The "all concrete" alternative

Garth Kelly

Structural and Technical Details

Scope of Project

A 2000 bed teaching Hospital with covered parking space for approximately 1 900 cars, Nurses Homes for 1 100 Staff members, Dining Room Complex, Assembly Hall, Administration Building, Auditorium, Boiler House and Ancillary Buildings.

Owner

Transvaal Provincial Administration.

The Design Team

Architects

Johannesburg Hospital Associated Architects
Colyn & Meiring
Cowin, de Bruyn, Cook, Glennie & Jury Inc.

Structural Engineers

Johannesburg Academic Hospital Consultants
W.J.S. van Heerden & Partners
J.W. Stein & Partners

Mechanical Engineers

Johannesburg Hospital Mechanical Engineers
Watson, Edwards and van der Spuy
Spoormaker and Partners

Electrical Consultants

Johannesburg Hospital Consulting Electrical and Transport Engineers
G.H. Marais and Partners
J.T. Williams

Water & Drainage Engineers

Salmon & Cilliers

Quantity Surveyors

Quantity Surveying Consortium, Johannesburg Academic Hospital
Lane & Dove
Van Rooyen, v.d. Walt & Visser
Carpenter Kling & Partners
Botes & Brink

Main Contractor

Hospital Contractors Johannesburg

A Joint Venture between:

Hochtief Aktiengesellschaft fur Hoch- und Tiefbauten, vorm. Gebr. Helfmann West Germany (Sponsoring Company)
Imprese F. Federici Italy
Imprese Italiane All'Estero Impresit SpA Italy
Prodilog Construction South Africa (Pty) Ltd. Johannesburg
Combrink Construction (Pty) Ltd. Randburg
Concor Construction (Pty) Ltd. Johannesburg

General

The Main Hospital Building, which was under erection from March 1974 to June 1976, is one of the most interesting precast structures in South Africa, containing approximately 23 500 precast concrete elements, certain of which are prestressed. The whole project started in August 1972 and will be completed one year ahead of schedule in August 1978.

Technical Description of the Building

The Main Hospital takes the form of a 360 m long double bank, 3 storey high nursing block inter-linked and vertically served by five vertical lift banks through a two storey high clinical and teaching podium. The complex can be said to be made up of five smaller hospitals each of 400 beds with the nursing units directly above and linking with the relevant treatment areas.

The width of the building over the podias is 144 m. The maximum height of the building 58 m and the minimum height 39 m. The difference in height as a result of sloping ground in the longitudinal direction of the buildings has been utilised for parking floors and service areas.

Design Criteria

As a modern hospital has to cater for the installation and connection of the most modern equipment at all times, ideally without major interruptions to essential hospital activities, the Client requested a substantial degree of flexibility

The three main features which finally guarantee this necessary flexibility are:

a) the structural grid in between columns in east-west direction is 12,80 m — in north-south direction 8,00 m.
b) above each nursing floor and each clinical (treatment) floor there is a service inter-floor which allows easy accessibility and freedom of movement, with a clear height between ribs of floor and ceiling panels of 1,95 m.
c) drywall partitions consisting of galvanised steel studs clad on either side with two layers of gypsum boarding. The cavity thus provided was utilised for the accommodation of all services for ward and treatment areas.

To provide the spacious service inter-floor the engineer was requested to design load bearing members in the form of roof trusses through which even persons could have easy access. No load bearing walls except the lift and staircase cores were acceptable, with the further restraint that even the façade panels could not be used as stiffening walls.

All Concrete Alternative

The tender design required a frame in structural steel — trusses and columns — as a supporting structure for precast concrete floor, ceiling and façade panels. Design criteria called for this steel structure to exhibit a two hour fire protection rating.

Bearing in mind the mounting steel shortage in South Africa at tender stage, as well as the cost of providing the necessary fire protection rating, an "All Concrete Alternative" was proposed by Hochtief Ag, Essen, West Germany, the Sponsor Company of Hospital Contractors Johannesburg. This alternative was accepted, affording as it did the added benefit of substantial cost savings to the Client and consequently all load bearing elements formerly in structural steel were changed to precast concrete elements. Certain of these were also prestressed of post-tensioned.

