Introduction:

"The surviving organism is fit for the environment" (Scott,1998:15)

Charles Darwin fully understood the relationship between an organism and its environment where every organism or system finds the fittest of all available environments, adapts that environment, and adapts itself to accomplish a better sustained relationship between them. There will always be a need for improving this adaption, because environments change and evolve and the organism has to adapt to the new circumstances to maintain a comfort level.

A building can be seen as an organism within a specific environment. A building is an organism that contains changeable systems within it that need to adapt to suit the changing environment the best. The fittest environment provides the things needed by the organism to achieve a certain level of health. (Scott,1998:22) The environment provides light, natural ventilation and renewable resources to be harnessed. These elements of nature of nature can be integrated into the design of a building to make buildings that are more responsive to the environment and its users, provide more humane places to inhibit, balance energy flows better, and which are more respectful to nature and our resources. Such a building can be seen as a healthy building.

The World Health Organization defines health as someone able to "seek and solve problems" or to recover from "insult or assault". (Scott, 1998:16) A building can be designed which responds to climatic conditions to solve problems like overheating during summer months by means of adequate natural ventilation and solar protection. By means of environmental design a building can recover from a state of user discomfort by harnessing the microclimate to create comfortable spaces for inhabitants. A building needs to have the ability to adapt to its environment. Therein lies success.

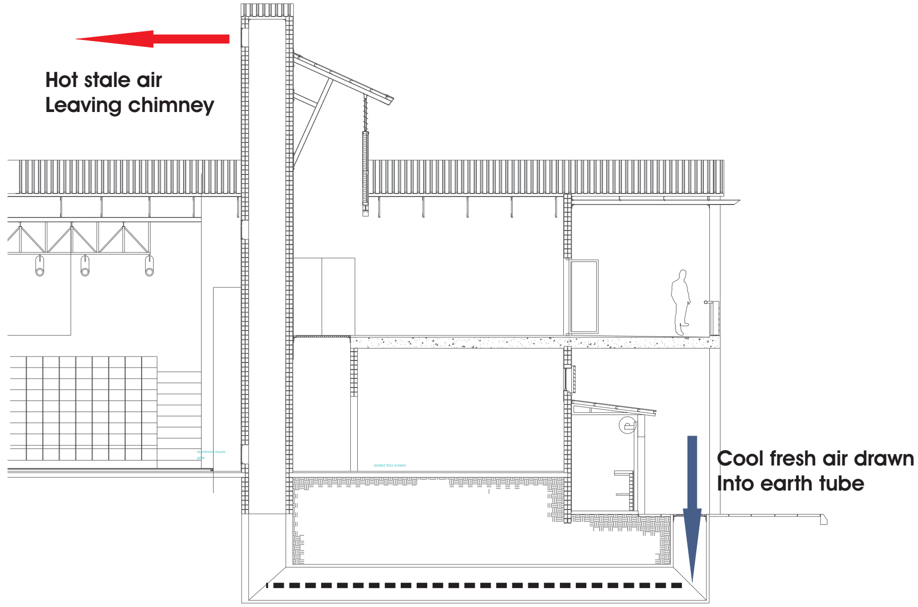
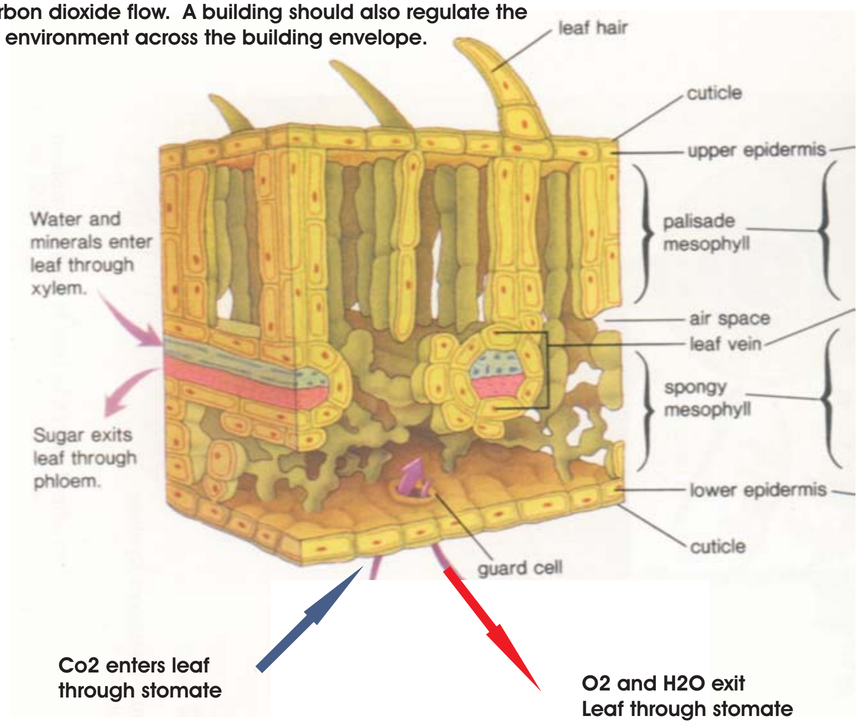


