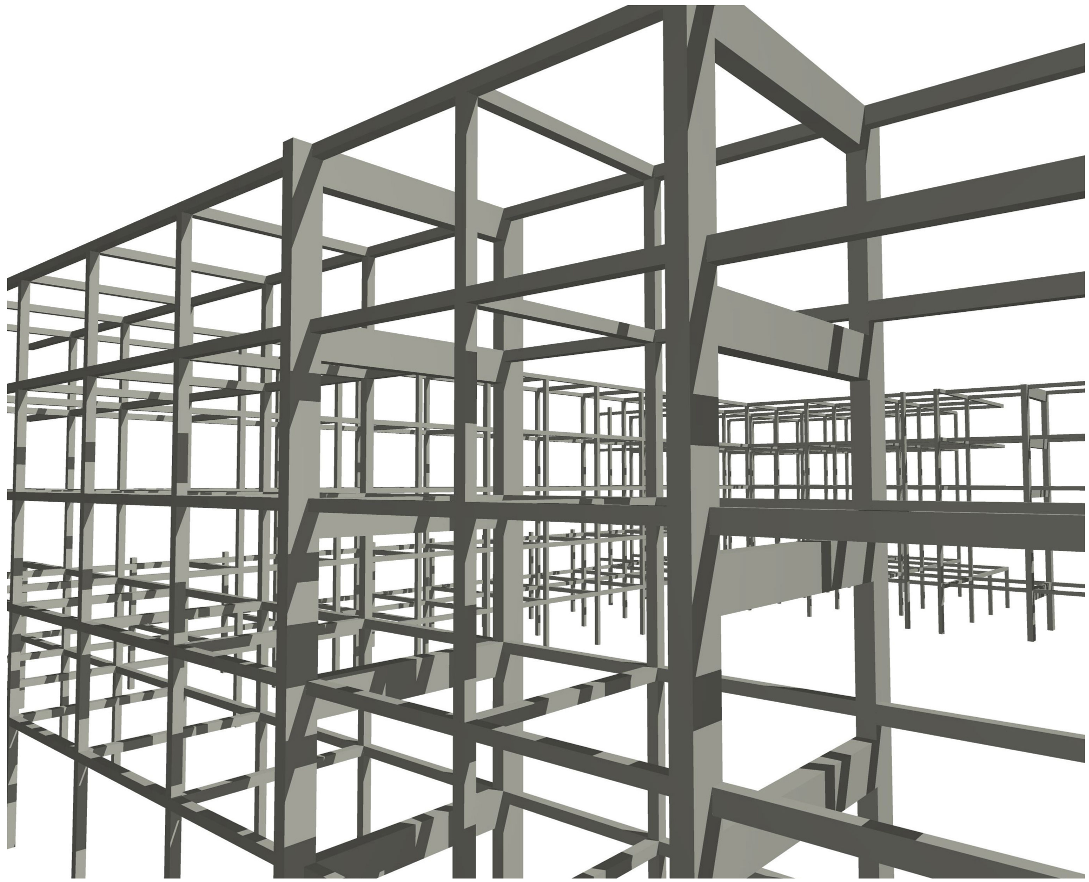
Technical evolution:

This chapter explores the use of concrete, steel and other materials pertaining to the main super-structure, the steel bridge structure (studio space) including a steel frame for the hydraulic lift shaft, and the eastern circulation wing with its ‘clip-on’ steel structure exhibition pods. In addition, the general performance of the building is briefly explained.

Main Structure:

The building comprises of two main structural systems, namely, reinforced concrete column and beam structure with concrete floors (main super-structure), and a steel structural system. The investigation concentrates on these two systems and explores the versatility of ‘clip-on’ steel structures versus the rather static concrete skeleton-like super-structure. To understand that these two systems can merge to create space relates to the dualism in design between design and production. One forms the basis for a product and the other creates the object.

Fig 1. Concrete super-structure



The ***concrete super-structure*** is laid out on a plan grid layout of 6X6 metres (Figure 1). This layout is based on parking bay spaces in the basement level below ground in conjunction with an optimum span for concrete floor spans. A six metre span eliminates the need for heavy reinforcement within the floor slabs and allows cast-in-situ concrete floors a minimal thickness of 170mm with the aid of pre-tensioning.

The ***floor system*** used throughout the building varies from cast-in-situ floor slabs to Bondek designed spans and hollow block floor slabs.

In the south and west wings of the building cast-in-situ slabs and beams are used because of the requirement for stiff floors and reduction of structural vibration that may arise from footsteps and activities on the above floor slabs, furthermore, these floors offer bracing to prevent any lateral movement within the structure.

Using Bondek flooring in the eastern circulation wing allows the use of permanent shuttering and a thinner slab for the upper level. Vibration, caused by footsteps and activities above, within this floor is greater but allowable in such a space. The expositionsed underside of the permanent shuttering gives an industrial finish to the space

The last floor type is a hollow-block system used in the bridge structure. Purely to decrease weight, this system was chosen to fulfil the requirement for use inside a suspended steel bridge structure.

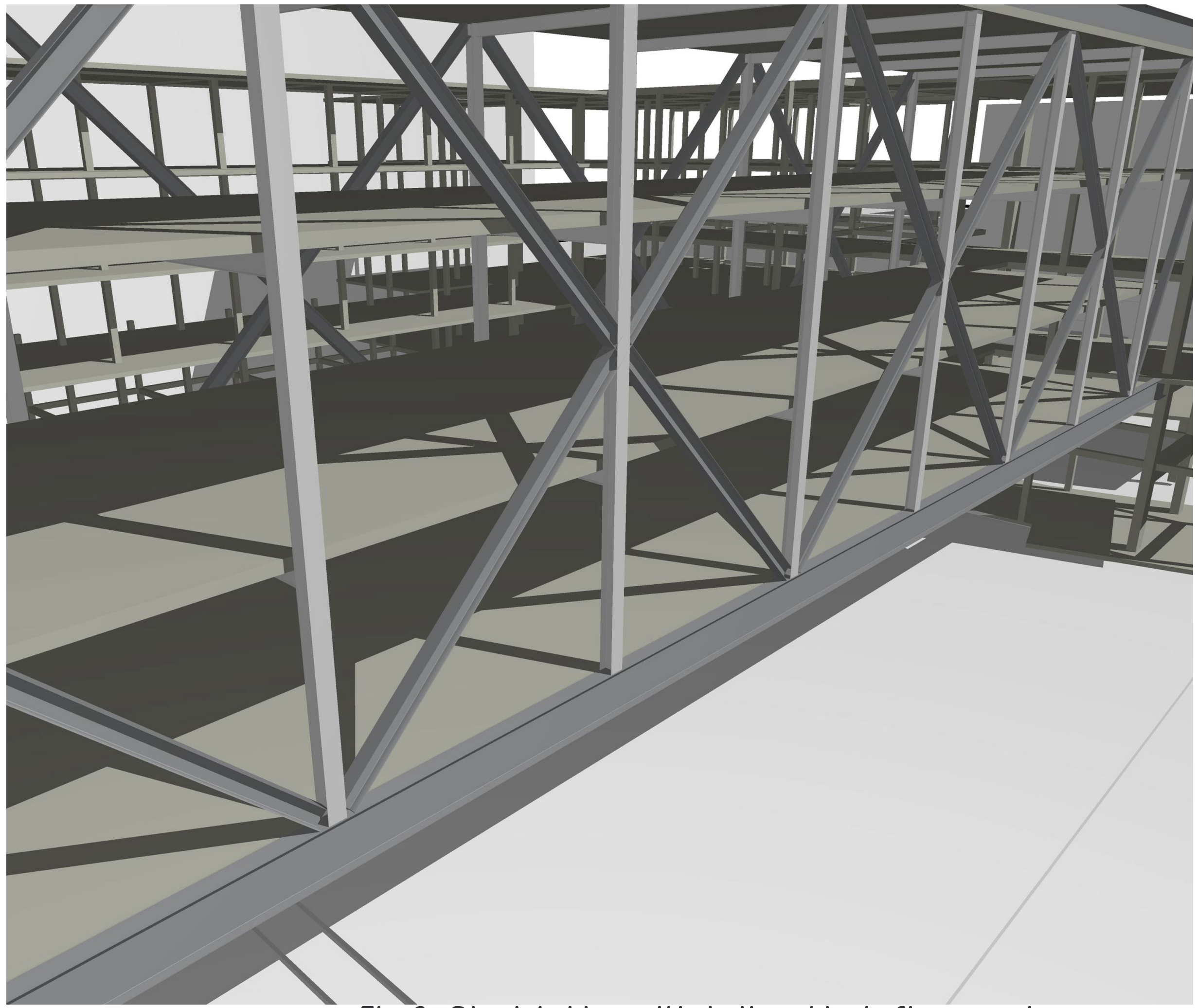
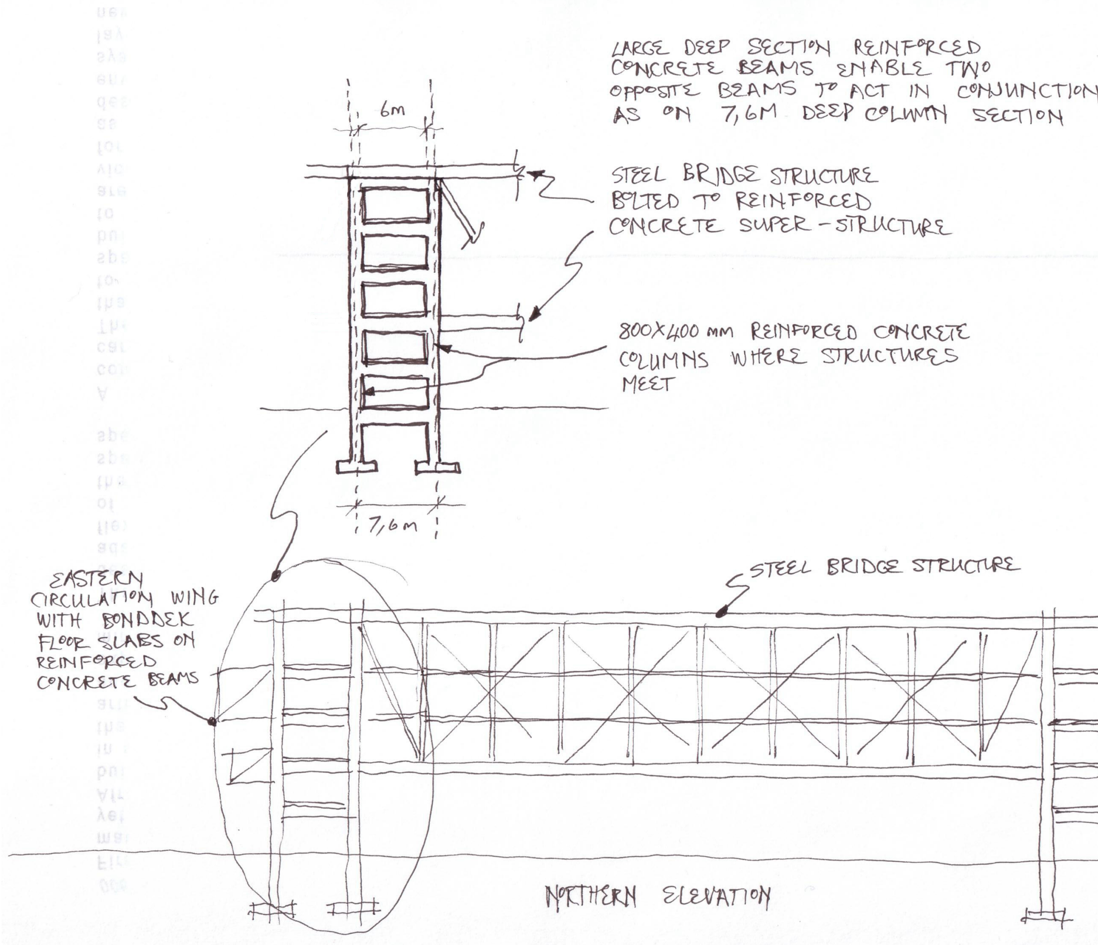