Precast and Prestressed Elements

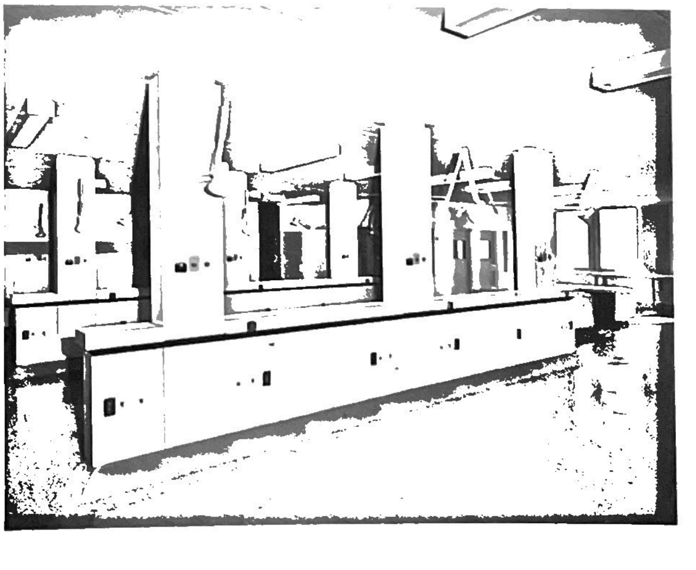
The 23 500 precast elements are made up of:

a) Precast elements only:

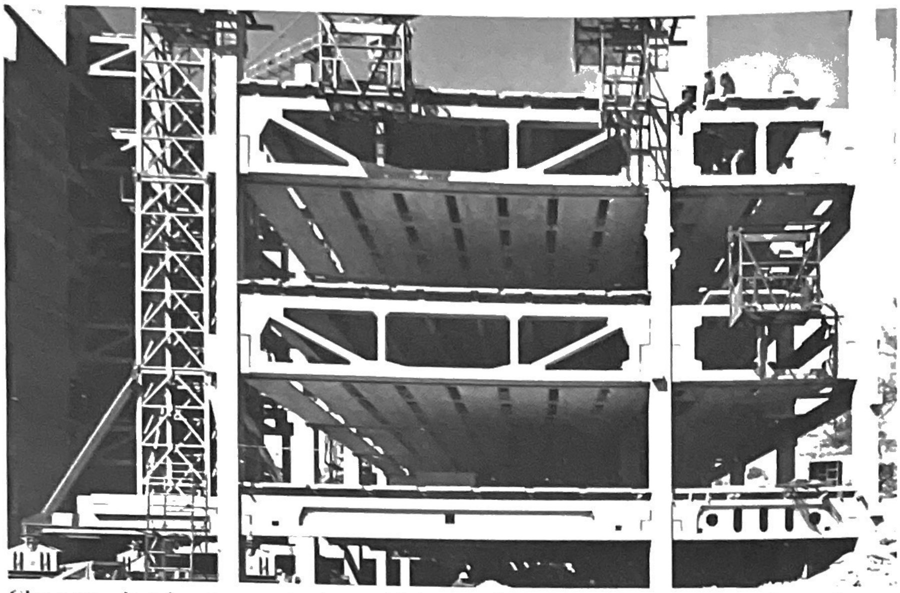
Ceiling panels: dimensions 8,00 x 3,20 m, approximately 5 800 pcs.

Façade panels: various lengths up to 8,00 m and up to 3,50 m in height, approximately 3 700 pcs.

Columns: 3 different sizes 0,60 x 0,60 m, 0,75 x 0,75 m and 0,75 x 1,00 m, lengths up to 12,00 m, approximately 1 750 pcs.



Panoramic view of the neonatal intensive care unit.



Close up showing trusses to interstitial, slots in ceilings above hospital floors for passage of services, and solid beams supporting floor slabs.

Wall panels; stairflights and landings; beams: approxiamtely 2 050 pcs.

b) Precast elements — prestressed or post-tensioned.

Trusses

The "All Concrete Alternative" utilised a truss of full service inter-floor height as one of the supporting members, similar to the structural steel design. Such trusses, in concrete, require less diagonals and offer more space for service installation and access of personnel.

The trusses span in east-west direction over the 12,80 m grid. They were post-tensioned and grouted in the storage yard with 4 Hochtief 25 HP stressing cables each, which run through the diagonals and the centre portion of the lower chord. These trusses have a height of 2,34 m and were extensively used for all 5 services inter-floors above Level 5 (Hospital Street). They number in total approximately 1 950 pieces of 7 different shapes.