Fig 215. Section of the building showing natural ventilation through the stack effect.

Fig 216. Structure of the section of a leave to show oxygen and carbon dioxide flow. A building should also regulate the internal environment across the building envelope.



Designers of buildings need to engage in a process of adaption. We need to design systems that have gone from instability to dynamic equilibrium. A higher level of symbioses with nature has to be achieved. The building as a living organism does not stand in isolation to its environment. The chameleon is a creature that adapts to its environment, summer to winter, and to different forms of local environments woody to jungle or whatever. Buildings should be adaptable as well. A building should change according to season, and between day and night, and between different uses. An intelligent skin of such a building must regulate energy flow through itself whether it is in to out, or out to in, and store any excess energy for later use. This energy can later be redistributed to other spaces in the building where it is needed.

Designers of buildings need to engage in a process of adaption. We need to design systems that have gone from instability to dynamic equilibrium. A higher level of symbioses with nature has to be achieved. The building as a living organism does not stand in isolation to its environment. The chameleon is a creature that adapts to its environment, summer to winter, and to different forms of local environments woody to jungle or whatever. Buildings should be adaptable as well. A building should change according to season, and between day and night, and between different uses. An intelligent skin of such a building must regulate energy flow through itself whether it is in to out, or out to in, and store any excess energy for later use. This energy can later be redistributed to other spaces in the building where it is needed.

To achieve sustainability, we have to diverse our buildings as lifeless isolated objects in the environment to breathing adaptable organisms. Designers must learn from nature and ecology. The basic principles of the eco-system can be applied to building design and usage: resources must be chosen carefully, efficiently put to use, and reused and recycled again. In nature there is no garbage.

Integration with nature should be our goal. To be able to do this you have to know the local situation and understand the "genus loci". Each and every aspect of a design has to be planned. This is a difficult task but necessary if we want a sustainable development. We have to develop an urban ecology and an ecological economy to get a sustainable future. Sustainable design does not only include technical barriers, but social, economical and political problems as well. To create an ecologically sound society we have to look at these basic principles of a society.

Social issues:

Occupant comfort:

The basis of occupant comfort in the design of an internal space is the combination of two primary elements: the external climatic conditions and the demands placed upon the internal climate by the activity that will be taking place within the space. The outer walls, floor, and roof of building acts as the barriers between this internal and external climates and the interaction, which occurs between them. A two-way flow of energy occurs across this barrier. This is where the flow of energy needs to be controlled by appropriate design of this envelope to fluctuate due to variations in the environmental conditions. The barrier can utilize external environmental conditions at times or inhibit its intrusion at other times. The design of the barrier can only be in a stable state when the internal and external conditions are equal. The manipulation of external conditions for either ventilation, heating, or cooling could allow for less energy expenditure. Conventional design ignores the biological potentials that the surroundings offer them.

