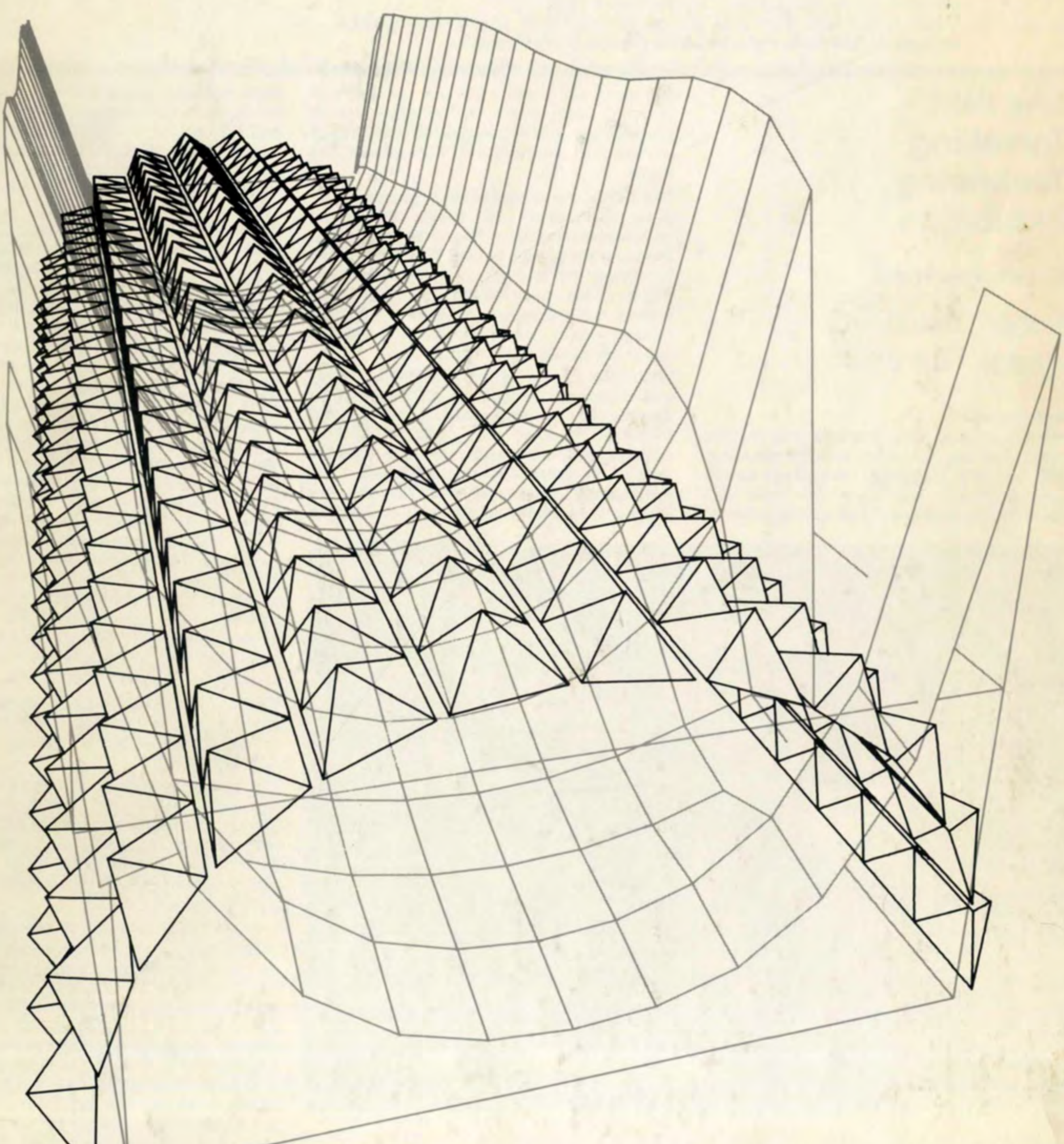
THE ARUP JOURNAL

DECEMBER 1984



THE ARUP JOURNAL

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Contents

Front cover: Graphical presentation of daylight levels across the floor of the IBM pavilion, superimposed on a perspective of the building.
Back cover: Detail of stainless steel arch and purlin connection, second floor gallery, Anugraha, Dell Park, Egham, Surrey (Photo: Harry Sowden).

The IBM Travelling Technology Exhibition

Architect: Renzo Piano

Robert Kinch
Alistair Guthrie

Introduction

Most buildings have two qualities in common: they are built once and do not move. The two IBM Travelling Technology Exhibition pavilions will each be built and dismantled 10 times. They will be sited as far south as Madrid and as far north as Helsinki. In all locations they must provide a comfortable environment for both human visitors and the electronic inhabitants (see Fig.1).

The aim of the exhibition is to present computer technology to young people in familiar surroundings. The architect, Renzo Piano, working with Arups, chose to do this by giving the building a transparent skin (Fig.2). This see-through building gives visitors the impression of being close to the natural world, while surrounded by the latest computer equipment.

The initial design work culminated in a full size prototype being built on the beach in Genoa (Fig.3). This was a two-pinned, triangular, trussed arch, with an internal radius of 4.9m. The web members were the ridges of polycarbonate pyramids. The single outer and double inner chords were formed from laminated timber. The connections between these elements were made using aluminium nodes. Two fundamental criteria had been established in this prototype: firstly that all components should act as part of the support system. Thus the role of the pyramids was not simply one of cladding; in the first prototype they were an integral part of the structure and their importance became even greater in the final structure. Secondly, all details should clearly demonstrate their function. Where aluminium connecting pieces were bonded to the timber, a finger joint was used. This allowed large glued areas to transmit the forces, where a bolted detail would have resulted in much larger timber sections. With the help of a video showing the arch against the backdrop of the Mediterranean, IBM were convinced that this should be the basis of the exhibition. The two structures now touring Europe have retained the principles of the original arch. The exhibition is enclosed by 34 arches, each of which is made from 12 transparent polycarbonate pyramids, six on either side arranged on a 5.3m radius. A single laminated timber chord, of 5.9m radius joins the tops of the pyramids. On the inside of the arch two laminated timber members form the double inner chord, following the curve of the arch on a 5.1m radius set 1.2m apart.

These connect to the base corners of each pyramid. Timber members join the internal timber chords where the pyramids are attached (Fig.4).

The timber members, in laminated beech, are made in sections and then finger-jointed to cast aluminium nodes to which the pyramids connect (Fig.5). The pyramids are vacuum formed from 6mm thick flat polycarbonate sheet, three pyramids being formed in each sheet.

The pyramids are connected to the inner timber by 200mm long stainless steel rods (Fig.6). A stainless steel block with a freely rotating cross-pin is glued to the polycarbonate. The rod is screwed into the cross-pin; a rubber block cast on the other end is pushed into the aluminium node during assembly (Fig.7). At the top of the pyramids stainless steel plates are glued to both sides of two faces. A formed stainless steel plate is bolted to these with a rubber block cast on a rod radiating from it. This rubber block has a push fit into the external aluminum nodes (Fig.8).

Fig.1
The IBM exhibition in London (Photo: Harry Sowden)

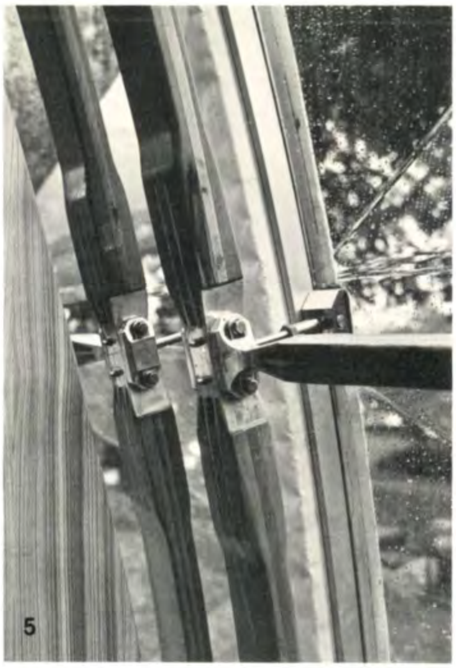

Fig.2
The transparent skin of the building
(Photo: Harry Sowden)

Fig.3
The original prototype
(Photo: Building Workshop)

Fig.4
The arch during assembly
(Photo: the architect)

Fig. 5
Typical timber aluminium joint
(Photo: Harry Sowden)

Fig.6
Pyramid-timber connection rod
and anti-condensation air nozzle
(Photo: Harry Sowden)

Fig.7
Connection joint assembly
(Photo: Robert Kinch)

Fig.8
Bottom joint between
external timber and pyramid
(Photo: the architect)

The exhibition comes complete with its own air-conditioning system. There are six free-standing air-handling units mounted along the centre line of the exhibition, with two further units positioned above the doors in the double-skinned walls at each end of the building. The floor-mounted units supply air to the floor ducts which discharge via perimeter grilles and circular twist grilles mounted in the floor. The units in the end walls supply fresh air to the exhibition and to a 'spine' duct which runs the length of the building at high level, supported by the crown of each arch. From this, vein ducts extend at each arch to arch junction. These follow the curve of the arch and vent directly onto the internal surfaces of the top four pyramids on each side of the crown, thus inhibiting the formation of condensation (see Fig.6).

To enable temperature regulation to be achieved while operating the air-conditioning plant at reasonable levels, passive environmental modifying devices are also used. These are double-walled, white, insulated polycarbonate pyramids which can be fitted within the transparent pyramids (Fig.9). They have a dual role acting as thermal insulation and shading devices, reducing thermal gains and losses and also internal light levels. Additional thermal control and shading devices, made from perforated aluminium panels are also used; these can be fitted into the bases of the pyramids using spring clips (Fig.10).

The only equipment which is not housed within the exhibition is the IBM mainframe computer, the chiller plant and the 400 kVA transformer and main distribution switchboard. All these are mounted in trucks which can be parked up to 75m from the exhibition. Cabling and pipework from these can either be buried or run on the ground surface covered by concrete covers.

The influence of polycarbonate

The most important factors affecting the design decisions for both services and structure had their roots in the physical and mechanical properties of polycarbonate. It has a very high coefficient of linear expansion, a low stiffness, which decreases rapidly with increasing temperature, it is extremely transparent and has a low thermal insulation value.