Fig 2. Steel bridge with hollow block floor system

Figure 1 shows the ***reinforced concrete frame***, consisting of 350X350 columns throughout the building. These columns are too slender to take the loads from the steel bridge connection. For this reason, the eight concerned columns that carry the direct loads from the bridge are increased in size to 800X400mm. This principle is illustrated with Figure 2 where the effective depth of the columns on opposite sides of the bridge structure is increased in section. In addition, the columns are joined with deeper section reinforced concrete beams; this changes the effective depth of each end support from 400X800mm individual columns to 400mmX7.6m composite columns, refer to sketch details in Figure 3 and 3D presentation in Figure 4.

Fig 3. Sketch of effective column design for carrying steel bridge



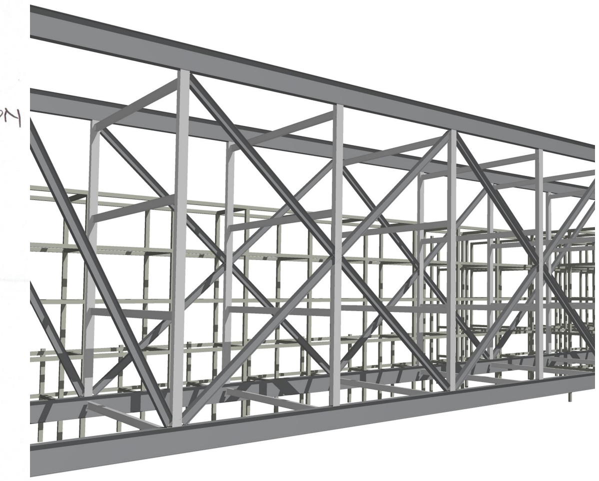


Fig 4. 3D of steel bridge structure

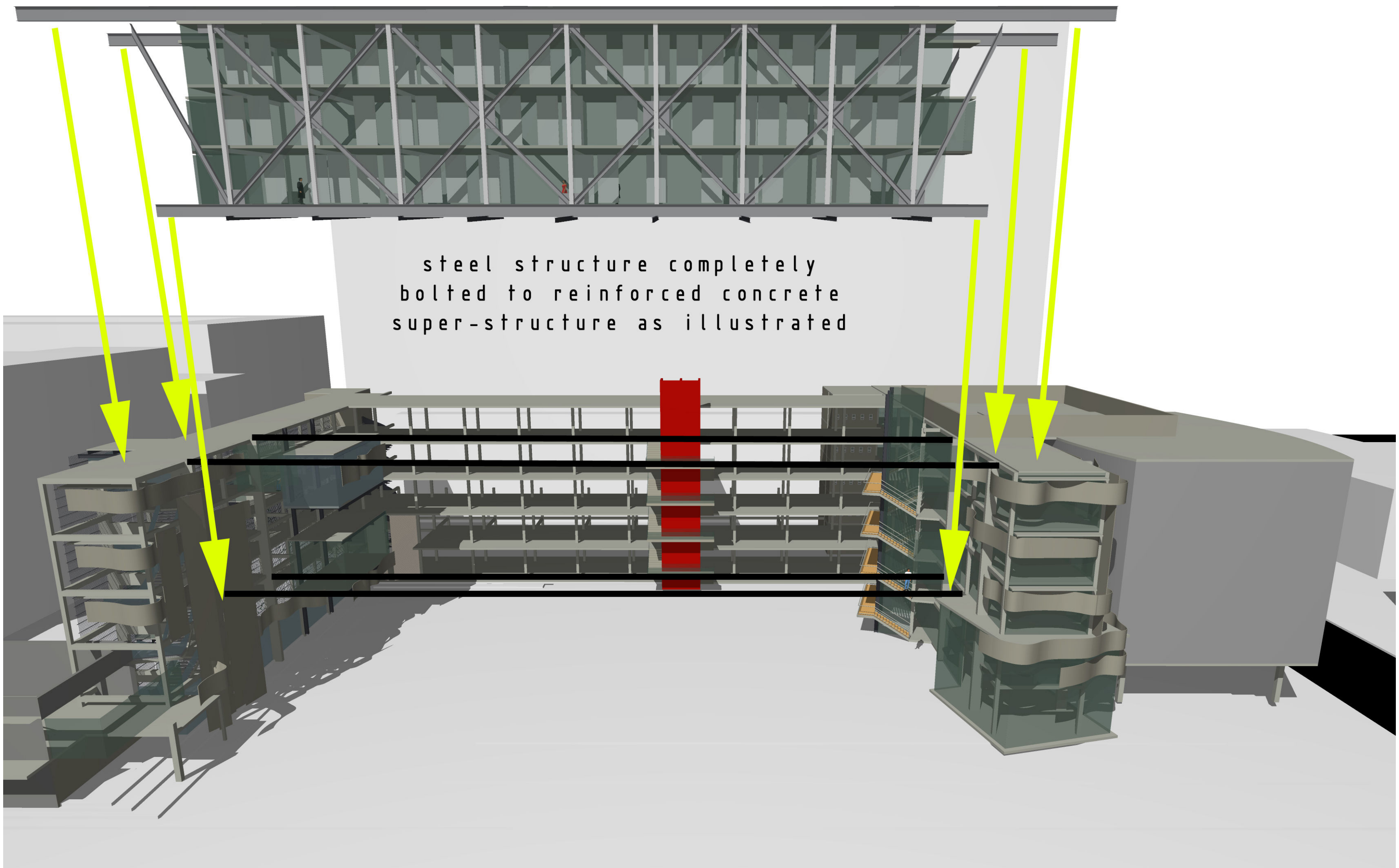


Fig 5. Placement of bridge onto concrete super-structure

The ***steel bridge structure*** consists of two primary overhead GR. 300W 305X914X201 Welded I-sections and two lower secondary GR. 300W 305X914X201 Welded I-sections (refer to Figure 2). Connecting these two sets of beams are vertical GR.300W 305X305X137 I-section members. Cross-bracing is provided with back-to-back GR.300W 381X102X55 channel sections bolted in double shear to pre-manufactured gusset plates. To support the hollow block concrete floors are GR.300W 406X178X61 I-section beams fixed to the vertical steel columns.