Besides being aesthetically pleasing, the human environment must provide light, air and thermal comfort. Proper acoustics and hygiene are also important. Human's productivity does vary accordingly to the conditions in their immediate environment. Benefits associated with improvements in thermal environment and lighting quality include:

- increased attentiveness and fewer errors;
- increased productivity and improved quality and services;
- lower rates of absenteeism and employee turnover;
- fewer accidents;
- reduced health hazards such as respiratory illnesses. (Bradshaw, 1993:9)

Comfort is best described as the absence of discomfort. Comfortable occupant conditions do not cause unpleasant sensations of temperature, drafts or humidity. Thermal comfort is a state of mind that is satisfied with the environment and is achieved through thermal control.

The factors that determine occupant comfort include:

- temperature of the surrounding air;
- radiant temperatures of surrounding surfaces;
- humidity of the air;
- air motion;
- odors;
- dust;
- acoustics;
- lighting;
- aesthetics.

There are three basic ways in which a living organism responds to its immediate environment: migration, form and metabolism. During migration animals like birds move from a cold environment to a warmer environment. Animals have large or small skin areas in relation to their volume to increase or decrease their rate of heat loss to the environment. An example is the enlarged surface area of an elephant's ears that radiate heat. Metabolism requires energy from food and the result is the production of heat. Animals with a high heat loss eat large amounts of food to balance their heat loss in their environment. These three forms of thermal response have their analogies in buildings. Migration: occupants can move from one area in a building to a more thermally comfortable area. The form of a building dictates the building's response to the environment: size, shape, exposed are, orientation, volume and openings influence the building's conditions.

Metabolism, the sustained processes of a building, must be concerned with maintaining the thermal equilibrium. Metabolic rate is a function of how well the form uses available energies to modify climate.

Metabolism:

Thermal comfort is a function of the physical environment plus the activity and clothing level of a person. People can adapt their clothing levels, activity levels and posture in response to thermal conditions. People metabolize the food they have taken into their bodies and convert it to electrochemical energy. This energy is used for growth, regeneration and operation of the body. When energy is converted from one form to another, heat is formed as a by-product of the conversion. The result is the generation of heat within the body, which needs to be rejected by means of sensible heat flow (radiation, convection or conduction) to the environment. As the need for energy increases, metabolism increases, and also the production of body heat.

To determine the desired environmental conditions for comfort, this metabolic level during certain activities needs to be taken into account. Metabolic rate is measured in *met* units. 1 *met* = 58.2 W/m (Bradshaw, 1993:20) For an average sized man the *met* unit corresponds to approximately 100 W. In table 1.1 the metabolic rate is given for different typical activities. Dancing has a *met* value of 2.4 - 4.4. This is a rather high metabolic rate. This activity will take place in studios and on stage. Adequate ventilation must be provided to remove this metabolic heat from a space.

Clothing of occupants:

Clothing determines thermal comfort. Clothes regulate body heat loss. Clothing has good insulative properties. Clothing insulation can be best described in terms of its *clo value. Clo* value is a numerical representation of a clothing ensemble's thermal resistance.

1 *clo* = 0.155 m .C/W (Bradshaw, 1993:21)

Clothing worn by Johannesburg occupants is rated between 0.5 and 1.5 *clo*. 1 *clo* = lightweight summers clothing. A dancer will wear clothing with a value of approximately 0.47 - 0.5 clo, seeing that their bodies generate more heat during dancing. Seasonal clothing variations of occupants allow indoor temperatures to be higher in the summer than in winter and yet remain comfortable. During winter additional clothing lowers the temperature necessary for comfort. Adding 1 *clo* of insulation permits a reduction in temperature of approximately 7.2 C without compensating comfort.

