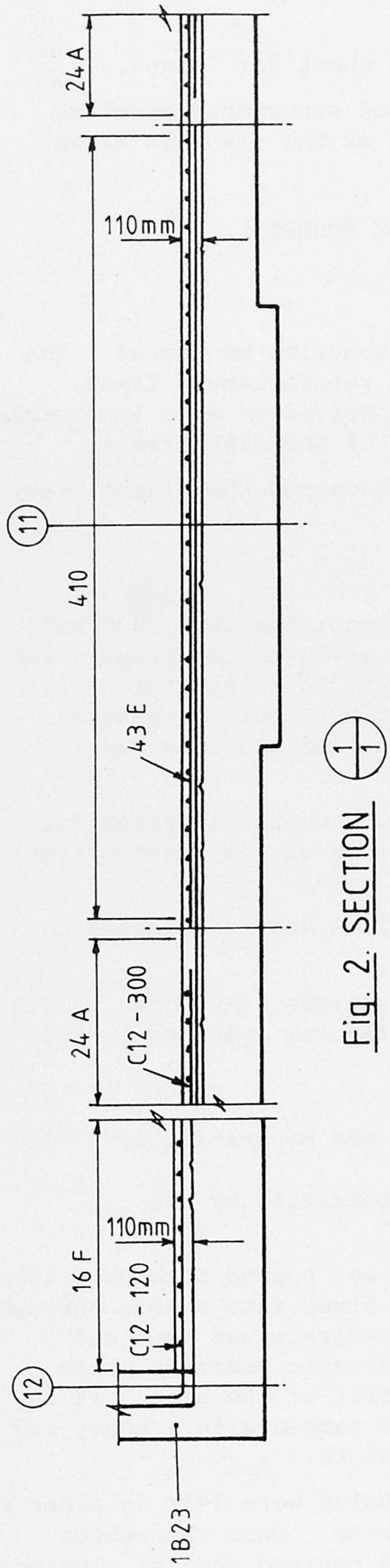

Fig. 2. SECTION

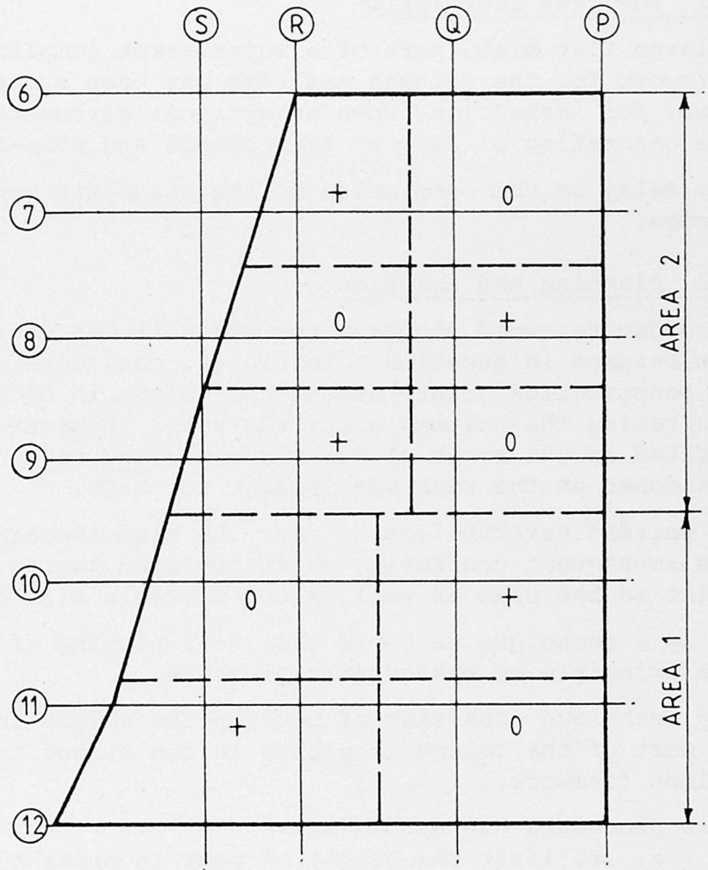

Fig 3 KEY DIAGRAM
(Pouring Sequences)

2.5.5 Curing

Curing was stipulated to be by covering with polythene sheet for 7 days.

After seven years of intensive use there are no signs of structural problems and contrary to expectations no cracking of the soffit of the slab has taken place.