Exhibition pod structure:

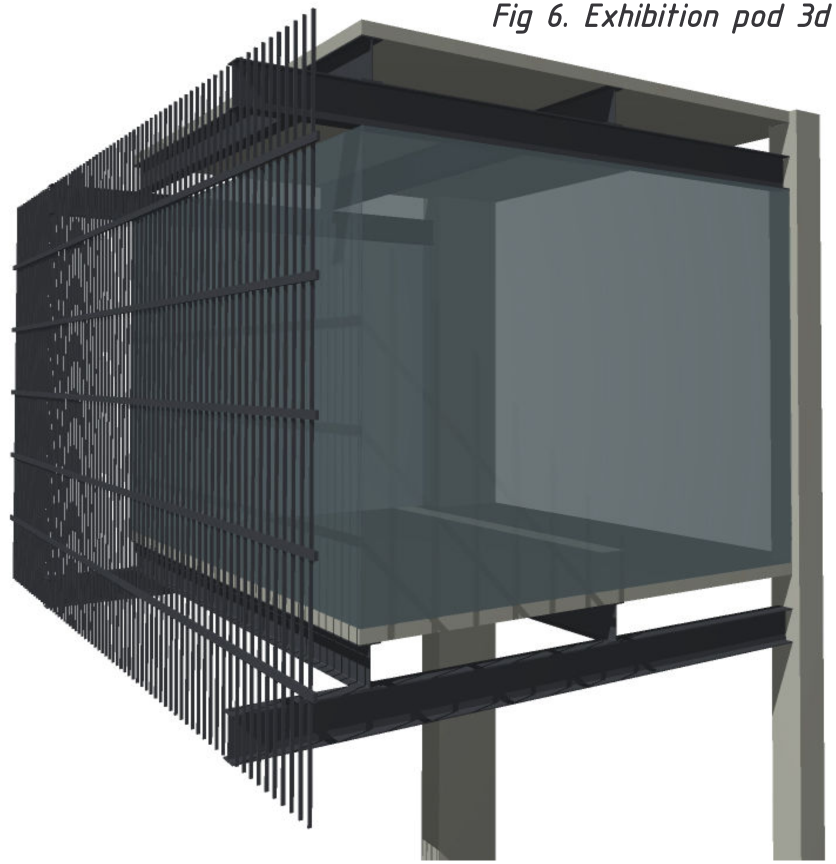
As part of the idea of creating spaces that have an industrial feel and presence, the design of the exhibition pods is an important link to the theory. The pods are designed as 'clip-on' steel structures that create pockets of space along the interior of the eastern circulation wing.

Referring to Figure 6 and 7, these spaces form part of the exhibition spaces of the building and deliberately intend to provoke inquisitiveness amongst users.

Each pod consists of 260x90x38 mild steel channel sections bolted to the concrete structure. These channels are connected to similar steel channels beams as support for Bonddek floors. 200x75x20x2.5 cold-formed steel lipped channels are used as purlins for roof sheeting that covers each pod. All steel used is of GR.300W and treated for corrosion.

Each pod needs protection from direct eastern sunlight and a steel frame and ***louvre screen system*** is employed to fulfil this task. Transverse channel sections that are bolted to the concrete structure extend 400mm past the edge of the concrete floor. These channels sections are provided with mild steel 5mm end plates to which the steel louvre and frame system are bolted.

Fig 6. Exhibition pod 3d structure



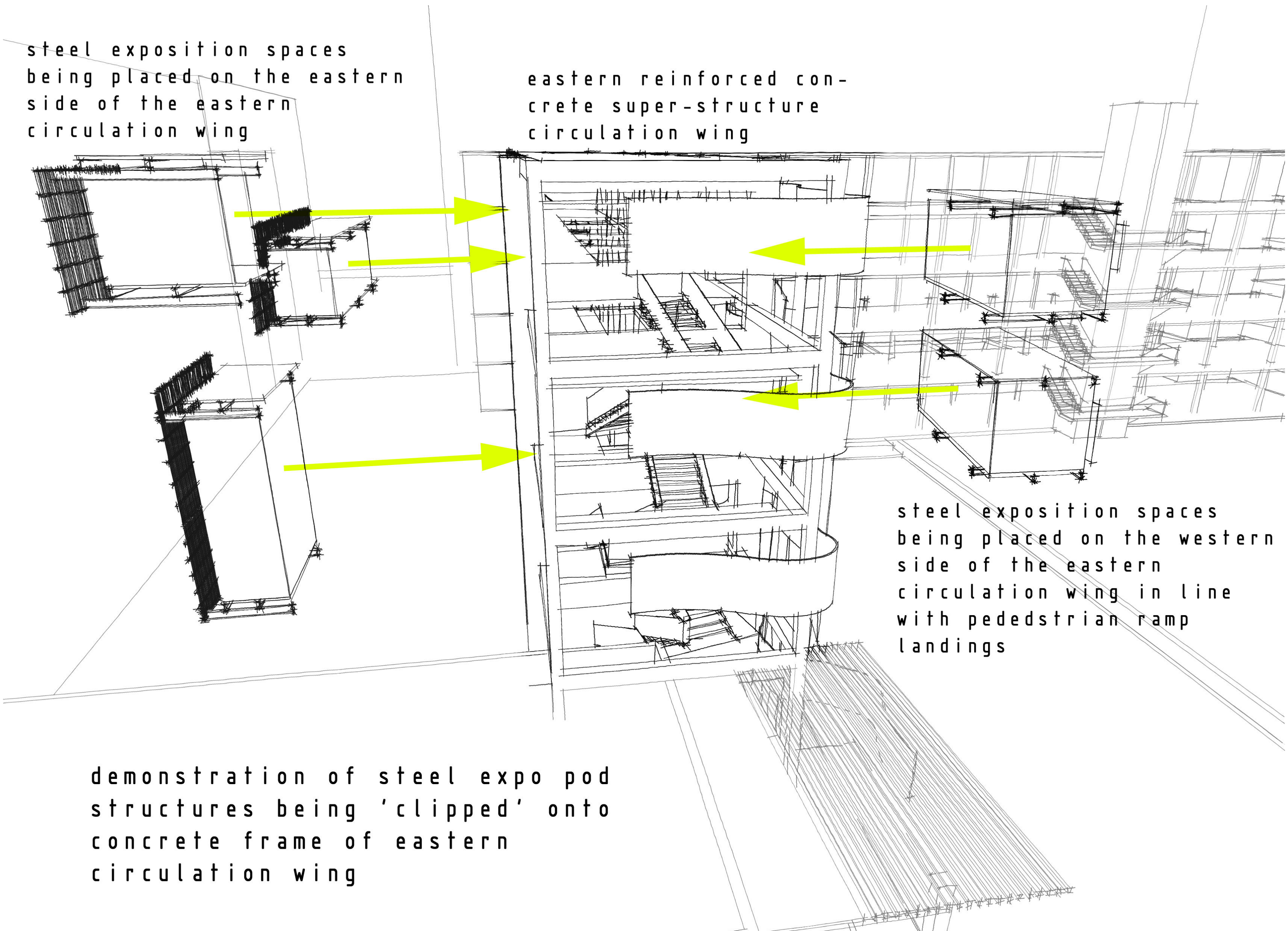


Fig 7. Exposition pods and eastern circulation wing composition

To keep the elements out, each pod is protected with a skin of 6mm ***polycarbonate sheeting***, being used instead of glass panes to reduce weight. This skin is used as a translucent sheeting rather than a glass curtain wall thus eliminating direct glare and diffusing the light into the space. Advantages for using polycarbonate screens are less expensive and lightweight when compared to glass; also, polycarbonate sheeting does not radiate absorbed heat like glass panes of the same section.

The principle of '***clip-on-spaces***' becomes important for the appearance and relevance of these pods as exhibition spaces. Adaptation and flexibility is associated with these spaces because these structures can be demounted or added to the building as required therefore making the building more adaptable for functional spaces. Variations of these pods are designed and therefore the pods offer flexibility of space.

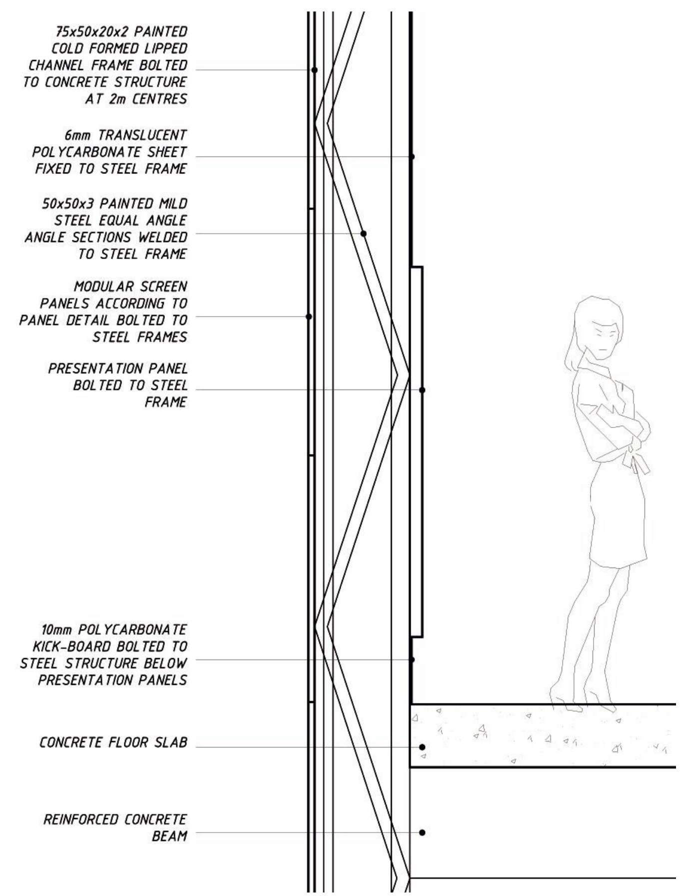
Eastern circulation space:

Referring to Figure 7 and the exposition pods, the eastern circulation wing consists of several key components. Firstly, the most important function is circulation, there is a staircase moving from ground level to fourth floor as well as a ramp at a gradient of 1:12 going up the same levels. There are exhibition pods that extend the wing into an exhibition space for the centre. The wing creates support for the steel bridge structure that becomes studio space for the centre (explained in Figure 3 under reinforced concrete frame).