Elements that effects occupant comfort:

Air temperature represents the temperature as read by the common thermometer and affects the rate of convection and evaporation of body heat. This is also known as the dry-bulb temperature. This is the most important determinant of thermal comfort. Absolute humidity is the amount of water by weight in the air. The amount of moisture that air can hold is a function of the temperature: the warmer the air, the more moisture can it hold. Relative humidity is the ratio of the actual vapor pressure of the air-vapor mixture to the pressure of saturated vapor at the same dry-bulb temperature times hundred. Mean radiant temperature is a weighted average of all radiating surface temperatures within line of sight. Mean radiant temperature affects the rate of radiant heat loss from the human body.

$$MRT = \frac{\Sigma T.\theta}{360}$$

$$MRT = \frac{T1\theta1 + T2\theta2 + \ldots\ldots Tn\theta n}{360}$$

T = surface temperature
è= surface exposed angle relative to occupant in degrees

During winter:

T1 = 9°C T2 = 16°C T3 = 22°C
θ1 = 74° θ2 = 106°

The MRT for the occupant = (9.74) + (16.74) + 2(22.106)
= 18°C

A MRT of 18 - 27°C is still acceptable (Bradshaw, 1993:27). Solar radiation during winter can increase the inside temperature.

During summer:

T1 = 20°C T2 = 24°C T3 = 33°C
θ1 = 74° θ2 = 106°

The MRT for the occupant = (20.74) + (24.74) + 2(33.106)
= 28°C

With adequate natural cross ventilation a lower inside temperature can be achieved.