In the original prototype, the pyramids were fixed rigidly to the timber members. In hot conditions, when the surface temperature can reach 85°C, the compressive forces in the pyramids resulting from restrained expansion would cause buckling of the polycarbonate. Early attempts to overcome this involved installing a spring between the pyramids and the inner timber chords. This was to allow the pyramids to move radially but not circumferentially, taking up dimensional variations by changing the radius of the pyramids. It had been decided to separate the timber inner chords and the polycarbonate by 200mm. Using a shear-stiff spring to achieve this articulation led to relatively high bending movements where it was fixed to the pyramids and timber. To increase the strength of the components to overcome this would have complicated an already involved manufacturing process and so the spring was abandoned.

The next solution studied, and the one finally adopted, was to use an axially stiff connecting rod pinned at each end (Fig.6). This allowed the pyramids to expand circumferentially relative to the internal timber chords. Variations in the dimensions of the polycarbonate were absorbed by changes in the overall arch radius. The fixing to the pyramids allowed rotation in the radial direction only, being fixed in the direction of the building's long axis. This allowed shear forces from longitudinal wind loads to mobilize the vierendeel action of the inner timber frame.

A consequence of the pin-ended rod was that under asymmetric loads, the inner timber members received radial loads only. Their stiffness acting as an arch was less than the truss formed by the outer timber chord and the pyramids. The inner edges of the pyramids thus became the inner chords

Fig.9
Insulating pyramids
(Photo: Harry Sowden)

Fig.10
Perforated aluminium panels
(Photo: Robert Kinch)

Fig.11
Bottom fixing detail of arch showing internal aluminium stiffening
(Photo: the architect)

Fig.12
Connection between arches
(Photo: Robert Kinch)

9

10

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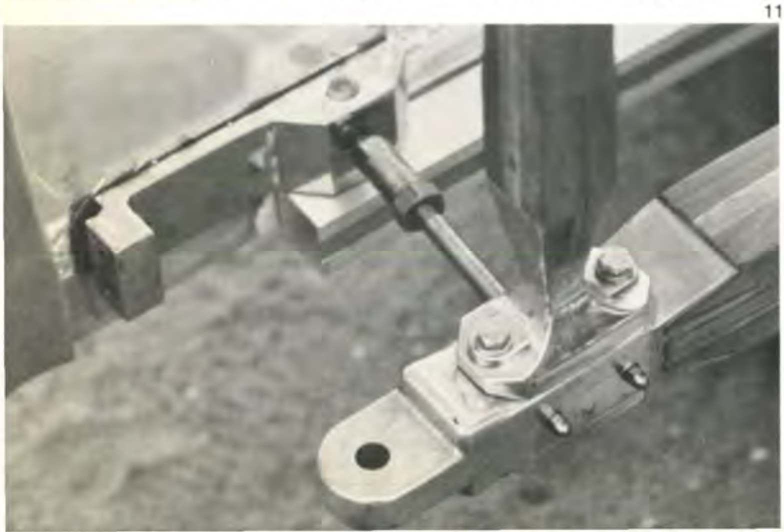
11



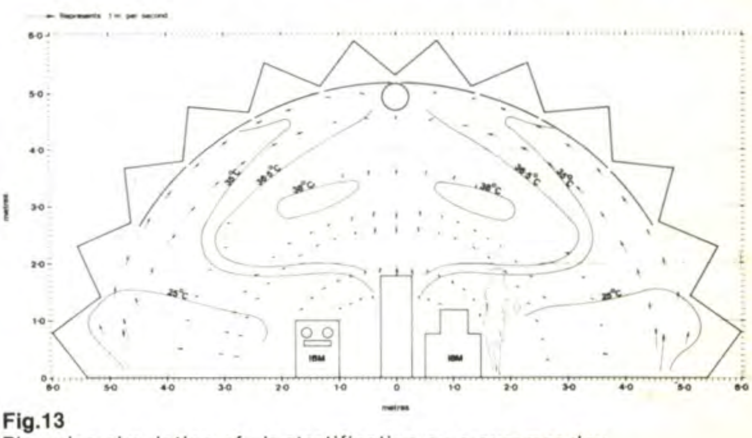


Fig.13
Phoenics simulation of air stratification on a summer day

of the truss. With the pyramids now forming both web and inner chord members, the low stiffness of the polycarbonate led to the introduction of arch to arch connections and stiffening of the chord elements of the pyramids.

The forces acting on the inner edges of the pyramids were sufficient to cause them to buckle. It was originally proposed to stiffen the edges by gluing a channel-shaped polycarbonate extrusion to them. In practice this proved very difficult. It was not possible to achieve true mating surfaces and the only transparent glue available caused extensive stress cracking of the polycarbonate. The extrusions were replaced by the aluminium channels, one outside and the other inside the pyramid edges. These were bolted together through the polycarbonate, slotted holes in the aluminium allowing differential thermal movements. The channels serve to prevent buckling only and carry no axial loads (Fig.11).

Analysis of the structure showed that deflections in both radial and longitudinal directions, under design loads, would be large. The longitudinal deflections of a single arch under wind load were too great to be accommodated by the waterproofing details. These deflections were accompanied by racking of the arch. By connecting the arches together at the crown and the mid-point on each side, the racking was minimized and the deflection reduced to an acceptable level. The connections were made between the aluminium nodes in the inner timber members. They serve to transmit shear between arches and also form supports for the vein ducts (Fig.12).

Radial deflections, although large, were not detrimental to individual arches. They did, however, require careful detailing of the joint between the end walls and the arches enclosing them. If these arches deflected to the point at which they receive support from the walls, large shear forces would be generated in the arch to arch connections. To prevent this occurring, the wall panels and the arches were separated by 150mm. This gap was then sealed by fixing flat polycarbonate sheets to the arch, allowing them to slide relative to the walls. A flexible gasket between these panels and the pyramids absorbs differential longitudinal movements.

The control of the internal environment was also dominated by the polycarbonate. The transparency of the building led to light levels so high that viewing the VDU screens would be akin to watching television in the garden. In hot and sunny conditions the transparency would also lead to greenhouse conditions. In cold climates the low thermal insulation value resulted in large heat loss with a great risk of condensation.

To increase the insulation value of the pyramids and reduce the light levels, the previously mentioned devices were used: white, double-skinned pyramids with fibreglass insulation and reflective, perforated aluminium panels (Figs.9-10). These were placed within the transparent pyramids. Other devices looked at were double-skinned, transparent pyramids either gas-filled or with a partial vacuum and coating the surfaces with selective screening treatments. These were discarded because of the permeability of the polycarbonate and its high expansion coefficient.

A computer program was developed to establish the thermal performance and give the required heating and cooling capacities of the air-conditioning system. This program had fixed parameters for heat gain from people and machines. Further data required were latitude and longitude, the month, time of day and the orientation of the building. A separate data file contained information on the location and number of insulating pyramids and aluminium panels.

This data file was amended after the program was run until an optimum design level of air-conditioning was achieved. When this had been done a study was made of the stratification of air layers of different temperatures with a view to reducing the cooling load. To do this a separate environmental physics modelling program, based on finite difference techniques, Phoenics, was used. A typical cross-section of the exhibition was analyzed using a two-dimensional simulation of turbulent air flow. The results, displayed graphically, showed the speed, direction and temperature of air flow at critical locations (see Fig.13). The analysis indicated that the body of hot air at the top of the exhibition would affect people in it. Improving the stratification pattern by increasing the number of air changes was considered. The quantity of air to achieve this was too large to be handled comfortably within the space. The solution which came from this analysis was to increase the volume and height of the space by enlarging the arch radius. The body of hot air was kept above the lower 2m of the exhibition.

Studies of internal light levels were also computer-aided. The program written for this required the same data as the thermal performance program, together with the information on the position of insulating pyramids and aluminium panels. Additional information required was clear sky or overcast and whether there was snow cover on the ground. Results were shown graphically, giving light levels across the floor of the structure (see front cover). By modifying the files containing the data on the insulating pyramids and shading panels, it was possible to specify the optimum positions for these shading devices. The program was verified using a 1:20 model of the pavilion under both natural and artificial sky and sun (see Fig.14).

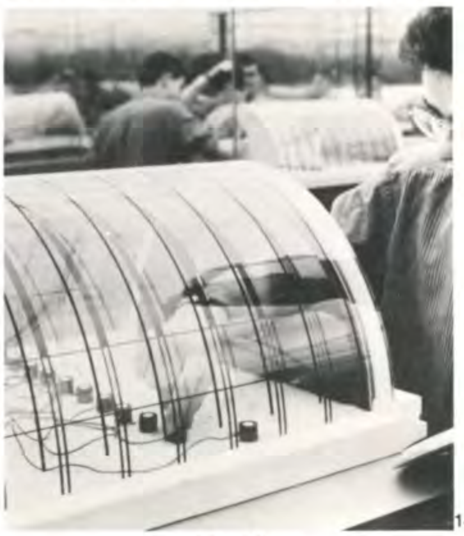
Condensation was controlled by supplying small quantities of heated outside air onto the inner surfaces of the pyramids. The air was blown, via aircraft type nozzles, from the 'vein' ducts (see Fig.6). The effectiveness of this solution was checked using the Phoenics program.

The final stage was to modify the thermal performance and light level programs to predict the number and location of insulating and shading devices. Given all the necessary data for any site, a diagram can be produced showing the ideal location of insulation and shading devices required.

Transportation and assembly

The need to transport and erect the exhibition was the second most important factor affecting the design. For transport, each arch is separated into four major components (see Fig.16):

(i) Two outer chord members
(ii) Four inner chord members
(iii) 14 inner chord cross members
(iv) Four sets of pyramids.