To make the space available for exhibitions meant that pin-up panels were required. Parts of the eastern side of the wing are provided with pin-up panels as walls but not the entire wall. The eastern side of the wing has horizontal floor slabs and the skin is intended to be transparent in order to respect the neighbouring building façade. This constraint led to the design of a 100X100mm mesh steel-screen system that provides a vertical support for a creeper plant.

This screen is fixed to the main structure with a lightweight steel frame that is bolted to the concrete super-structure, refer to Figure 8. An evergreen Flowering-ivy (Sencio macroglossus) creeper was introduced to eliminate as much direct eastern sunlight along with the screen itself.

Fig 8. Detail of steel creeper screen fixed to lightweight steel frame and bolted to concrete structure on the eastern wing



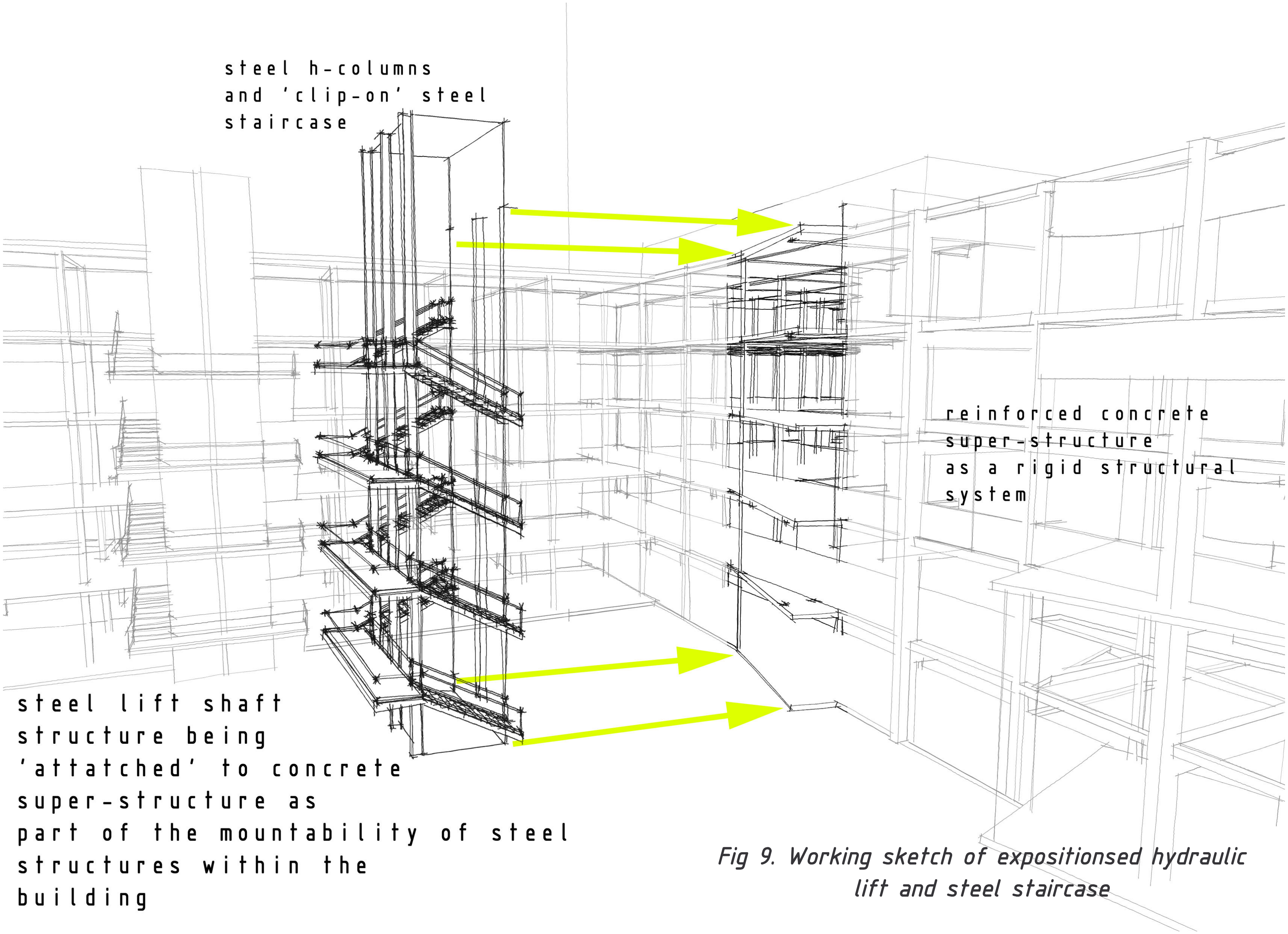


Fig 9. Working sketch of expositionsed hydraulic lift and steel staircase

Hydraulic lift shaft:

Accompanying the 'clip-on' steel exposition structures is the hydraulic lift shaft. Not as adaptable and flexible as the exhibition pods, this shaft is put together much the same as the exposition pods (Figure 7).

Pre-manufactured steel beams, columns and braces form the basic structure responsible for all forces exerted by the twin lift system and the staircase attached to the shaft. The shaft is designed as a separate structure that can be bolted onto the main concrete structure to provide vertical circulation.

Attached to the shaft structure are expositionsed twin hydraulic lifts with clear-glass panels, an expositionsed steel staircase wrapping the structure, and the expositionsed supply and return ducting from the on-roof air-conditioner plant.

To enhance the industrial feeling of the building, this shaft is designed as a service duct bearing expositionsed ducting as explained and being a raw steel structure with rather elementary steel details.

Studio interior spaces:

One of the most important designs within the centre was the design studios. These spaces need maximum natural lighting during the day and good ventilation in order to promote positive working conditions for design students.