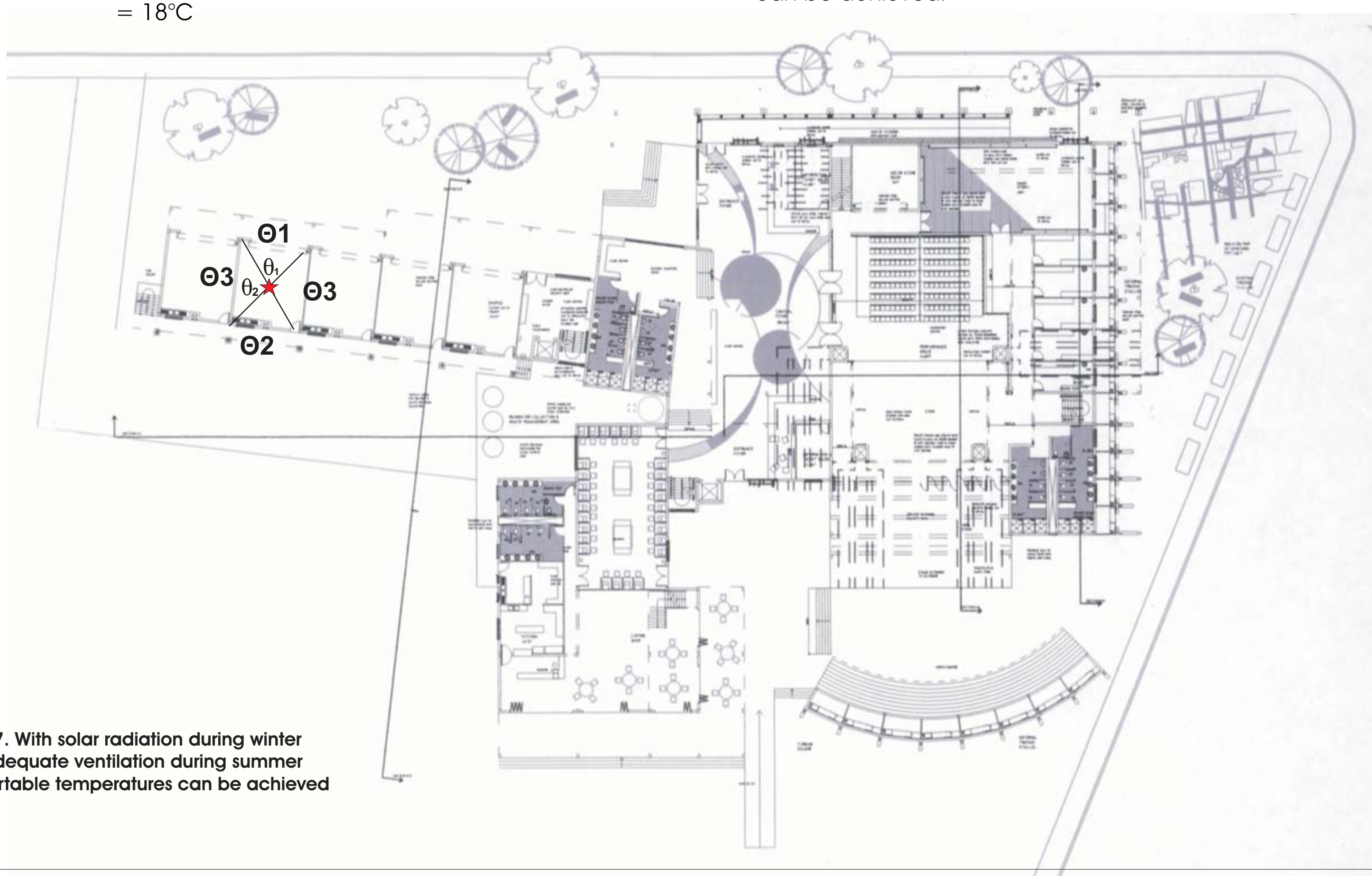


Fig 217. With solar radiation during winter and adequate ventilation during summer comfortable temperatures can be achieved

Air movement affects body heat transfer by convection and evaporation. Air movement is the result of natural or forced convection. Natural convection of air over skin allows for continuous loss of body heat. Insufficient air movement promotes stuffiness and air stratification. Unpleasant drafts are experienced when air motion is too rapid.

The psychometric chart is a graphic presentation of the condition of the air at a given location, relating temperature to moisture. The chart also expresses the energy content of the air. This total air energy is the sum of both the temperature content of the air and the vaporized moisture content of the air.

The ideal design conditions for comfort are:

- when altitudes are from sea level to 2134m;
- mean radiant temperature is nearly equal to dry-bulb temperature;
- relative humidity is 40% (20 60% range)
- air velocity is less than 0.2 m/s

There is no minimum air movement necessary for thermal comfort within the comfort envelope on the chart. The maximum allowable air motion is lower in winter than in summer. In winter, the average air movement within the occupied zone should not exceed 0.15 m/s (Bradshaw, 1993:31) In summer, the average air movement in the occupied zone can go as high as 0.25 m/s under standard temperature and humidity conditions. Above 26 C comfort can be maintained by increasing the average air motion 0.275 m/s for each 1 C of increased air temperature up to a maximum of 0.8 m/s (Bradshaw, 1993:31). At this point, loose paper, hair and light objects start blowing around.

If activity increases above the 1.2 *met* level, sweating increases. To maintain comfort, clothing has to be adjusted, the air motion must be increased or the temperature must be decreased. When one of these conditions is out of the comfort range, adjusting one or more of the other conditions will restore comfort with little or no additional energy.

The design and construction of a comfortable, energy-efficient building depends upon the prevailing climatic conditions. In Johannesburg summers are warm to hot with the highest recorded temperature 35 C during January and the coldest temperature was 5 C during June. The air is fairly dry: about 30% humidity.

When the temperature and humidity conditions of a quantity of air is known, it is possible to find out the amount of energy (in Btu/lb or kj/kg) needed to be added or extracted from the air to obtain some other desired condition.