14

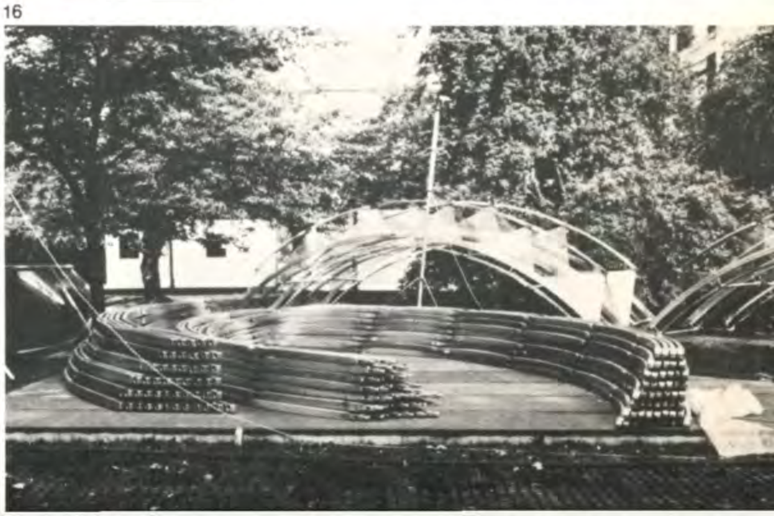
Fig.14
Model for validating light intensity program (Photo: Harry Sowden)

Fig.15
General view of interior showing spine and vein ducts with insulating devices positioned (Photo: Harry Sowden)

Fig.16
Arch components in London: inner and outer timber chords with half arches (Photo: Robert Kinch)

15

16



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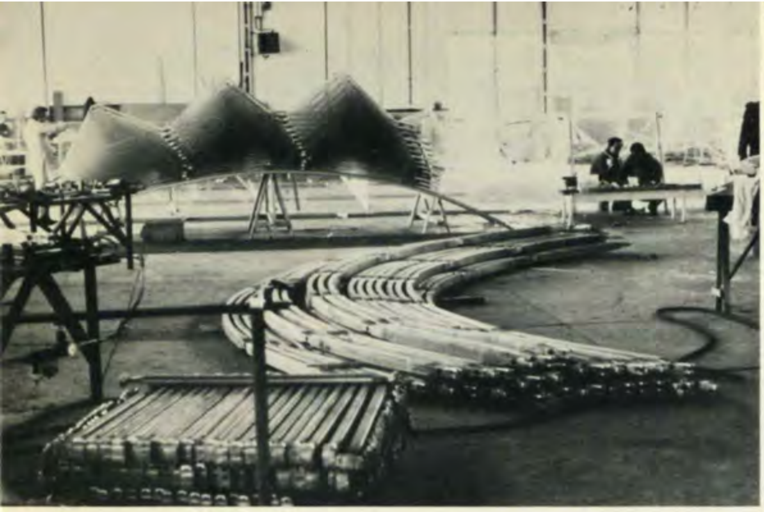

Fig.17
Arch components in the factory during fabrication (Photo: Robert Kinch)

Fig.18
Air conditioning units during assembly (Photo: Robert Kinch)

Fig.19
The exhibition at night (Photo: Harry Sowden)

18

Each of these components can be manhandled, the number of men being determined more by size of component than weight. The way in which each arch is divided up was determined by comparing the number of trucks required with the time needed for assembly. Transportation became the dominant influence in every case except one. Single pyramids could be stacked more economically. However the joint between pyramids was time-consuming and expensive to make and could lead to tolerance misalignment between arches. During maufacturing, many more components were needed to be fixed to the pyramids; the number of specially made connecting pieces used during assembly would have been increased fivefold. Perhaps most importantly of all, the number of joints requiring weatherproofing would also increase fivefold. For these reasons it was decided to form the pyramids in the largest number possible.

This was determined as three by the maximum size of polycarbonate sheet available.

An advantage of this was that the manufacturer of the pyramids was able to use just two moulds; one for the top set of pyramids and one for the bottom.

This ensured that all sets of pyramids were dimensionally compatible (see Fig.17).

It was only after the components had been decided upon that joints could be designed. Where possible misalignment of members could happen without affecting the ease of assembly, bolted connections were adopted. For those joints where misalignment due to temperature and tolerance effects could make assembly difficult, a more tolerant type of connection was developed. Those were the joints between the timber members and the stainless steel connecting pieces. Here tapered rubber blocks were cast onto the steel; these allowed a push-fit even when perfect match was not achieved. The joints were secured using bolted stainless steel pressure plates after assembly.

It was decided very early in the design process that no site connections would be made directly to the polycarbonbate. This was because it was felt that any structural connection would rely upon shear transfer and require a 'friction grip' type of connection. The level of site supervision needed to achieve this would be unreasonably high. In addition, if this type of connection were made in the factory, periodic checking would be required, as the polycarbonate would creep under sustained pressure. For these reasons, all bolted connections to the pyramid were rejected and glued junctions adopted.

The measure of success

The pavilions now touring Europe are proving popular with visitors. In Paris, the first city visited, the IBM target figure of 1000 people a day was reached. In Milan and London daily figures in excess of 3000 people have been recorded.

The logistics involved in transporting, mounting and dismantling such an exhibition are very complex. In Paris assembly took seven weeks; this has been reduced to less than four.

The lifespan of the buildings and their current itinerary is 30 months. After that there are currently no plans for the future of the pavilions. What do you do with a retired building?

Credits

Client:
IBM Europe

Architect:
Renzo Piano

Fabrication and erection contractor:
Calabrese Engineering spa

The Shopping Mall, Ashley Centre, Epsom: electrical installations

Architects:
Renton Howard Wood Levin Partnership

Robert Wood
Jacob Chan

Introduction

Epsom, a town best known for horse racing, was chosen by Epsom & Ewell Council to be the site for the development of a shopping centre. This is due to its central location and the fact that its retail catchment area population totals about 170,000 of which 75% are in the above average income group. A competition was held and out of entries of seven development/architect teams, Renton Howard Wood Levin and Ove Arup & Partners were chosen to develop the scheme. Epsom & Ewell proposed that the development should increase the shopping area of Epsom but retain the semi-rural character of the existing town centre. The architect successfully planned and skilfully integrated the Centre into an area which contains many 18th century buildings from Epsom's 'Spa' period, using bricks and pitched roofs to harmonize with the existing listed buildings. The Mall has been designed in the form of a loop off the High Street enabling shoppers to pass from the Mall into the High Street and vice versa. All the shop fronts open onto an enclosed pedestrian Mall which forms the spine of the Centre. Along this Mall are a number of internal 'squares' each different in shape, scale and character. It provides a choice to shoppers between the traditional High Street and the internal shopping mall, providing protection from the weather and having a traffic-free pedestrian environment.

An existing building at the centre of the High Street was demolished to provide the East Entrance to the Mall. The building was partly rebuilt and refaced in the 1930s and was therefore not in character with the the nearby 18th and 19th century buildings. The new Mall entrances were carefully detailed to blend with the surrounding buildings.

The complex consists of a shopping mall, a four storey office building known as Fina House, a theatre and a multi-storey car park with a capacity of 800 cars. The Centre itself has a total shopping area of around 24,000m^2, comprising 41 shop units, plus 14 units which are located in an open square at the north western entrance to the Mall and a number of multi-storey department stores such as Marks and Spencer, Army and Navy, as well as a single storey complex for Mothercare and Waitrose.

The services

In winter the heating in the shopping Mall relies on heaters over the external doors and heat gains from the shops; and in summer the automatic smoke ventilators are used to provide natural ventilation, which keeps the internal temperature at a comfortable level for the shoppers. Rain detectors are used to close ventilators automatically on rainy days.

An independent boiler plant has been installed to serve the landlords' areas which include the Mall and management offices, while the tenants are provided with mains utility services. The tenants are responsible for providing their own facilities for heating, air-conditioning and ventilation.

The electrical installation can be divided into three sections (i) Electrical supplies (ii) Power & lighting (iii) Communication systems.

Electrical supplies

Four new South Eastern Electricity Board substations have been located around the perimeter of the Centre providing supplies for the landlord and a low voltage service to each tenant. Close liaison with the Board

Fig.1
General view of the West Square
(Photo: Harry Sowden)

Fig.2
Model of Ashley Centre
(Photo: copyright the architects)

3

was essential to ensure suitable routes for supplies to all tenants and also to satisfy the phased requirements of the development. The substations are located approximately at four corners of the site. Two of the substations house a single 1000 kVA transformer while the other two house twin 1000 kVA transformers providing even power distribution and minimized cable lengths to the Centre and supplies to the adjacent buildings such as Fina House and car park.

The landlords' incoming 400A, 3 phase, 415V supply is terminated in a metering chamber within the landlords' switchroom. This supplies a cubicle switchboard which houses all outgoing services, and landlords' metering of retail service areas. The load consumptions in each section of the landlords' areas are monitored by a check meter.

Remote switchboards are located in service cupboards in the Mall and trucking corridors, providing local electrical supplies for lighting, general purpose power and communication systems. A standby generator is provided to serve the Mall smoke extract installation in the event of a local fire within the Central Mall.

The cables to the various shop units are generally located in the trucking corridors and the Electricity Board meters to shop units are positioned within the shop premises with external reading facilities. The cables to the various shop units are generally located in the trunking corridors and run along on special cable racks which have been installed for this purpose.

Lighting

The lighting is designed to enrich the aesthetic environment and each section is treated differently to highlight its own character.

The lighting within the enclosed sections of the Mall consists of recessed mounted fluorescent luminaires within a Formalux ceiling grid and the lighting was designed to average 200 lux at the floor level.

A transitional lighting system using recessed tungsten luminaires has been installed between the enclosed sections of the Mall and the sections which feature daylight. The transition lights are controlled by photo electric cells to reduce the daylight glare which the shoppers may meet when walking from one section into the other.

The West Square, which has a five storey atrium with a stepped roof on one side, is provided with two lamp posts and wall-mounted globes using 70W high pressure sodium lamps.

Additional spot lights are mounted on lighting tracks which have been installed within the bottom of the trusses to highlight the West Square marble facings and the colourful advertisement banners. Similar lighting arrangements are also used in the central square which has a two storey glazed sloping roof.

In other 'squares' which are also lit partially by natural light, ornamental half-globes and 'bulb' shaped clear glass pendants using tungsten lamps are provided.

Most of the tungsten lamps circuits are dimmer-controlled to increase lamp life. The fluorescent luminaires are normally switched on during the shopping hours, the discharge lamps are switched on during the evenings and fluorescent luminaires can be switched on for security purposes at strategic points. All the landlords' normal and security lights are controlled from the security control room console.

Emergency lighting

A non-maintained emergency lighting system is provided throughout the Centre within the landlords' and public areas. The emergency lighting system is rated for one hour 110V d.c. from a central battery set and the luminaires will be switched on during local mains power failure. The system is designed to illuminate the escape routes to allow shoppers to leave the Centre safely when the normal lighting fails.

Small power

The small power arrangement within the Mall was designed to provide local power points for cleaning and temporary small decoration lights such as Christmas fairy lights.

The arrangement consists of 13A socket outlets mounted within the false ceiling forming part of the recessed fluorescent fitting and the service cupboards along the Mall.