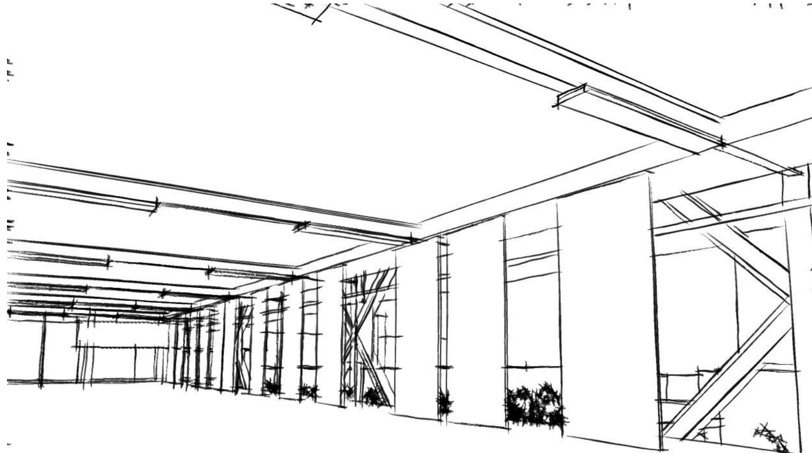


Fig 10. Sketch of interior towards northerns facade

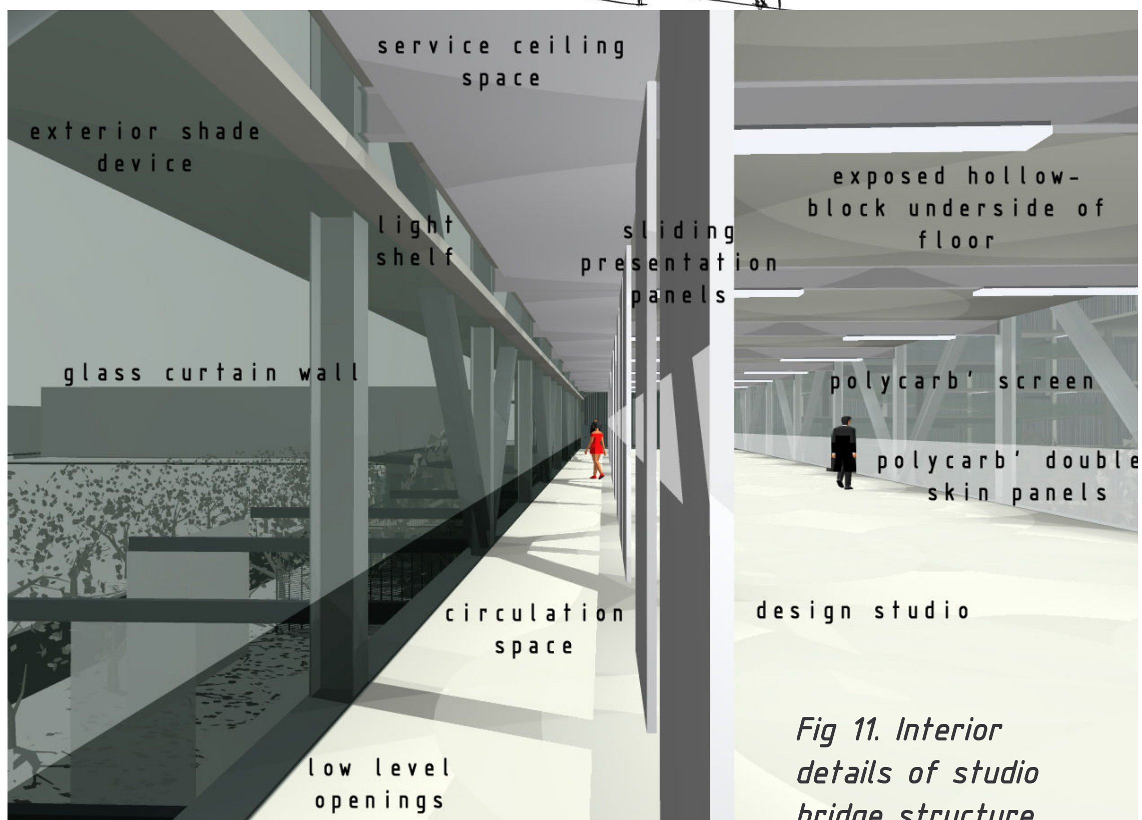


Fig 11. Interior details of studio bridge structure

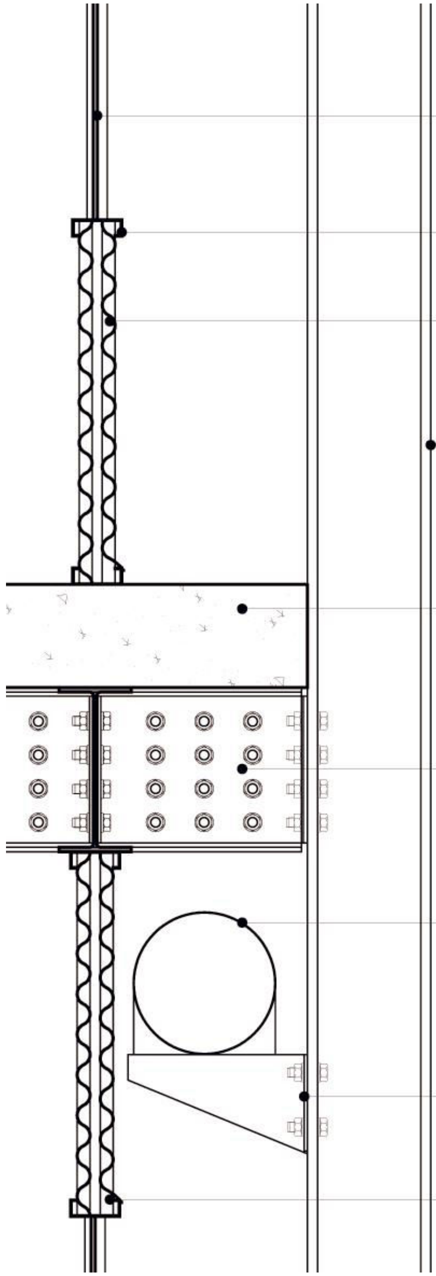


Fig 12. Section through southern skin of studio space

Firstly, the studio bridge structure faces north and south and thus makes efficient potential for using natural lighting. A glass curtain wall is provided for the northern skin for several reasons. Firstly, this is a skin of tinted heat-absorbent glass intended to radiate absorbed into the space to heat the space in winter only. This glass also eliminates a most of the direct glare from outside. The southern side is provided with composite double polycarbonate sheeting panels on the lower level and 6mm transparent polycarbonate screens above this.

Tinted heat-absorbent glass poses a potential problem causing radiation of heat during hot days. For this reason, horizontal shade devices (explained later on) are provided at each level on the outside of the façade. Low-level openings provide passive ventilation operated by users as required.

Using ***polycarbonate*** panels (refer to Figure 12) becomes more sensible in the studio space; these panels are lightweight and provide insulation against heat loss. Polycarbonate panels cost less than equivalent double-glazing, and weigh considerably less. A 6mm screen is provided above the double sheet panels instead of clear glass; these screens have an 82% light transmittence. This saves weight and does not compromise lighting levels within the space, making full use of the southern light. Screens are installed by manufacturer, braced and supported to the manufacturer's specification.

Furthermore, the studio space is divided into two, namely; a circulation space on the northern side and the design studio on the south. A sliding panel system defines these two spaces and is used as pin-up boards for the students.

Northern façade sun-shade device:

In order to use solar gain for passive heating within the north facing spaces, a shade device was designed that allows only limited amounts of sun into the space during specific times throughout the year.

This shade device is designed as a multi-purpose composite sun-shade. Firstly, it is intended to stop direct sunlight from shining onto the glass façade during summer days while allowing limited sunshine into the glass façade during winter. Secondly, this shade structure doubles as a solar water heater.

Being expositionsed to sunlight during winter days, it makes sense to use this solar gain to heat water panels; the shade device allows for use as a solar water-heating element. On the bridge structure there are three levels where the shade structure is required, on each shade structure a water heating system is employed. The water is heated when the sun shines onto the panels and may reach up to 60°C. This is achieved by using solar heating water panels joined together as specified by the manufacturer. These panels are supported on a frame and suspended with steel ropes to the main bridge structure. The water in the panels is circulated through a closed loop system at a specified velocity for each level by means of a computer controlled electric pump, as per Figure 14. Heat is generated in the fin heaters within the space. In summer, the velocity of the system is speeded up to prevent too much solar gain when the panels are expositionsed to sunlight. The top solar panel system is hot-water supply because these panels are expositionsed to direct sunlight all year round; this creates hot water supply for the geysers during the months when the heater system becomes redundant. In addition, the top set of solar panels provide shading for the lower panels.

Environmental Performance:

The prevailing wind in Pretoria comes from a northerly direction and even on still days, there is a slight breeze moving through the city spaces. This wind is used as a feature for the courtyard space of the building; refer to Figure 15. Facing towards the north the courtyard is in the direct path of the prevailing wind. The large mature Jakaranda trees act as a windbreak for high velocity winds and allows air to pass underneath the crowns of the trees. Air moving into the space is forced up into the open volume due to a high-pressure pocket together with a low pressure created by wind moving over the top of the building.

This allows the courtyard ventilation throughout most of the year provided there is a light to moderate breeze. Wind is generally no more than moderate with few days of the year being wind-still.

All windows opening onto the courtyard do so at a high-level. The reason for this is that warm air escapes through these openings and is drawn out with the aid of the updraft illustrated in Figure 15. This principle allows ***natural ventilation*** to work well within the spaces surrounding the courtyard.

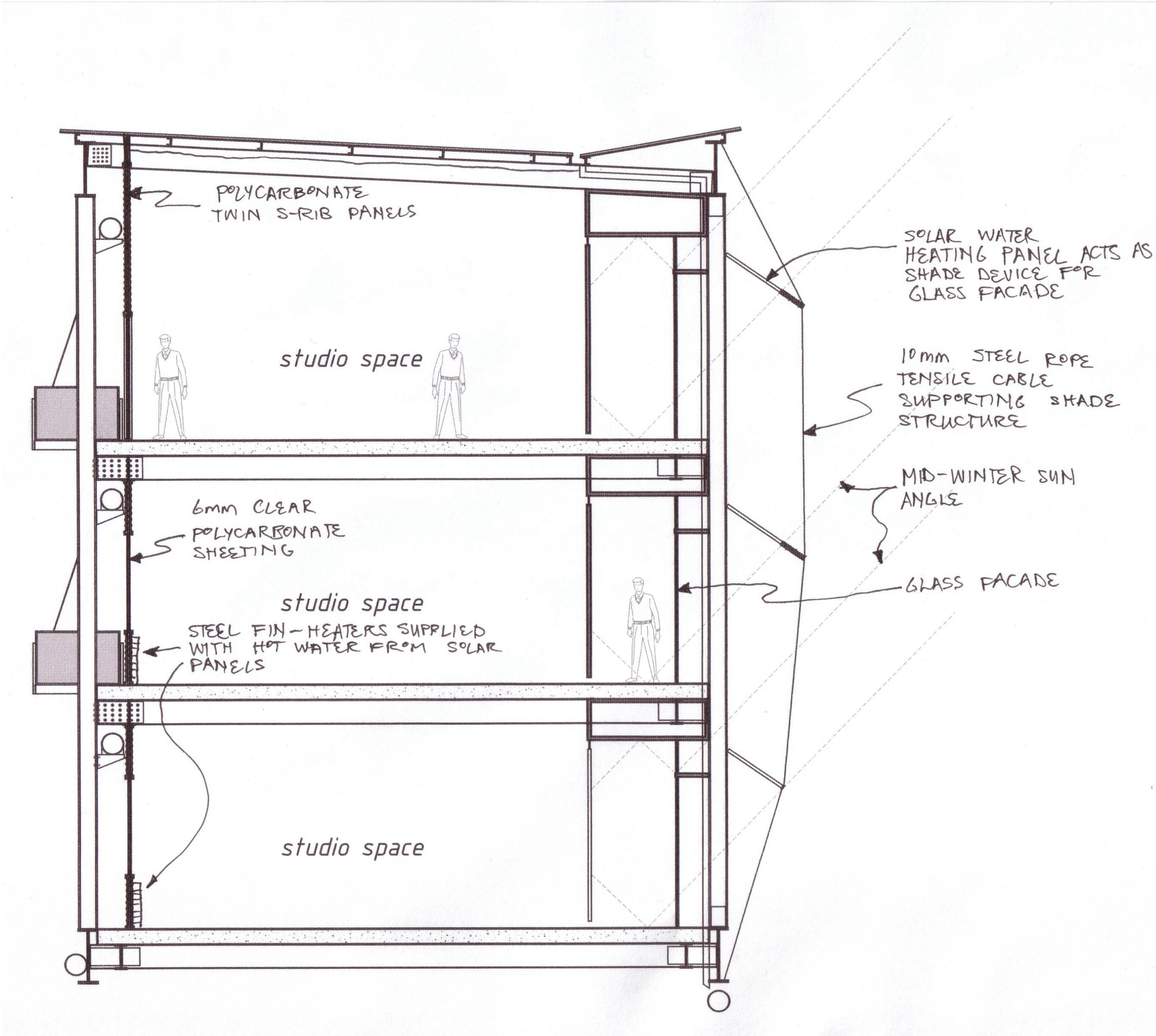


Fig 13. Section through studio bridge structure showing sun-shade device placement