3. THE SOLUTION TO A SITUATION WHERE COLUMNS HAD TO BE POURED AFTER AN EXTENSIVE SLAB

3.1 The Case Description

A large flat slab, part of a Supermarket complex, was about to be poured. The formwork for the columns and slab has been erected and reinforcement fixed, ready for inspection, when exceptional circumstances appeared to make impossible the concreting of many of the columns and consequently of the slab itself.

Any delay in the completion of the structure would have caused the client heavy losses.

3.2 Planning and Solution

In order to avoid stopping the works it was decided to pour the slab, but not the columns in question. Initially, consideration was given to the preparation of construction joints around the column in order to provide access for concreting the columns after the slab. However such joints would have been located in the zones of maximum shear and bending stress and the idea was abandoned as the risk was thought too high.

We decided nevertheless to pour the slab immediately but adopted a system for the subsequent concreting which obviated the inconvenience of the construction joint in the slab as well as the possible risk of settlement.

It is a technique we could call self-pinning of the column and it is based on the principle of hydrostatic pressure.

The technique consisted of pouring the column in three stages. As shown in Fig. 4, most of the column is poured in two stages through lateral openings in the column formwork.

This procedure has double aim:

- a. to limit the height of pour in order to avoid the separation of aggregates.
- b. to allow after each pour as long a period as permitted by the circumstances, for shrinkage to take place.

The third and shortest part, at the top of the column, was poured through a 100mm diameter pipe projecting some 900mm above the slab and fixed into a hole through it (Fig. 4). For this third and last pour non-shrink concrete was used and poured to the top of the pipe forming a column of hydrostatic pressure which produced an upward pressure of concrete against the soffit of the slab. It is recommended that the wet concrete in the pipe should be tamped with a heavy rod during the pouring in order to increase the upward pressure.

At the very top of the column's formwork several 20mm holes were left in order to avoid the formation of air pockets between column and slab. Once the cement slurry started to emerge through these holes, they were caulked and the pouring of the pipe finished as described before.

Twenty four hours later, the pipe and concrete above the slab were removed. After the usual time for curing, the whole area was stripped.

No settlement of the structure has been observed.