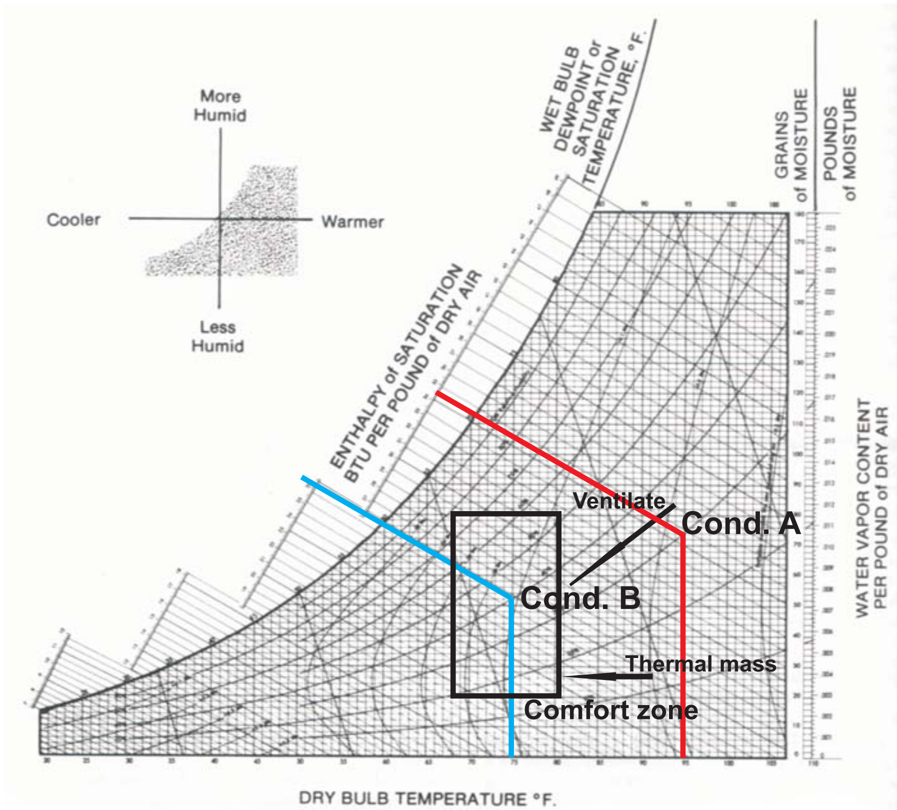


Fig 218. Psychometric chart during summer.

Condition A (outside temperature): 35 C (95 F) and 30% humidity
Condition B (desired temperature inside): 24 C (75.2 F) and 40% humidity

The netto energy difference is the enthalpy of A minus the enthalpy of B. The amount of heat that must be removed is 35 Btu/lb 27 Btu/lb = 8 Btu/lb = 18.6 kj/kg.