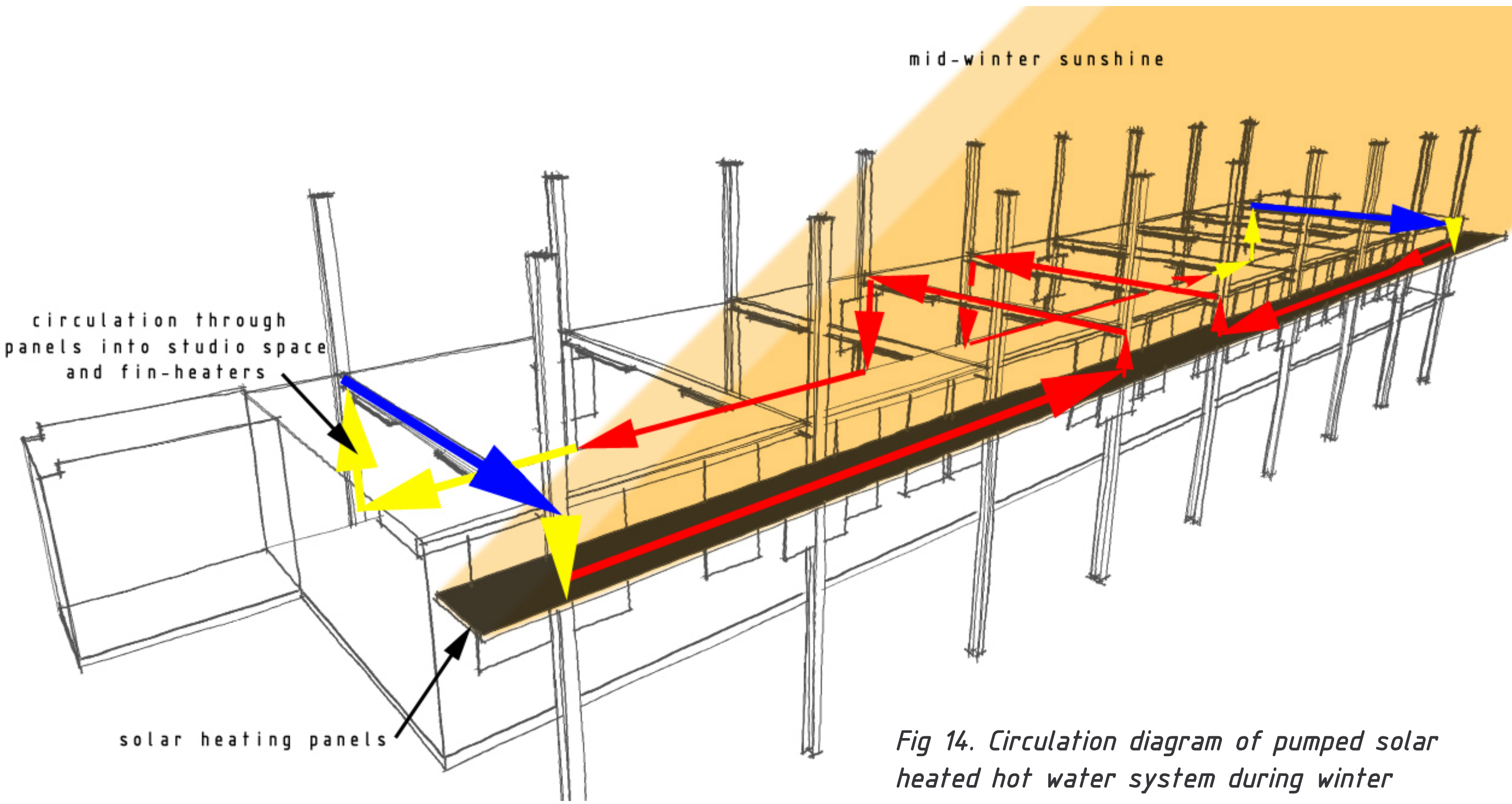


Fig 14. Circulation diagram of pumped solar heated hot water system during winter

Thermal Performance:

Having mass structures such as concrete and brick absorb heat during the day and radiating this heat in the evenings, creating the flywheel effect. This leads to a more stabilised interior temperature and results in a greater temperature lag.

This principle is used in the design of the studio space where the concrete floor acts as the mass element for the space. In the office and training space, the brick wall infill work and concrete floors radiate gained heat during the evenings, refer to Figure 16.

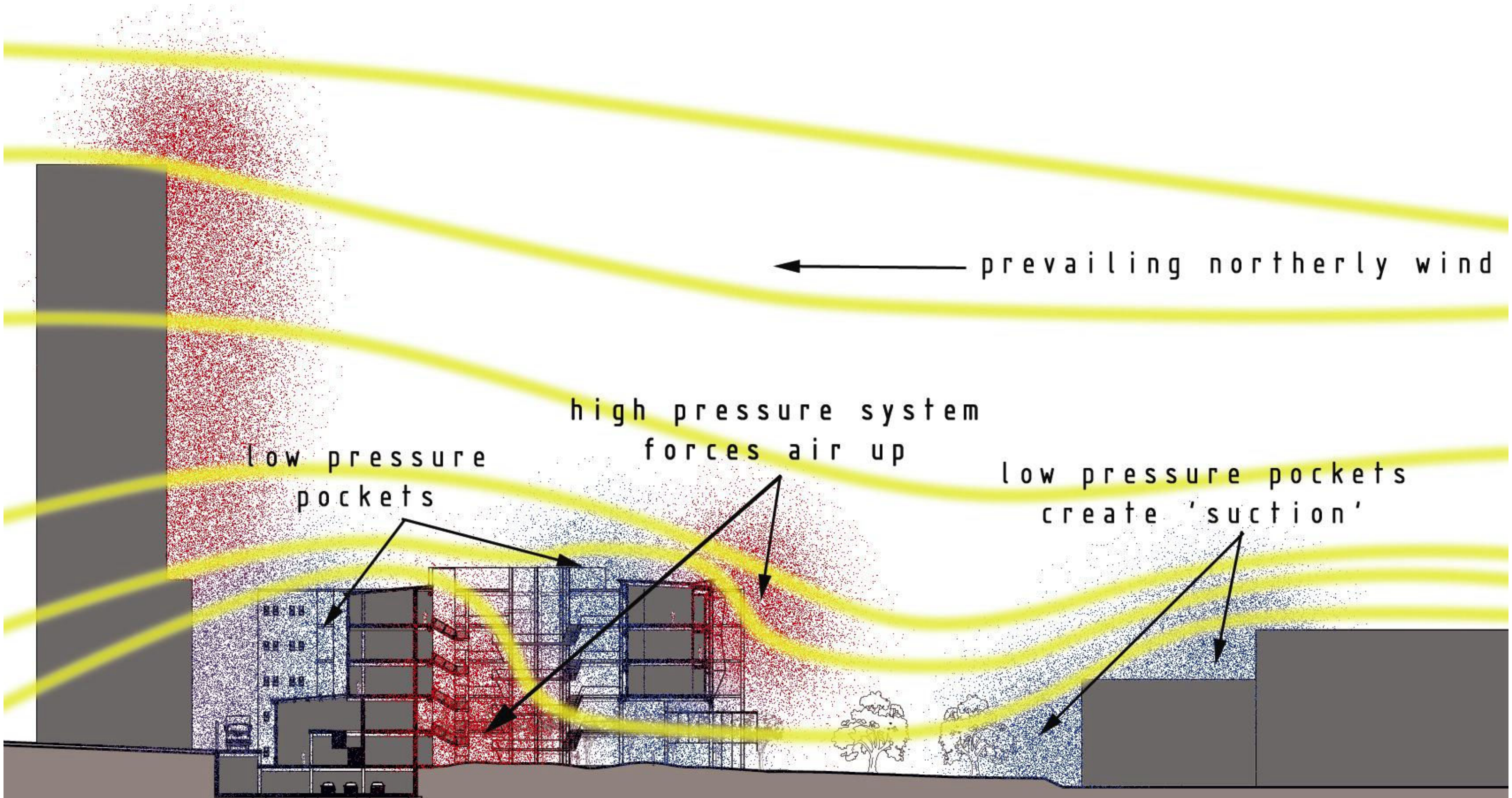
The interior roof space is not provided with suspended ceilings due to the requirement for radiated heat from the expositionsed and painted concrete floor slabs. In the studios, the same treatment is given except that a service ceiling space is provided above the circulation space, this makes the waste of design studio ceiling space redundant, refer to Figure 13.

Mechanical ventilation:

This is a critical design consideration. When designing for a multi-purpose building, the requirement for ventilation is important. There are many different spaces throughout the building and not all necessarily require mechanical ventilation. However, computer rooms, auditoria and studio spaces are high priority for mechanical ventilation.

Computer rooms need to be kept at around 21°C and dust-free. Also this system will remain at a positive pressure to insure minimal dust infiltration.