Lifts

Three glass-fronted lifts with views over the West Square have been installed to link a five storey car park to the shopping Mall.

The Mall therefore provides a pedestrian distribution system from the car park to nearby areas of the town. All the lifts will automatically park at the fifth level in the event of an emergency and with one of them being designated as a fireman's lift.

Communication systems

These are some of the most interesting parts of the project and consist of the systems which provide the safety and security to the shopping centre. These include the fire alarm system, the public address system, the UHF portable communication system, the shop/landlord interface unit, the burglar alarm system, the internal telephone system, the intercommunications system and the closed circuit television system.

Originally, each system was designed as 'hard wiring' but was ultimately developed into a multiplex system to reduce the amount of wiring, space and installation time.

Fire alarm system

The site is divided into four main areas, each fitted with an alarm system controlled from a panel monitoring the zone in that area. Each of these panels is linked via the multiplex system to the security control room console. Within the loop there are transporters which monitor and transmit signals to the master controls within the control console. The information is displayed on a print-out together with a visual display at the computer terminal and

4

5

Fig.3
West Square looking towards Centre management offices

Fig.4
Central Square looking east

Fig.5
West Square: view from balcony

(Photos: Harry Sowden)

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indication of the affected zone on a graphic mimic, as well as on the repeater mimic for the Fire Officer's use.

The relevant loudspeaker zone on the public address system will automatically operate at the same time.

Each shop unit is supplied with a landlord's interface unit, where it has the facility to signal a fire or burglar alarm condition within that shop to the control room console as well as the signal from the sprinkler flow switch.

Smoke dams, Mall doors, lifts parking and smoke vents will be operated if a fire condition exists within the Mall areas. All the systems are connected to the main console via the transponders using the fire alarm multiplex loop.

Optical beam detectors were originally intended to be installed in the West Square because of the high and open space. However, smoke detectors were finally installed at high level because large decorative banners were to be hung from the stepped roof.

All the break glass units in the Mall are positioned in service cupboards by the Mall entrances. The general public cannot access them, thus preventing vandalism.

Public address system
The Centre Management required a public address system to be installed to provide background music and public announcements; therefore it is sensible for economic reasons to use it to form part of the fire alarm alerts system and to replace alarm bells. This provided additional facilities for the Centre management or fire officer to talk to the shoppers directly from the control room. A microphone is specially designed for this purpose.

It consists of five amplifiers with total output power of 120W. The amplifiers are located in the control room. 120 loudspeakers have been installed in the Centre. The system is arranged to provide for selective paging into the 25 fire zones from microphone or announcement machine with an automatic alert tone.

The background music is available in all public areas and each can be controlled manually from the security office. The music system has an automatic cartridge player with manual track control.

When a fire alarm has been transmitted from a shop unit or Mall an alarm is then signalled from the computer into the public address system. The system will automatically transmit a coded alarm into the particular zone or zones affected to enable the signal to be verified.

After 30 seconds, the evacuation tape will start and inform the shoppers to leave the complex. The tape is continuous and can only be overridden by the firemen's microphone or the alarm input being cleared.

UHF portable communications system
This system provides an instant voice communication between the security office and security personnel.

It consists of a control unit with a transmitter installed in the security office. This provides the facility to individually or group call the five pocket size transceiver units. A licence is required by the Home Office to operate this equipment.

Its main use is for crowd control, and its principal advantage is that it allows the transmission of information to a number of listeners simultaneously over a large area and through a high level of ambient noise. The other alternative would be to install telephone sets at numerous locations which would not be an ideal solution.

Interface units
There are 88 interface units which provide the means of interconnecting all retail units alarm circuits requiring integration with the landlords' communication system.

The unit consists of a metal box with six enclosed compartments for the shop connections, i.e. fireman's neon sign switch, an extract fan, a fire alarm and public address, a Mall fire indicator, an internal telephone and burglar alarm.

Burglar alarm system
The Mall doors and landlords' areas are connected to a burglar alarm system monitored in the security office. In addition the system also monitors the individual alarm system in each shop unit via the interface unit.

The burglar alarm system is controlled from the multiplex system in a similar way to the fire alarm system. A separate loop of the multiplex signalling cable is dedicated to burglar alarm equipment signals. This information is also displayed on the printer, the visual display unit and on the burglar alarm mimic which is used to detect any intruder involving unauthorized entry taking place out of view and during closing times.

This does not activate any alarm sounder but alerts the security staff who may then call the police to arrest the intruder.

Fig.6
View across the open square
(Photo: Bob Wood)

Fig.7
Security control console showing the mimics on the left and the VDU in front of the security offices (Photo: Bob Wood)

Internal telephone system
A private telephone system comprising 80 telephones is provided to allow communications between the Centre management, the security office and all retail units to guard against false alarms and assist in the day to day communications with tenants such as goods delivery.

Intercommunication system
An intercommunication system is installed to provide a direct speech system between the security office and the lifts, and lift motor rooms.

Two weatherproof and vandal-resistant intercom units are also installed at the service roads and service deck entrance to allow communication between the centre security personnel and the incoming lorry drivers.

There are two vehicle barriers, one automatically controls goods vehicles in a service yard at the western end of the centre and the second controls the entrance of vehicles to the service deck which covers the first floor of the shopping centre.

The advantage of this is that the security guards do not have to be in positions by the barriers to control the inflow and outflow traffic.

Closed circuit television monitor system
Three external cameras and four internal cameras are strategically positioned in the landlords' service areas and the Malls. All the cameras have pan, tilt, and zoom control and the external ones have washers, wipers, thermostatically controlled heater and blower units. The seven cameras are coaxially connected to two sequential switching units, linked to four 228mm monitors and one 430mm close-watch screen.

Two of the four monitors will receive pictures from external cameras whilst the other two monitors will receive pictures from the internal ones. Indication is given on each monitor as to which camera picture is being shown.

The close-watch screen is mounted adjacent to the four monitors on the control room console. This will provide the facility to transfer any picture from any monitor whilst maintaining control of the relevant camera with no loss of the sequential switching arrangement. The time each picture is held on the monitor can be varied from about 2 to 45 seconds. A video recorder is also installed for recording from the close-watch screen. The system allows the operator full remote control of camera operation and recording facilities for security and crowd control.

This diminishes the personal risk to security staff and removes the predictability of the regular security guards patrol. It provides an active deterrent, having the advantage that the presence of the cameras gives the impression that the individual is being watched whether or not the security staff are aware of his presence. An alternative method would be frequent patrols of security guards.

Control console
This is the 'brain' of the communication systems. It houses all the master controls for the communication systems as well as lighting controls, and the microprocessors for the multiplex system.

The console is constructed using a mild steel frame and is 7m in length.

The fire alarm and burglar alarms mimics are located at the left hand sides while the CCTV screens are mounted on the right hand sides.

Multiplex system
A multiplex system as mentioned previously is used to provide monitoring and remote control facilities for the burglar alarms, plant alarms, fire alarms, sprinkler alarms, smoke vents, smoke dams and interconnections with public address system.

The main controlling element of the system is a Central Process Unit (CPU) which is housed within the control room console. This CPU collects data from the 58 transponder units which are installed via two independent communication loops and relates this data to the visual display unit, and the line printer by using the relevant software.

A d.c. uninterruptible power supply is also installed within the control console. This unit is an automatic standby a.c. power source which ensures continuous central operation in the event of the mains power failure for 72 hours.

29 monitoring transponders and 29 monitoring and remote control transponders are installed to provide the facility to monitor 464 alarm points and remotely control 232 points. The monitor transponder is used for monitoring contact input points such as alarm signals from shop units or landlords' fire alarm panels, etc.

The monitoring and remote control transponder is used to activate and deactivate the relay unit for on and off control of devices such as smoke vents or Mall doors.

The alarm monitoring and control transponders connect to the CPU via two communications loops. One loop is used for burglar alarm and plant monitoring and the second for fire alarms, sprinkler alarm smoke vents and smoke dams. Each communication loop consists of two twisted pair cables and both are wired on a ring principle. In the event of a single line fault, the system remains completely functional. The fault is immediately detected by the system's automatic self test operation and reported to the system operator.

The transmitting alarm signal information over the loop is by a conversion of the alarm signal to a digital data format. Each transponder is assigned a specific numerical address. The microprocessor communicates with a given transponder by sending its address in digital form over the loop. All of the transponders on the loop receive the address but only the transponder which has been programmed for that address responds. The transponder responds with a digital signal which contain the status of all alarm contacts connected to that transponder.

This system offers advantages such as the redundancy of installing wiring from each of monitored or controlled points to the CPU. Transponders are connected to this wiring in the locations chosen to be monitored or controlled. Transponders can be added, moved or removed as required without additional wiring.

Two mimic display panels installed within the console provide a pictorial representation of the Centre. One mimic indicates burglar and plant alarm point status and the other indicates the status of the fire and sprinkler systems. Three light emitted diodes (LEDs) are provided for each display point. The LEDs are continuously lit for acknowledged alarms and intermittently flash for new alarms.

A repeater mimic indicating fire and sprinkler sections is installed near the East Mall entrance.

Lightning protection
The lightning protection generally consists of an air termination network which is connected to the reinforcement of the concrete structure.

Conclusions

Excavations for the Shopping Centre started in November 1980 and the first phase was opened to the public in November 1983. The second and final phase was opened to the public in April 1984.

The electrical installation was carried out by Balfour Kilpatrick (Wallington) Ltd, with the communication systems forming a subcontract to them being carried out by Mather & Platt Ltd.

The total electrical contract sum was approximately £1 million.

The Queen formally opened the Centre on 14 October 1984.

Credits

Client:
Ashley Avenue Developments Ltd.
Architect:
Renton Howard Wood Levin Partnership
Quantity surveyor:
Gleeds
Management contractors:
Bredero Construction Co. Ltd.

Expert or knowledge based systems: consequences for the industry

David Taffs

This paper concluded the Conference on the Impact of Computer Technology on the Construction Industry held at the Bloomsbury Crest Hotel, London, 25-27 September 1984.