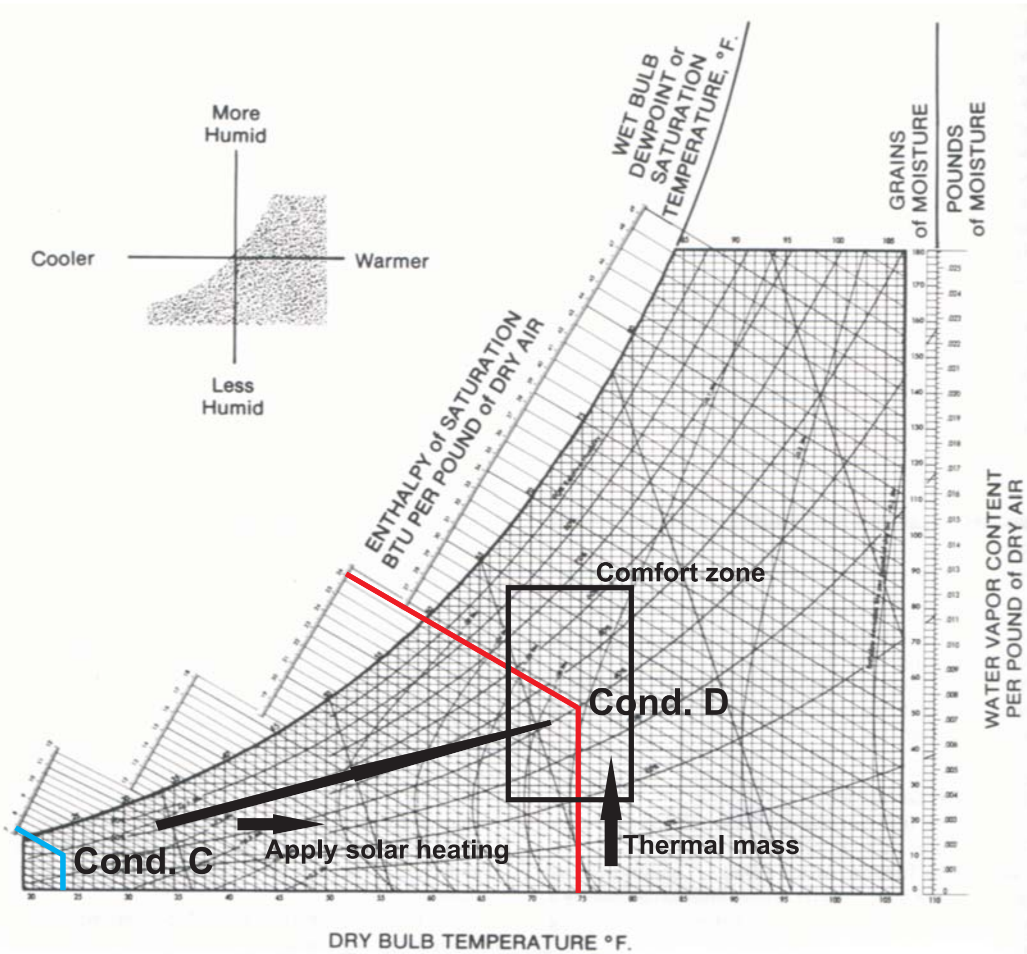


Fig 219. Psychometric chart during winter.

Condition C (outside temperature): -5 C (23 F) and 30% humidity
Condition D (desired temperature inside): 24 C (75.2 F) and 40% humidity

The amount of heat required is 27 Btu/lb 7 Btu/lb = 20 Btu/lb = 46.52 kj/kg

The conditions within Johannesburg's macroclimate show that a reasonable building would offer a fair level of comfortability, with a bearable heat load in summer while some additional heating would be required during winter.

Natural lighting:

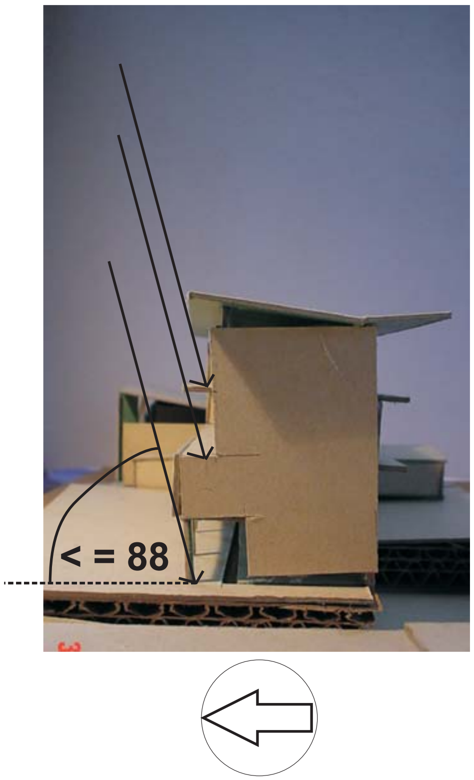
Sunlight, direct and diffused, has the potential to save electrical energy by reducing the demand for artificial lighting. Daylight illumination depends on how much sky is visible from the point in question. The luminous flux (lumen) is used in practice for the design of lighting. It is the flow or amount of light from a light source, emitted through a solid angle. Sunlight is a highly efficient source of illumination, making it a comparatively cool source. On a bright day, sunlight can produce levels of illumination 50 times as high as those recommended for artificial illumination. It provides approximately 90 to 120 lumens of illumination per watt of total energy, compared to 40 to 75 lumens per watt for common fluorescent and 15 to 25 lumens per watt for incandescent light (Bradshaw,1993: 283). Electrical light introduces about twice as much heat per unit of light into a space as does daylight. Large areas of glazing introduce increased daylight into spaces, but can affect the amount of energy needed to heat or cool a space. Efficient shading from direct sunlight can prevent heat gain during summer. Heat losses during winter can be minimized by double glazing, insulation and operable thermal barriers for use during non-daylight hours.