Solid Beams

Below Hospital Street, in the parking levels, typical I-beams executed in the prestressing beds span in the east-west direction over the same 12,80 m grid. They vary in height and are 1,39 m high under the Hospital Street and 1,20 m high under parking floors. The applied prestressing force is either 150 Mp or 180 Mp. They number approximately 800 pcs. The levels below Hospital Street contain concentrated service installations — supply motors, etc., — and to accommodate these special I-beams with preformed openings, in a standard pattern, were provided to certain zones within the building.

The prestressing system was the Afro seven wire strand system as locally used in South Africa.

Floor Slabs

At right angles to the trusses and solid beams the prefabricated floor slabs span in the north-south direction over 8,00 m. The floor slabs have two ribs with sheet metal sheaths cast in for post-tensioning. The width of each slab is 3,20 m. Finally the floor slabs were post-tensioned together from façade to façade using Hochtief 50 Mp prestressing cables and cable lengths up to 72 m with special couplings for cable extensions.

At the erection stage the floor slabs behave as a single supported beam. However, after post-tensioning they become a continuous beam, achieving a saving in reinforcing steel and also reducing the deflection.

The position of the post-tensioning cables in the floor slabs was selected only after model tests were carried out. This was to ensure that no excessive stresses arose at the element support points, caused by creep and shrinkage after post-tensioning under own weight.

After erection adjacent slabs are connected at the cross joints by a ring reinforcement. In the longitudinal joints welding connections were executed to transfer loads from slab to slab. A total of approximately 8 150 slabs have been thus combined.

Three Dimensional Stiffening of the Precast Structure

Expansion joints in the north-south direction cut the 360 m long building into 5 blocks of approximately 70 m each. In addition the North and South Podia sections were cut off from the high rise structure by expansion joints in the east-west direction. Fifteen individual structural complexes were thus created.

For the reasons enumerated below the typical method of transferring horizontal loads through combined floor slabs into central lift- and stair-cores and other vertical load bearing walls, thus keeping the columns free of bending movements, could not be used:

i) The outer dimensions of the lift and staircase cores offered very little resistance in an east-west direction

ii) There are no load bearing walls except in the lift and staircase cores

iii) In any event the walls in the cores offered reduced resistance to bending and torsion moments owing to the frequent door and services openings.

To solve the problem a special analysis on tensions and deformations was carried out. This showed that trusses and columns, or solid beams and columns, when rigidly connected together could well be used to carry horizontal loads. As a result of this study a structural system was chosen wherein lift and staircase cores, as well as columns acting as frame members, contribute accoringly to their rigidity to the overall stability of the building within an acceptable degree of deformation. In execution the trusses and solid beams were rigidly connected with and through the columns by straight or slightly curved post-tensioned Hochtief stressing cables. In this manner formerly single supported trusses and beams were thus transferred into continuous beams.

To complete the picture floor slabs combined not only individually by post-tensioning and sheer conections, but also rigidly connected to the upper chord of trusses and solid beams, finally transfer the horizontal loads from the façades, or from slight column excentricities, to the lift and staircase cores. The frame is in this way tied together, thus ensuring the safe combination of the multi-storey portal structure and core structure.

Summary

The above-described precast structure was proposed by Hochtief Ag, Essen, West Germany and discussed and agreed upon with the Architects and Consultants at the end of 1972.

The agreement provided that Hochtief Ag would produce the structural analysis of the precast frame and elements, as well as the complete design, for one complete block of the building, highrise and podias form Level 0 to Level 16. Thereafter the Structural Engineer would develop the design for the remaining structure.

Only one year later the manufacture of precast elements commenced, while erection started in March 1974.

The building was erected in approximately 25 months at an average of 950 elements per month. The approximately 23 500 precast elements (excluding concrete filler slabs, walk-way planks and balustrades) have a volume of 75 000 m³ of concrete. Nine hundred tons of 8 mm stressing wires and one hundred tons of 12,5 mm 7-wire strands were used in the precast elements. The total amount of concrete used in the building approximates 155 000 m³, and reinforcing steel 14 000 t.

The design and execution of this building offers not only flexibility to cope with future developments of hospital and medical services, but it is unique in that the structure is the first in South Africa where all the load bearing elements have been prefabricated and connected together by post-tensioning.