Introduction

Consultant:
What is the nature of the operation?
Subcontractor:
Finishing off behind the boiler house.
Consultant:
By 'finishing' do you mean plastering, carpeting, etc., to the rear wall of the boiler house?
Subcontractor:
Of course not, I mean getting in the remaining drains.
Consultant:
'Remaining drains'; do you mean surface water or sewage drains?
Subcontractor:
Yes.
Consultant:
Which?
Subcontractor:
Surface water.
Consultant:
By 'getting in' do you mean going inside?
Subcontractor:
I mean build them.
Consultant:
Shall we look at the drawings?
Subcontractor:
Yes, drawing no. 57/168D.
Consultant:
Please indicate start and finish point of each drain run.
Thank you. Do you want an estimate of time and cost?
Subcontractor:
No, just get on with the excavation for now.
Consultant:
The total run of drains is 51m.
Total excavation is $37m^3$.
Boiler house foundations are noted.
Existing land drain is noted.
Boundary fence is noted.
Are there any obstructions above ground?
Subcontractor:
No, and ignore land drain.
Consultant:
Cut through land drain?
Subcontractor:
Yes.
Consultant:
Are there any other obstructions or services below ground?
Subcontractor:
No.
Consultant:
The short runs into the inspection chamber should be dug by hand.
Tip spoil by fence.
The rest can be dug by machine.
Remove boundary fence for access.
Five trips of an $8yd^3$ truck are needed.
OK?
Subcontractor:
No, access through that fence is forbidden. We must come in west side of boiler house.
Consultant:
Width of access is too small for normal truck and excavator. Shall I investigate alternatives and availability of suitable plant?
Subcontractor:
Yes and print results (his parting comment as he leaves to answer a phone call).

The above exchange would not be exceptional if conducted by two human beings. When, however, the consultant is nothing more than a machine, our powers of comprehension are taxed beyond credulity.

Future generations of computers will be available and affordable that can converse with us in our natural tongue. They will be able to interpret what we mean and give advice on our problems, the advice being derived from facts and experience embodied within the computer. As well as systematic deductions from known criteria and rules they will also be capable of creative work. There are aleady research examples of childrens' stories, plays, music and pictures that have not been produced with the aid of a computer but created by them unaided by man.

Our existing hardware and software are incompatible with the future systems of which we speak. For the past 20 years we have enjoyed a stable environment. New hardware might have appeared every week getting smaller, cheaper and more powerful, but our computing environment was stable in that programs written in 1964 in sensible languages would run on today's computers with little change. The future is not going to be anything like as accommodating and comfortable for us. There will be some blood-letting, the bastions of the professions are coming under siege and we shall not all survive.

Artificial intelligence

The definition of an expert system is given later in this article. It has its origins in the field of artificial intelligence, a subject that was oversold in the early 1970s and as a consequence was deprived of research funding when progress did not live up to expectations. Nevertheless useful work was done on which we are now building. Pattern recognition and heuristics (the technique of the computer teaching itself experientially) are two such topics.

In the former, robots were built to recognize shapes and colours and manipulate objects even to the point of removing obstacles and superimposed elements in order to reach the target. With the prevailing technology, the movements were geriatric. By contrast, in 1984 there are missiles containing microchips that moments before being launched are electronically etched with views of their victims. The missiles will then steer themselves around other objects, ships and aircraft until they find something to match one of their stored images. Doubtless there are other scientists frantically devising ways in which their armoury can holographically disguise itself as anything from a supersonic bedstead to a rocket-firing rhinoceros.

Heuristic techniques were used to allow the computer to learn from its mistakes. If, having made decisions, it failed to achieve its objective, it would alter its decisions and retry. An element within the process was the computer deliberately introducing an error occasionally to test its hypotheses. Let us hope we catch such aberrations when our electronic masters decide to introduce them on structures like the Humber bridge.

The Japanese initiative

It was not until the publication in 1981 of the JIPDEC report by the Japanese that the rest of the world was galvanized in to action. New buzz words, expert systems, were substituted for artificial intelligence and research funds came flooding back. The reason was that the Japanese had boldly announced their development plans leading to a take over of the world. They argued that in the future, power would rest with those who controlled information and they were going to develop the necessary tools before the end of the century.

Since then the Japanese have had to make some cuts in their considerable budgets for the programme, but achievements are not far behind their original targets. The UK's answer was to set up the Alvey Directorate[2] which publishes a regular newsletter explaining its activities. The European Economic Community's response was to allocate funds to what is known as the Esprit programme[3], a long-term research and development objective to parallel that of the Japanese. Many other developed countries are embarking feverishly on similar schemes. The combined effect is a concentration of resources on an unprecedented scale.

What are expert systems?

Artificial intelligence was once neatly defined as the science of making machines do things that would require intelligence if done by man. With the information explosion it was inevitable that the definition of expert systems became somewhat more verbose.

According to the British Computer Society's Specialist Group 'an Expert System' is regarded as the embodiment within a computer of a knowledge-based component from an expert skill in such a form that the machine can offer intelligent advice or take an intelligent decision about a processing function. A desirable additional characteristic, which many would regard as fundamental, is the capability of the system on demand to justify its own line of reasoning in a manner directly intelligible to the enquirer. The style adopted to attain these characteristics is rule-based programming[4].

Knowledge engineering

Regrettably, in order to discuss a new subject we must learn an additional vocabulary. Expert systems are a subset of intelligence knowledge based systems (IKBS). These are systems which can use logical inference to apply knowledge to perform a task. The difficulty is in knowing how to obtain and store the knowledge, both factual and heuristic, in a form in which it can easily be updated, retrieved and manipulated to simulate human reasoning. This is known as Knowledge Engineering and a number of organizations now employ 'knowledge engineers' who specialize in this field.

There are at least six different methods used to represent knowledge, the most popular being production systems. In its simplest form this is nothing more than a set of rules, called productions, which are of the form IF condition THEN PERFORM action. The specialist subject to which the knowledge applies is referred to as the domain and the stored knowledge is not referred to as a data base but a knowledge base. Shells are expert systems designed in such a way that they can be used to hold a variety of knowledge bases.

Situation model

The situation model contains all the facts supplied by the user and the deductions arrived at by manipulation of the knowledge base. It is continuously updated during the course of the enquiry and represents the current situation.

Inference engine

Fig. 1 overleaf shows the components of an Expert System. The kernel of the system is the inference engine. This component contains the methods of plausible reasoning which can be applied to the knowledge base to give the appearance of intelligence.

In production systems the inference engine proceeds by examining the rules to see if any can be matched by the facts in the situation model. When a match is found, the deduction made possible by the rule is used to update the situation model. The cycle is repeated until a conclusion is reached. This processing of matching facts and updating from the rules is called forward chaining. An alternative approach is to postulate a solution and to check back through the rules to establish the facts that support such a solution. This method is known as backward chaining.

An important characteristic of an expert system is that its responses can be questioned by the user. It does this by chaining backwards or forwards explaining the rules and facts it has used in making its deductions. An experienced user may not agree with the knowledge base and should therefore be able to modify the rules and facts to reflect his view of the domain. This often happens where the postulates cannot be quoted with certainty but have to be qualified by a truth probability. Making deductions from such inexact information is achieved by using fuzzy logic, Bayesian logic and other probability methods.

Programming languages

Finally, after much exhortation, it is with some sense of achievement that we can claim that many more of our professions are now conversant with the traditional programming languages BASIC, FORTRAN, PASCAL and COBOL. The rest of the world also progresses and we must unfortunately acknowledge that these languages are unsuitable for the future generations of expert systems. The reason is that conventional languages are 'prescriptive', i.e. they have to be prepared in meticulous detail and with every conceivable operation anticipated and fully incorporated. The new techniques are better handled by 'descriptive' languages which can accept information about the domain as a series of self-contained statements and have the ability to deduce conclusions that vary with the nature of the enquiry or task.

The programming language chosen by the Japanese as the basis for their future development is called PROLOG (PROgramming LOgic or PROgramation LOGique for those who wish to acknowledge some of the original work carried out in Marseilles while trying to solve the sort of logical problems set by Lewis Carroll in his children's stories). A line of PROLOG defines something the computer should know rather than something it should do. Adding to a conventional program means carefully inserting new instructions and, also if necessary, modifying remote structures and variables to avoid upsetting its operation. There is no such penalty in enhancing the Knowledge Base in PROLOG, each piece of program has a validity of its own and is available without the need to define its use. PROLOG automatically arrives at conclusions based on the domain facts and rules it has been given even where these are incomplete. As more information is made available by the user, PROLOG can improve the quality and thoroughness of its conclusions. For the purists PROLOG is based on the Horn clause, subset of the clausal form of predicate calculus or first order classical logic. For the pragmatists a typical FORTRAN statement appears as 'A = B — C' where the difference between B and C is assigned to A. In contrast PROLOG has no assignment, GOTO or IF constructs and its typical form appears as 'concrete (no2 _ bay, poured)' which could mean the concrete has been poured in the second bay. Fig. 2 shows an example of micro-Prolog program.

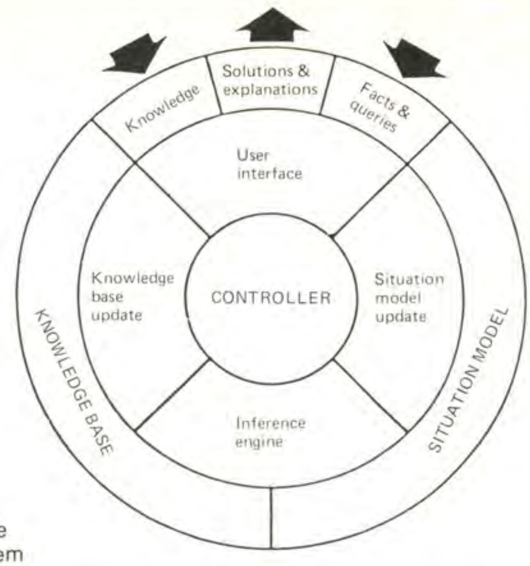

Fig.1
Basic architecture of an expert system

Program	**Description**
Place (Cardiff 274 51.4 -3.2) Place (Manchester 449 53.5 -2.2) Place (Liverpool 510 53.4 -3) Place (Ipswich 120 52.1 1.2) Place (Edinburgh 419 55.9 -3.2) Place (Glasgow 762 55.8 -4.3) Place (Newcastle 192 55.0 -1.6) Place (Chichester 24 50.8 -0.9) . .	Facts about places, e.g. Cardiff has a population of 274,000 latitude of 51.4 and longitude of 3.2 west.
Chichester has cathedral . .	Fact with only one parameter
x city if place (x zl yl xl) and 200 LESS zl x city if x has cathedral . .	Some rules about cities A place is a city if: —its population is over 200,000, or —it has a cathedral, or —etc.
x NW-of y if place (x zl yl xl) and place (y z2 y2 x2) and y2 LESS yl and xl LESS x2 . .	Rules about relative locations. x is North West of y if x has greater latitude and smaller longitude.
Cardiff job St-Davids-Centre Glasgow job Glasgow-Mosque Plymouth job Theatre-Royal . .	Facts about locations of Arup jobs
rating (Kylesku-bridge highly successful..)	Facts about rating of Arup jobs
	Examples of a Question to the Program
which (x y z : job (y x) and y NW-of Liverpool and rating (x failure z))	Which jobs North West of Liverpool were rated as failures.
Gorbals-High-Rise Glasgow Duff-computer-analysis. Contractors-drawings-from-superseded-disk	Possible (fictional) answer, giving: job, location and reason.
No (more) answers	

Fig.2
Examples of micro-Prolog program

Implications for the industry

This brief introduction to the subject was intended to provide enough background to allow us to induldge in some crystal ball gazing. The sceptics should note that there are expert systems already in use.