Fig 15. Airflow diagram



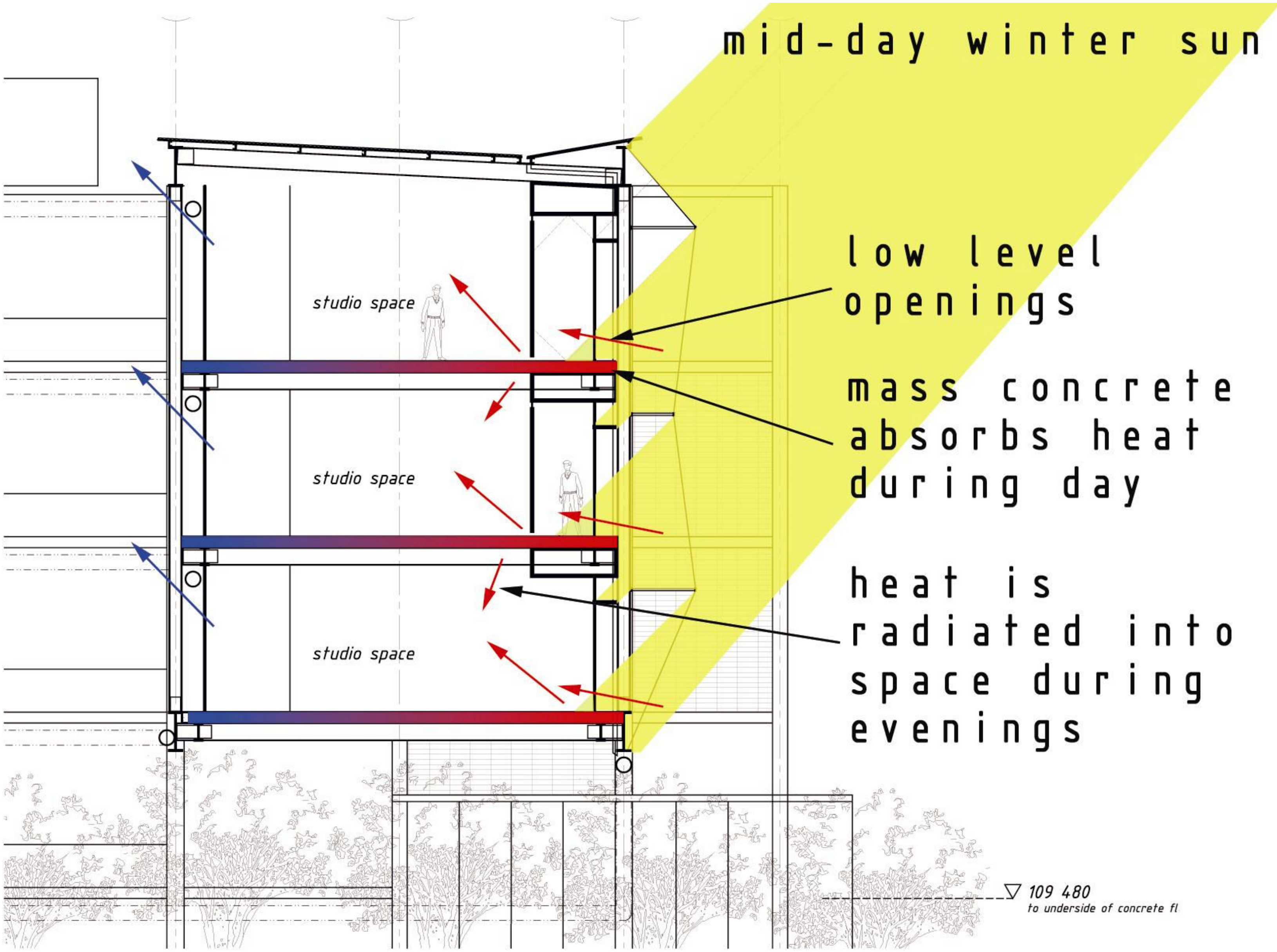


Fig 16. Air movement through natural ventilation within studio spaces

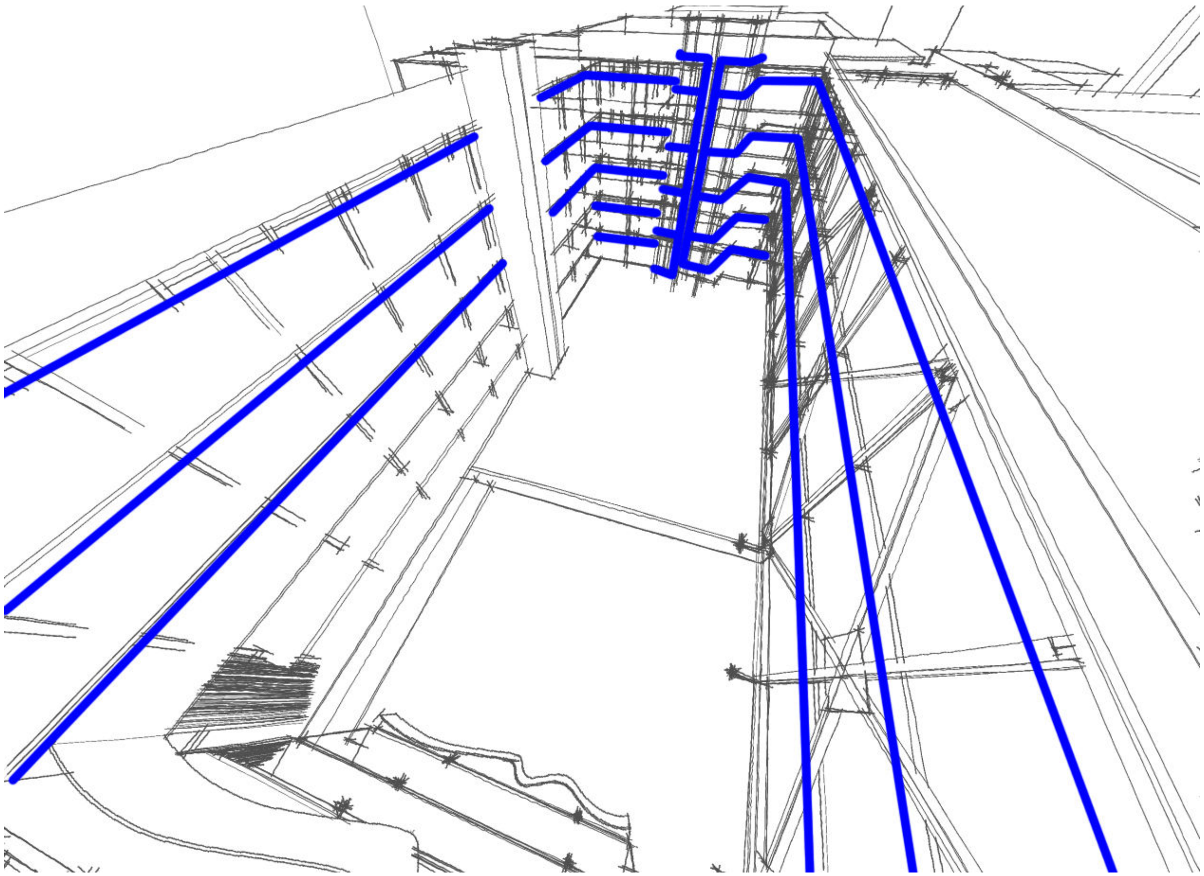


Fig 17. Air conditioner chilled water ducting as architectural feature

To keep the studios at around 22°C for optimal comfort may be required to employ the secondary mechanical system is to regulate the interior temperature. The advantage of having this system available is to also minimise dust that may enter when natural ventilation is used. User participation is required to close all openings to allow the system to operate efficiently.

The auditoria are closed spaces that require mechanical systems to ventilate and regulate the interior comfort zone.

To meet these requirements “chilled water fan-coil units” are introduced. This system allows for a central chiller plant that supplies the entire building with chilled (6°C) water. This water is then supplied to individual fan-coil units that provide ventilation ducted to air-conditioned zones.

This system is used as an aesthetic element (Figure 9) within the building. All piping from the central chiller plant is ducted vertically along the hydraulic lift shaft to each floor and then makes a loop around that floor back to the return piping. Each fan-coil feeds off of loop and this system allows for adaptability and flexibility within the building.

More units can be fitted as required to the loop and may also be removed, depending on the demand for mechanical ventilation.

All piping from the plant room is expositionsed along the building in order to illustrate this system to all participators. This adds to the human interaction component of the design, relating back to elementary design of machines for industry. Adaptability and flexibility have been explained, but contribute to the significance of using and expositionsing this mechanical system.