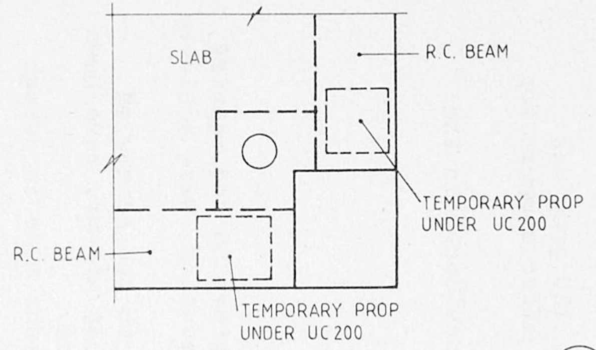

FIG. 6

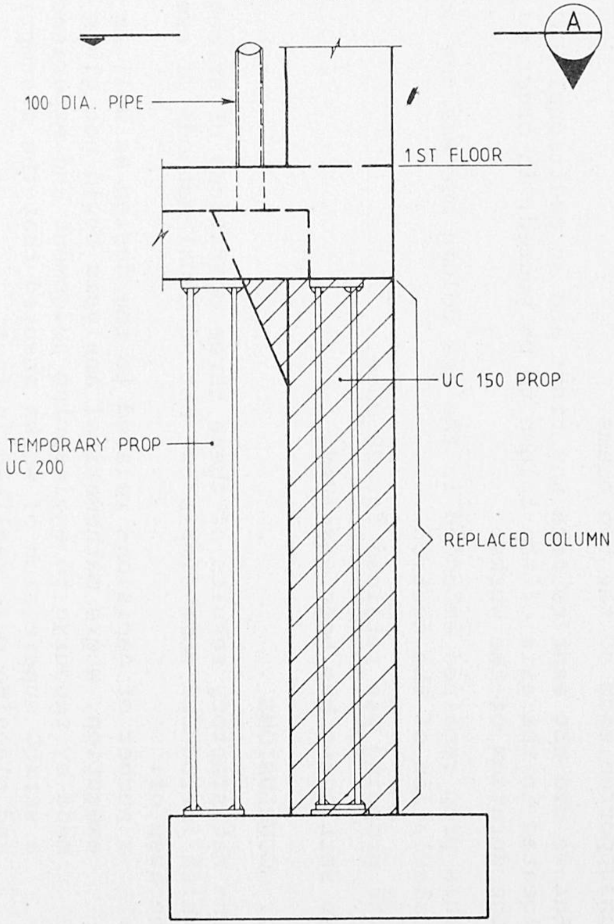

FIG. 5

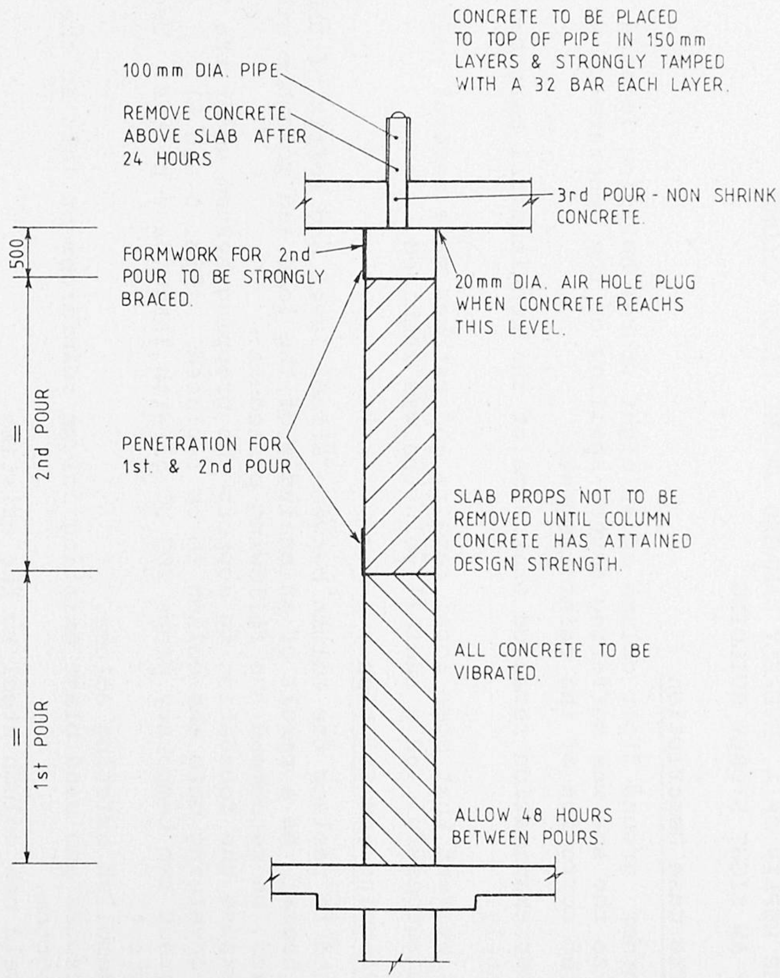

Fig. 4

4. THE REPAIR OF A SEVERELY DAMAGED GROUND FLOOR COLUMN OF AN EIGHT STOREY BUILDING

4.1 The Case Description

The corner ground floor column of an eight storey building located in Newcastle close to the sea was suffering severe spalling of the concrete as well as advanced corrosion of the reinforcement.

A closer examination revealed that some of the longitudinal bars had rusted completely.

It was evident that some local repairs and patches made several years before had been unsuccessful and a radical solution was required.

4.2 Planning and Solution

We opted to replace the column between street level and soffit of the first floor beams. As a result of an analysis of the load and possible risks involved, we recommend the following procedure:

- expose the foundation to support the propping system under the two beams converging onto the column to be replaced. (Fig. 5 and 6).
- erect two temporary props 200 UC 52 with large base plates. Use expanding grout.
- demolish existing column.
- expose and sand blast existing column reinforcement left at the top and the bottom.
- weld new column steel to the existing.
- replace column.

The replacement of the column was carried out using the same technique described in Chapter 3, with additional precautions.

The calculated load of the corner column over the 1st floor could have produced an excessive shear in the converging beams. The real situation, due to the exterior brick walls in all panels up to the eighth floor and roof was reassuring, because it was reasoned that these panels would act as vertical shear walls and not significant load would flow through the column on the provisionally unsupported ends of the two beams.

But we did not want to take any risks and an additional U.C. 150 prop was located in the axis of the column to be poured, in order to offer support for the duration of the works.

This prop remained embedded in the new column but was not considered in the calculation of the section.

The propping was retained for 28 days.

No settlement has been observed.

5. CONCLUSIONS

The satisfactory results of these three operations of strengthening and repairs, which introduced some simple but not so usual methods of execution, were achieved because of:

- a number of decisions related to the design as well as to the stages of execution, where mathematical analysis could not given an answer, have been made by recourse to engineering judgement and experience.
- a strict supervision of works assured that the assumptions made in design and planning were realised in fact.