In the medical world one system[5] was tested against consultants when diagnosing meningitis. The computer was proved to be slightly better than the best consultants and twice as good as the students.

Another system[6] is used for predicting the location of mineral deposits from geological data and has claimed its first find.

In the field of structural engineering there is a system[7] that gives advice about how to use the MARC suite of analysis programs having been given a description of the structure.

Such systems are far from ideal but they are significant achievements. A recent survey of expert systems in all areas of education and industry[8] showed there was a dearth of development related to construction. Even a researcher who concentrated in this field found little to report[9]. With some persuasion from myself one of the first initiatives was taken by the Royal Institute of British Architects Conference Fund who sponsored a research project in 1980 to assess the impact and promote greater awareness of the subject[10]. This work was then carried on by the Construction Industry Computing Association who organized workshops of experts who attempted to set up knowledge bases in their various domains using the prototype shell system developed by John Lansdown for the Conference Fund. Further information is available from the Association's offices in Cambridge and they would also like to hear from anyone who is currently undertaking research or development of expert systems related to construction.

Clearly these systems will provide an alternative or additional source of advice to that provided by the expert. This must have an impact on the professions. The layperson is often suspicious of dealing with and paying for the services of experts especially when opinions differ from one to another. In medical applications it has been found that they prefer to deal with a machine which is impersonal and forgiving of their ignorance and uncertainties besides being infinitely patient. If this is true of medicine I suspect it will be even more so in our fields. So the structural engineer may feel his services are indispensable but this view will not be shared by the architect who has access to a computer that appears to answer all his questions. The Department of Architecture of Sydney University has developed a prototype system[11] that gives advice on the design of a slab. It will choose from different materials and size the elements. The structural engineer may argue with the logic and wisdom of the advice but he will need to be very persuasive to prevent the architects running their own computer program instead of trying to communicate with him.

Some local government officers spend their time dealing with planning and building regulation enquiries. Such information can conveniently be held in a knowledge base accessible to all. The smallest computers linked to a television set, could be used to run the local council's expert system with the situation model built up by the user being stored for subsequent monitoring and record purposes. In Australia, the code for siting buildings in the state of Victoria has been partially implemented as a prototype.

Organizations specializing in particular domains may acquire shell expert systems into which they build and update their collective expertise. Their systems could then be made publicly available at a fee. Geotechnical consultants and quantity surveyors are possible examples. As a consequence far fewer firms will be needed to cope with the industry's workload. A system that assists with the specification of site investigations is already under development at the Genie Civil and Urbanisme, INSA, Lyons. Steven Fenves at Carnegie-Mellon University, USA, is investigating how to set up a system that will allow groundwater flow problems to be solved by a wider, less skilled range of people.

Implications for the design office

The introduction illustrates the contribution that expert systems could make on site to the construction phase. Not only could they be applied during construction but in the early design stage advising on the construction problems of alternative designs. Rules of thumb could be learnt by the system and applied to expedite design, the advantage of this approach being that time spent on optimization and searching through permutations of possible alternatives is avoided. The crude solutions could then be analyzed in detail and refined by the system, checking against Codes of Practice and other criteria. Rules in the knowledge base will vary with local conditions reflecting that skills and materials in one zone may differ from those in another.

Design offices will have access to systems that will advise and evaluate designs producing sizes and costs at scheme design stage. The approximations will then be passed through a more rigorous process of analysis before producing final details. The expert systems will also advise on rationalization of the details to minimize the amount of documentation produced by the computer and easing construction difficulties. Any conversion to a foreign language or system of units could be an option on output together with automatic invoking of specifications and bills of quantities.

At least one expert system is currently being developed to assist with computer-aided draughting. Its purpose is to anticipate the actions of the user and call up the next modules of program automatically. This philosophy can be extended to reflect the idiosyncrasies of each person's approach to design and drawing. Having identified the individual from the signing on procedures his profile of characteristics is then coupled to the knowledge base to influence the decision-making process.

Growth of systems

The opinions of the experts differ but this is no obstacle to an expert system as it can allow its rules and assumptions to be modified by the user during the course of any enquiry session. A more important aspect is the continued improvement and expansion of the knowledge base that one would expect as succeeding generations add their experience. Initially a great deal of pump priming effort must go into creating the most modest of expert systems. Yet once there is something that holds out the promise of a useful response it will attract customers. The value of the system will then improve the more it is used, unlike conventional systems that progressively become outdated by new design methods. The enhancement process will fit conveniently into office procedures and pressures. It may involve no more than a few seconds extra time to key in a new rule or observation. The incentive is there for the user as he can expect to obtain the immediate benefit of an improved answer to his investigation. It requires positive additional action on his part to then remove his enhancement from the system.

Monitoring of the changes and enhancements are necessary. Output should be labelled with the version numbers of the knowledge base and situation model. At intervals the changes should be listed and a validation procedure invoked to ensure that the system still meets with general approval.

Further research and social implications

Notwithstanding the progress that is being made there is still much to be done. We are a long way from having programs that can comprehensively interpret natural language or generate it to explain situations as they evolve. We are even unable to reach agreement on the meanings of particular constructs. So the rate of change will not be revolutionary but it will happen. An OECD report estimates that 20,000 extra jobs will have to be found every day for the next five years throughout the developed world if we are to reduce unemployment to the levels of 1979. With such statistics how strange it is we direct so many resources into replacing human endeavour by machinery.

There is no shortage of personnel in the UK construction industry. There is a finite workload that is unaffected by the size of rewards paid to the professions. We may compete with one another reducing fees to the point where quality of design may be less than optimum but it will not generate more work for the industry. In order to be competitive and win our share we improve efficiency which means less time spent on our tasks, therefore fewer staff are needed.

We have seen an expansion in the professions over the last century. I suggest we have now reached the turning point in our industry and our numbers will now diminish not by 5 or 10% but by significantly more. Expert systems and their derivatives will ultimately provide better design and management services with little demand on our time. Expert systems with robots as peripherals will make an equal impact on the construction side of our industry.

The future

This may sound a gloomy forecast, but the future need not be bleak if we face up to the challenge. The greatest disservice we could do ourselves would be to ignore or deride the subject. An industry that stagnates provides the stable environment in which computer applications thrive.

The real savings to society will come from improved construction techniques, less maintenance and better materials, not by reductions in design fees. We have to educate our clients to reward us adequately for our use of new technology where it contributes to improved quality or cost benefits.

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Anugraha, Dell Park Conference Centre

Architect: Lambert Gibbs Associates

Michael Courtney

Job team:
Alan Frampton / Steve Fisher / Bob Collett

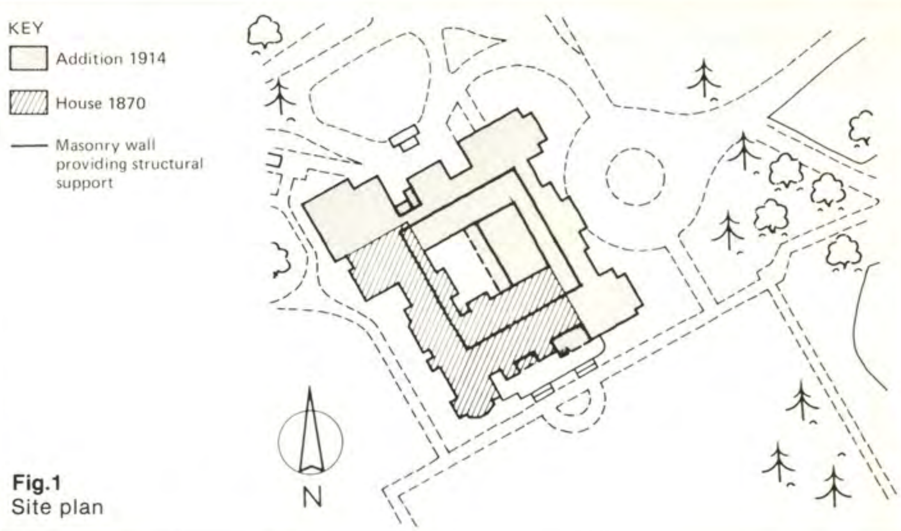


Fig.1
Site plan

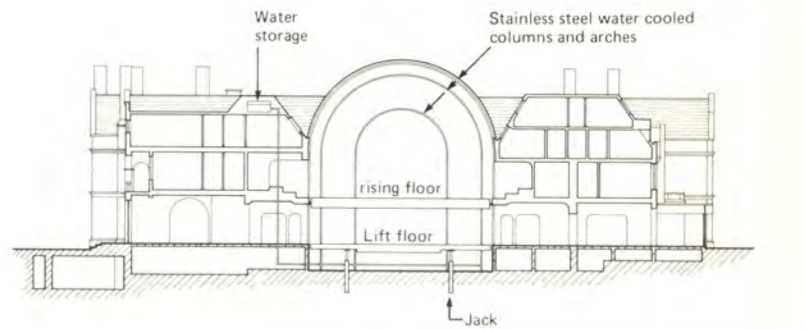


Fig.2
Section

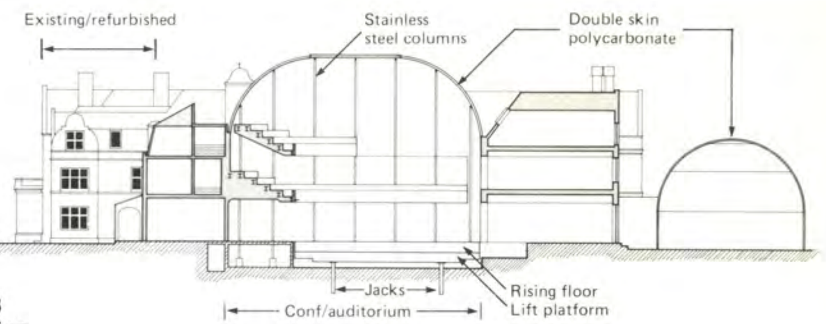


Fig.3
Section

Introduction
In May 1981 Amanco Ltd. approached us to assist them in the conversion of an old house at Dell Park, Englefield Green, to an international conference centre with residential facilities. The Subud (an Eastern philosophical organization) had decided to hold a world congress in Britain in August 1983. To achieve this they determined to create their own congress centre as a normal commercial venture, but capable of holding their congress, and had formed Amanco to carry out this task.