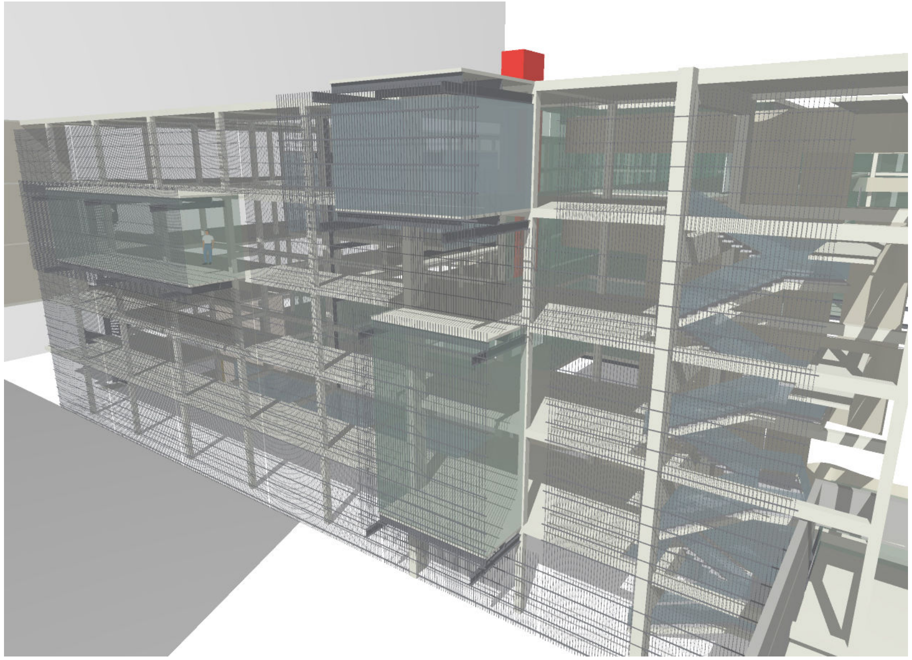


Fig 18. Steel screen structure fixed to steel frame on concrete super-structure

Skin Design:

Screen system

On the eastern side of the eastern circulation wing, steel screens (as explained earlier) are fixed to the main structure as per Figure 10. These screens are designed to accommodate the growth of an indigenous evergreen creeper. The creeper creates a natural filter and buffer from the elements and the screens act as balustrades as well as a wall system for the circulation and exposition space.

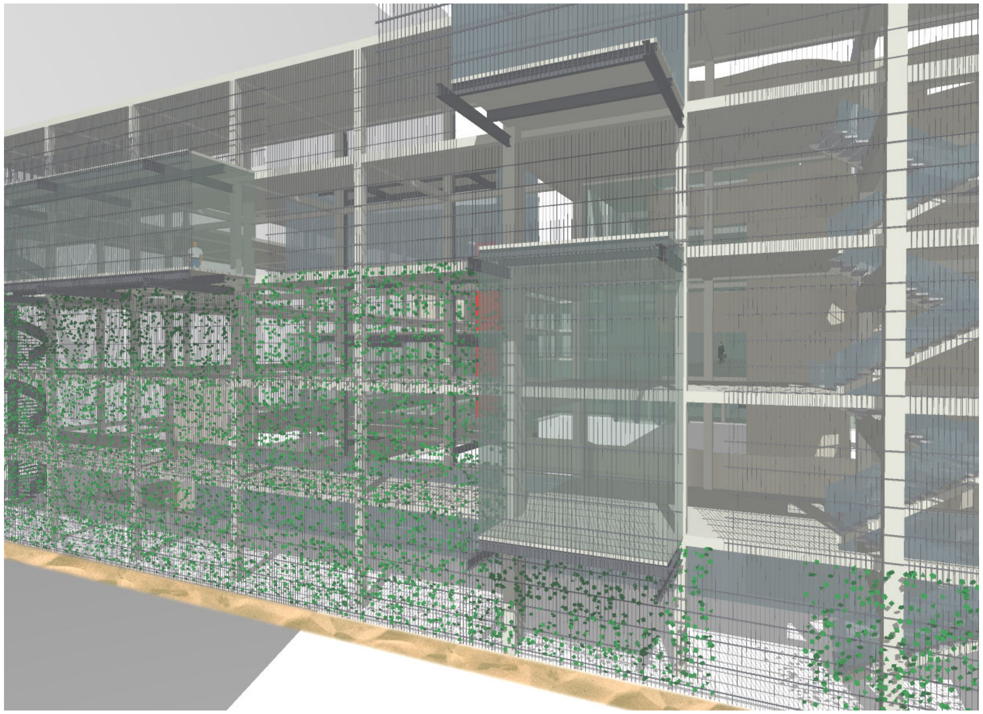


Fig 19. Steel screen with evergreen Flowering ivy creeper

Creeper system

Two different systems are designed for the building, one for the above mentioned eastern wing and a separate creeper system for the northern façade of the internal courtyard. This creeper is deciduous and offers the dynamics of nature because is filters direct sunlight in summer and allows direct solar heat gain in winter on those mass materials named earlier.

The indigenous evergreen creeper on the eastern wing:
Senecio macroglossus (Flowering ivy), fast growing and hardy, grows in sun and semi-shade.

Deciduous creeper inside the courtyard:
Gloriosa superba (Flame lily), Hardy deciduous perennial creeper grows well in semi-shade.

The plants proposed are watered with an installed irrigation system as recommended by landscape architect.

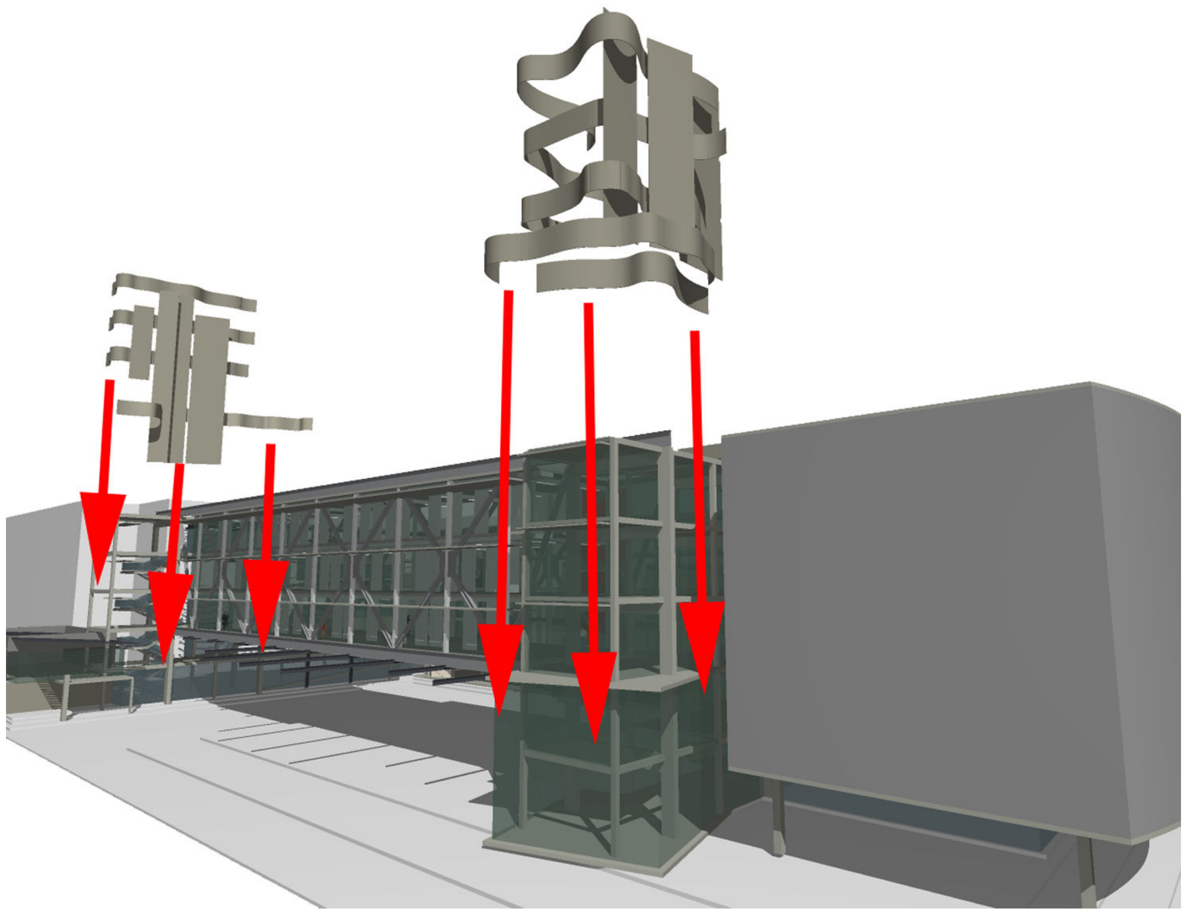
Polycarbonate panels

To reduce cost, translucent polycarbonate s-rib wall panels are used instead of glass curtain walls.

These panels are made up of two s-rib skins of polycarbonate sheeting placed next to one another with a 25mm cavity specified inside a steel profile frame as per Figure 12.

These panels help to diffuse light and in so doing eliminates glare that may cause undesired effects within the exhibition spaces.

Fig 20. 3D placement of plywood screens



Secondary exterior skin

A secondary exterior skin cuts out direct sunlight and solar gain that may create uncomfortable spaces.

This system is designed to address the technological progression of the building and its adaptability for new technologies. A skin of unprotected 1.5m high exposed bent steel sheets becomes a secondary skin to the building with the implication that it must be replaced when it deteriorates to an unacceptable level.

The skin consists of 1.6mmX1.5mX2.4m sheets of steel bolted to a lightweight steel structure fixed to the building super-structure as in Figure 20. Each panel is 1.5m in height and fixed with galvanised screws. The aim of this construction is to keep the skin away from the main skin as a secondary solar restraint and provide a lightweight solution that is exposed.

It is designed to weather and degrade, to be replaced with time, thus keeping the facades of the building dynamic in terms of colour and materials. The main objective of the screens is to minimise direct sunlight onto specific spaces.

These panels can be built in the centre's workshops and be installed by local contractors. By offering this procedure to the centre, the costs of machining and production of the skin is marginalized. The steel supports for this skin system are provided on the superstructure during construction.