Hanafi Fraval was appointed project manager and Lambert Gibbs architect, with a brief to create an architectural practice for the project.

The brief
The client management prepared a very detailed document defining its needs: 110 bedrooms, a versatile auditorium capable of seating 600 normally but extendable to 1000 for concerts and to 2000 for the occasional congress, a restaurant, a coffee bar, bar and lounge, extensive hotel and catering support facilities, recreational facilities and a car park.

The quality of the facilities was also carefully detailed. The bedrooms were to be small but highly finished, all with toilet and bath or shower facility. The auditorium was to have the latest projection and screen equipment, simultaneous translation facilities, facilities for each delegate to be contacted from reception and to be able to reply, sound projection and good acoustic properties. The roof was to be transluscent but to exclude the aircraft noise generated from the overhead Heathrow flight path.

Figs.4a-b
4a: Second floor plan
4b: First floor plan

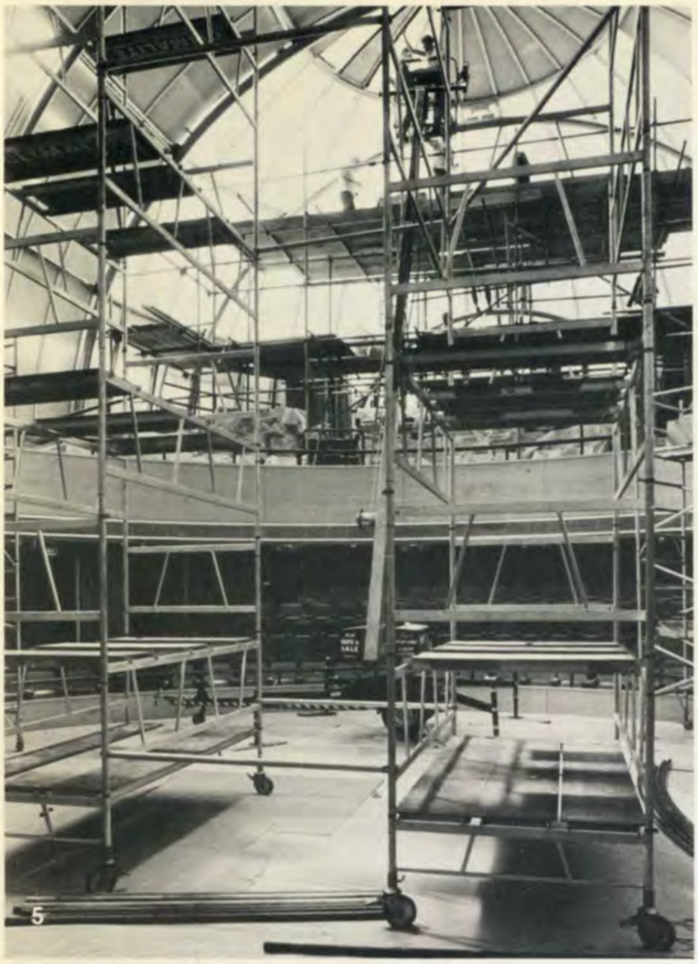


Fig.5
Completing the inside of the Great Hall dome. The rising floor is in the 'up' position; dark areas on the roof show where the blackout system of liquid-filled panels has been installed. The liquid turns opaque on the application of heat, either electrical or natural.

Fig.6
Roller guides for rising floor on stainless steel column.

Fig.7
Underside of all-welded steel grillages for second floor balcony (timber floor on angles visible above).

Fig.8
The central area dome.

Fig.9
View across centre courtyard to steel frame of south wing during construction.

Fig.10
View across centre courtyard to north-east corner during demolition.

Fig.11
Main hall during construction. Stainless steel column and arch being lifted in to support universal beam and perimeter channel at bottom left.

Fig.12
Decorative corner of original building.

(Photos: the job team and Harry Sowden)

Fig.13
Access from indoor garden to main hall; the arches and columns were brought from elsewhere in the old building.

The auditorium had to be capable of being sub-divided into smaller conference rooms by both horizontal and vertical partitions. The hotel management facilities were planned to take advantage of modern electronic engineering with point of sale debiting of accounts, direct communications with all rooms and central control of environments, room and staff allocation and electronic locking to all bedrooms.

The entrance foyers were to be large welcoming spaces with high quality finishes, compatible with the existing building.

The extensive drives and roads in the grounds were to be tastefully lit and the car park was to be secluded within the trees.

The existing house

The existing house had belonged to the Schroder family. Part of it had been constructed in 1870 and part in 1913 so that it now took the form of wings around a small central courtyard.

The building was generally three storeys above ground consisting of large rooms such as halls, living rooms, ballrooms and kitchens at ground floor level, large family bedrooms at first floor and servants' small rooms under the roof at second floor.

The structure of the house was essentially three concentric rings of load-bearing masonry walls: the façade to courtyard, one internal corridor wall and the external façade with timber floors spanning between.

The timber floors had concrete pugging in fill at first floor as an acoustic treatment. At places where the floor spans exceeded the capacity of the standard floor joists, steel beams had been inserted. The lath and plaster ceilings were supported by separate timber joists spanning independent of the floor joists.

A full structural survey and some testing was undertaken to establish the position and size of structural members and the quality of materials. In carrying out this some errors in the original dimensional survey were discovered.

The timber proved to be of very good quality except where it had been damaged by weather penetration. The brickwork proved to be high strength bricks laid in sand lime mortar.

The roof structures were very interesting. They were apparently conceived as conventional rafter/purlins/ridge board structures with three lines of vertical support. The insertion of flat areas of roof, the removal of some of the purlin struts, during the installation of water storage tanks when the house was used as a hospital during the war, and the varying shape and position of the roof created numerous areas where unbalanced forces exist. These forces have to travel quite long distances through the roof structure before being supported. The roof boarding however, stiffens the structure and dissipates the forces, and nailed joints act as moment connections. The roof formed an intricate, delicate arched compression structure.

There was an existing brick built basement under part of the house.

Geology and site conditions

The ground consists of approximately 1m of topsoil and fill on dense silty sand: the Bagshot Beds; approximately 10m thick, over London clay. The ground water table is close to the top of the Bagshot Bed stratum and the area has an abundance of water.

The silty sands of the Bagshot Beds provide very good foundation support so the site investigation was restricted to trial pits to prove the level of the silty sand, the level of the ground water table and details of existing foundations.

The scheme

The form of the existing house strongly influenced the planning of the renovation. It was logical to place the auditorium in the central courtyard with a new roof above: making a single, large three-storey volume.

The existing rooms on the first and second floors of the surrounding wings could be subdivided to make the required bedrooms. The public areas, foyer, circulation, restaurant and kitchens conveniently occupied the ground floor with staff rest room, lockers and storage in the basement.

Plant would be located in a small, new external plantroom, in the existing basement plantroom, on the roof, in the roof spaces and anywhere else available.

A large car park was to be situated in the grounds secluded in the trees and the greenhouses and stables were to be converted into games rooms, tennis courts, laundry and storage.

Structural engineering advice

After an initial study of structural implications we recommended that to make the auditorium, the courtyard structure, including existing house walls and floors, be demolished to the edge of the existing internal masonry support wall, temporarily propping the existing roof, but that the surrounding areas should be replanned in detail to avoid any but minor alterations to the vertical structure or to the roof. This would minimize costs, time and construction problems. We advised that there would be severe water and waterproofing problems if any changes were made to the existing basement.

We advised that the best contractual method to achieve completion in time and to a realistic budget would be to appoint a management contractor, in order to be able to design and construct concurrently. We also advised that the budget, which had already been increased from £2.5m. to £4.0m.would need to be substantially increased even though the laundry and games facilities had been deleted from the brief.

All these recommendations, apart from the budget advice, were agreed and accepted. The advice regarding appointing a management contractor was followed. The advice

Fig.14
Completed building from the south.

regarding an increased budget has, perforce, been followed. None of the other advice regarding replanning to contain time, costs and problems has been followed. This has led to an interesting, exciting and at times somewhat fraught life.

Management contract

Completion of the project in time for the congress in August 1983 was defined as the critical objective. The only way to achieve this was to design and construct concurrently. With the design team designated it was agreed that the only way to achieve controlled, co-ordinated and programmed design and construction was by using the services of a good management contractor. The services to be provided by the management contractor were identified as: advice during the programming of and the monitoring of progress of design with particular emphasis on the inter-relationship of different aspects and disciplines in design and on the construction aspects, advice on costings and budgets, definition and control of the interfaces between all the different construction packages, control of quality of work on site, programming of work on site, co-ordination, especially dimensional, of the work on site.

Submissions were invited in June 1981 from a short list of management contractors each of whom was furnished with the architect's planning drawings, a copy of the client's brief and a statement of ideas of the possible services and structural installations. Evidence of previous successful work, a method statement for both work and organization, a statement of staffing levels and a preliminary programme, were requested together with the names of key personnel and a fee offer based on the JCT prime cost percentage fee form of contract suitably amended.

Three of the contractors were subsequently interviewed, to meet their site teams and to put specific questions regarding work organization and responsibilities. The questions and answers formed part of the eventual contractual description of the management contractor's scope of work. Laing Management Contracting, although not submitting the lowest fee offer, demonstrated their understanding of the problems, their ability and intention to deal with them and the quality of their technical personnel, and were awarded the contract.

To achieve the most rapid start on site possible, the strategy was formulated that contracts would be rendered on small parts of the work when designed and subsequent similar work packages would be negotiated with the successful tenderer. This strategy has worked very successfully in terms of design and construction but the proliferation of small contracts, for example there were four general construction contracts and three structural steelwork contracts, has created problems and more work for the quantity surveyors.

The building

The building is now very nearly complete. It has overrun the intended programme by 50% and budget by 200%, probably because the original estimates were unrealistically low for the client's stated needs; the architects wanted a centre worthy of the Subud and the project managers wanted the latest technical and electrical control services.

The auditorium roof is a cylindrical dome, clad in two skins of polycarbonate, supported by water-cooled stainless steel tubular column arches. The galleries are crescent-shaped, supported on one edge only by the stainless steel columns and constructed from fully welded steel grillages. The subdivision of the auditorium is achieved by a steel floor lifted by screw jacks into position at first floor level and locked into place by hydraulically operated pins. The existing roof is supported by 21m long, 914mm deep universal beams. This structure and the solution of its problems was presented on paper to the Partnership Innovation Seminar.

To accommodate the planned openings at ground floor between the auditorium and the surrounding corridors and rooms, to provide the large support free spaces in the restaurant, kitchen and foyer, and to provide space between the projection room and the auditorium, it was eventually necessary to replace the existing internal masonry support wall by steel frames in all wings. To achieve the last 10 bedrooms the South Wing was in fact demolished and replaced by a steel frame structure with the original brick and stonework facade reinstated.

A new basement was inserted beneath the auditorium extending beneath the existing West Wing and linking with the existing basement.

Staircases were moved and new stairs inserted. The capacity of the existing timber floors were proved for the revised loadings including acoustically insulating partitions.

The roofs were strengthened and stiffened by additional members. Masonry remaining after alterations was proven for any additional loads placed upon it.

Fig.15
Completed hall with the floor down, set out for a banquet.

Conclusions

The illustrations show the house as it was and as it is now. The very exciting and unusual concepts and intentions have been realized to a most unusual extent.

While management contracting did not prove to be the miracle to achieve somewhat extravagant ideas, due to lack of money, lack of design information and lack of time, a great deal was achieved.

In a recent programme the BBC series 'Tomorrow's World', featured some of the sophisticated techniques which are being commissioned in the auditorum. This is the second time in 10 years that some part of one of our structural projects has been featured in this programme.

Credits

Client:
Amanco Ltd. (now known as Anugraha Ltd.)

Architect:
Lambert Gibbs Associates

Contractor:
Laing Management Contracting Ltd.

Service engineers:
Max Fordham & Partners

Quantity surveyor:
Colin Packington & Partners

Structural Steel Design Awards 1984

In the 1984 Awards, sponsored by British Steel Corporation and the British Constructional Steelwork Association, and administered by Constrado, awards were received by the Liverpool International Garden Festival Exhibition Building, and the Renault Centre, Swindon, Wiltshire.

Extracts from the descriptions and the Judges' comments are given here.

The Liverpool International Garden Festival Exhibition Building

For The Merseyside Development Corporation

'The building was the centrepiece of the Liverpool Garden Festival, the first of its kind to be held in the United Kingdom. The Festival was conceived as the focal point for urgently needed urban rejuvenation of this once great city. From this principal idea stemmed the brief for the building which was required to perform two distinct and separate functions. These were firstly to form a $7500m^2$ covered but column-free exhibition hall and secondly to provide the shell within which on completion of the exhibition a sports centre could be erected. The shape adopted is that of a 90° dome halved and joined with a linear barrel vault. This gives the space requirements with the structural efficiency of the curvilinear form resulting in minimum material content and favourable ratio between external surface area and plan area.

The structural frame is made up from two primary elements.

(1) A two-layer barrel vault structure of 60m span and 78m long, comprising braced arched frames of three-pin configuration at 3m centres. The upper and lower booms are connected by longitudinal members. The lower longitudinal member connects through to the domes providing the path for the axial forces, and also supports services and acoustic panels in selected areas. The upper longitudinal member acts as a purlin for the polycarbonate sheet cladding. The intermediate arch frames are connected by braced frames which, with the on grid frame, transfer their reactions to bipod frames at 6m centres.

(2) Half domes of span 62m at each end of the vault. These are of segmental ribbed single layer construction with circumferential rings at 3m centres connected through via the longitudinal lower vault members.'

Judges' comments

'A simple and elegant building making straightforward use of structural steel with careful modelling of connections to provide a light, airy festival hall and subsequently a major leisure centre at reasonable cost and within a short time scale facilitated by extensive offsite fabrication.'

Designers:
Arup Associates
Steelwork contractors:
Tubeworkers Ltd.

The Renault Centre, Swindon, Wiltshire

For Renault (UK) Ltd.

'The design concept attempts to integrate a response to both the site and the brief by using a "module" which can fill out the site irregularities with the potential for random growth over time. The development of a masted structure with a lightweight suspended roof—akin to a vast three dimensional umbrella—offered large spans in two directions with economy of means. Visually the bulk and skyline could then be broken down in scale as a considered alternative to the anonymous bulky enclosures which dominate so many industrial estates across the nation.

The first stage provides a total area of 24,250m^2 with an expansion potential of 67% allowing for a further area of 16,350m^2. The suspension structure provides connection points for direct attachment of future "modules" without disruptive influences on those already existing. The building terminates in a "prow" containing the showroom and an open entrance canopy.

The structural "module" comprises arched steel beams which are supported from the top of prestressed circular rolled hollow steel masts, at quarter points. The mast system prestressing tension rods link the beams 1m out from the column centre-line to top and bottom fixings.

The remainder of the structure consists of arched beams on the diagonals of the column grid, likewise supported from the masts, on which rest steel purlins at 4m centres. In essence the structural system is an unbraced continuous portal frame. Loading on one bay affects the behaviour of adjacent bays and the beam elements play a role in spanning not only between the prestress ties but also between the masts themselves.

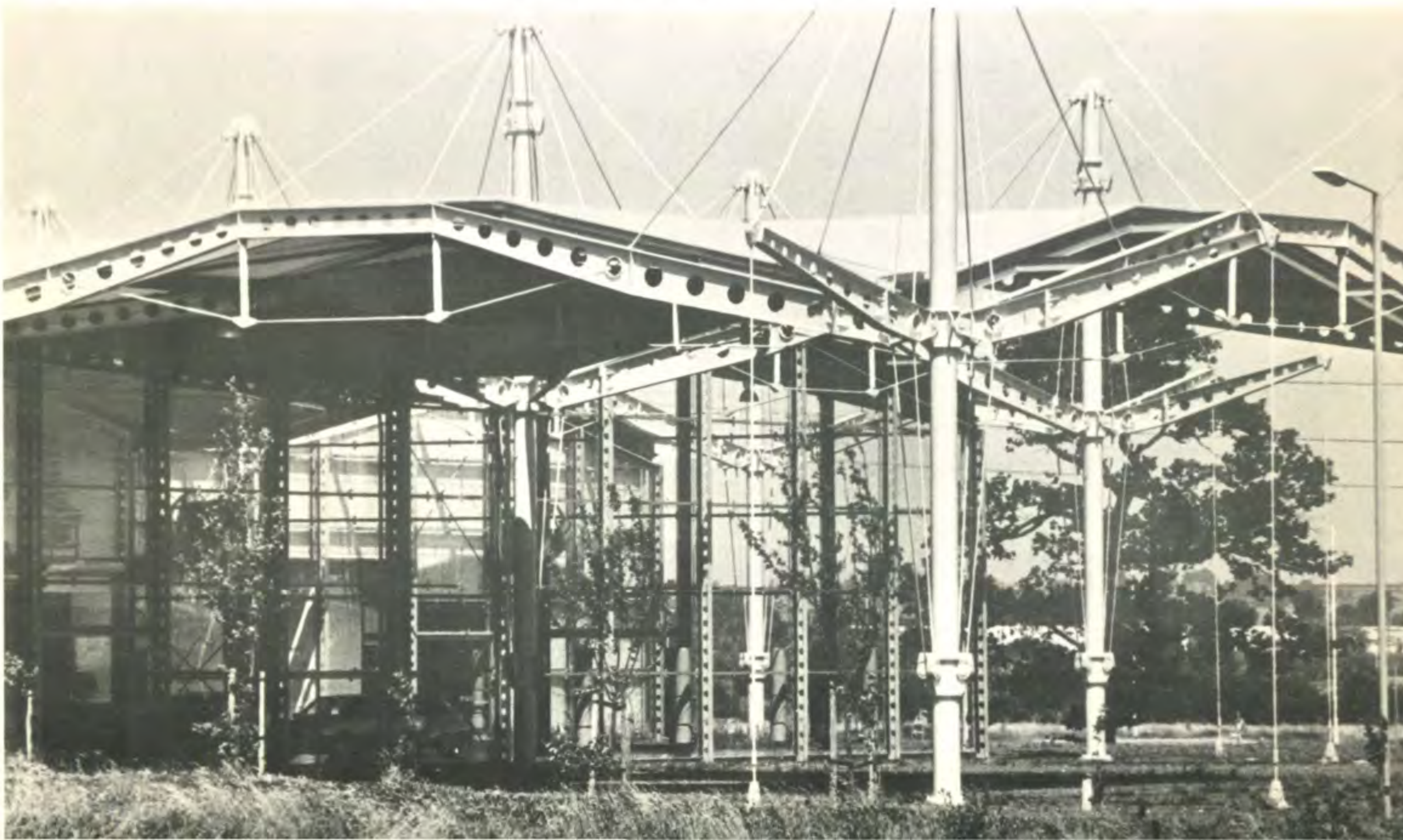
The external wall panels are a low cost system, developed for the project, in which expanded polyurethane foam filling between two outer skins of steel acts structurally to permit a 4m horizontal span, as well as providing very high insulation performance. Glazing to the wall and rooflights is a newly developed assembly system of 10mm thick flat bed armourplated glass suspended on bolts countersunk into the thickness of the glass.

Steelwork erection commenced in January 1982, the warehouse being operational by December 1982 and the whole Centre completed in May 1983 at a cost of approximately £8.5m.'

Judges' comments

'A joyful and elegant solution for a warehouse facility where the well detailed use of an exposed structural steel frame generates the architectural concept.'

Architects:
Foster Associates
Structural engineers:
Ove Arup & Partners
Steelwork contractors:
Tubeworkers Ltd.



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