Latitude, time of the year, air pollution levels, humidity, landscaping and nearby buildings determine daylight conditions. There is more sunlight during winter than in summer. The duration of bright sunshine exceeds 80% in winter and 60% in summer in Johannesburg. Day lighting affects the amount of fenestration into a building, the appearance of it on the façade, the building shape and the building's orientation.

Daylight must meet the same visual performance criteria as artificial lighting in providing adequate levels and quality of task illumination. Although daylight cannot be used all the time, even a building, which is used, round-the-clock can use daylight for a few hours during the day and thereby reducing the lighting energy consumption. Indirect sunlight provides illumination levels that are 10 20% as bright as direct sunlight. When the sky i overcast, the daylight is diffuse, coming from all directions, including ground reflection. This is still more light than is needed, so a daylight system can be very useful.

JOHANNESBURG & PRETORIA Latitude (nearest) 26° South
Both cities taken as longitude 25.5°E (Add 4.5° or 18 minutes to solar time)

Solar times		*06.00*	*08.00*	*10.00*	*12.00*	*14.00*	*16.00*	*18.00*
Clock times		06.18	08.18	10.18	12.18	14.18	16.18	18.18
Azimuth	21/12	112E	101E	91E	0	91W	101W	112W
Altitude	21/12	10	35	63	88	63	35	10
Azimuth	21/3 & 9	90E	76E	53E	0	53W	76W	90W
Altitude	21/3 & 9	0	26	51	65	51	26	0
Azimuth	21/6	-	55E	34E	0	34W	55W	-
Altitude	21/6	-	14	32	40	32	14	-



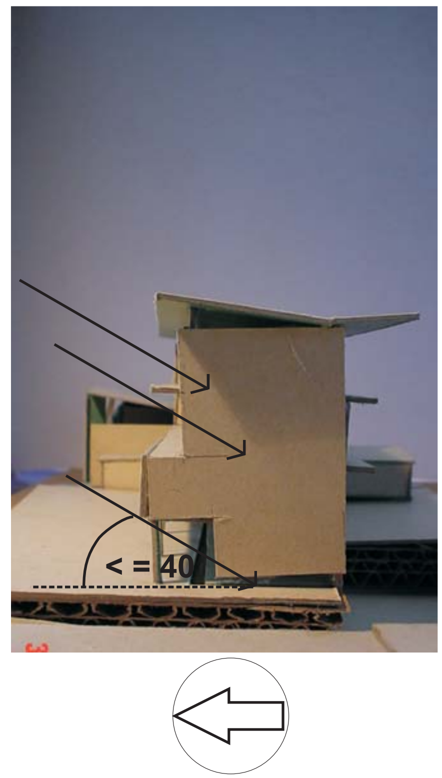


Fig 220. Indirect sunlight must be avoided during summer to prevent heat gain.

Fig 221. During winter direct sunlight must be admitted to interior spaces for direct heat gain.

Fenestration for daylighting may be trough the roof and are identified as top lighting. Side lighting is vertical windows. Top lighting are more effective than side lighting because the quantity of light from the sky is greater than that reflected by the landscape. Lighting from above is most useful in areas where light is needed but visual contact with the outdoors is not. This method distributes illumination more uniformly to all the walls. Clerestory windows, when orientated northwards, can maximize solar heat gain during winter. A roof light provides natural lighting right through to the circulation space next to the dressing rooms. A mentis grid walkway lets light through the first floor level to the ground floor. The walkway next to the studio situated over the stage receives natural lighting through polycarbonate roof sheeting. Overhangs minimize solar heat gain in the cooler season. South-facing windows are appropriate if heat is not needed. They provide a steady light level. South facing windows are used in this dance studio. Placing the top of windows as near to the ceiling as possible allows the light to reflect of the ceiling for optimum indirect lighting effects. The central atrium receives daylight through large openable glass surfaces covered with movable aluminium louvres. This space also receives filtered natural light through the printed fabric-covered glass panels at the northern entrance.

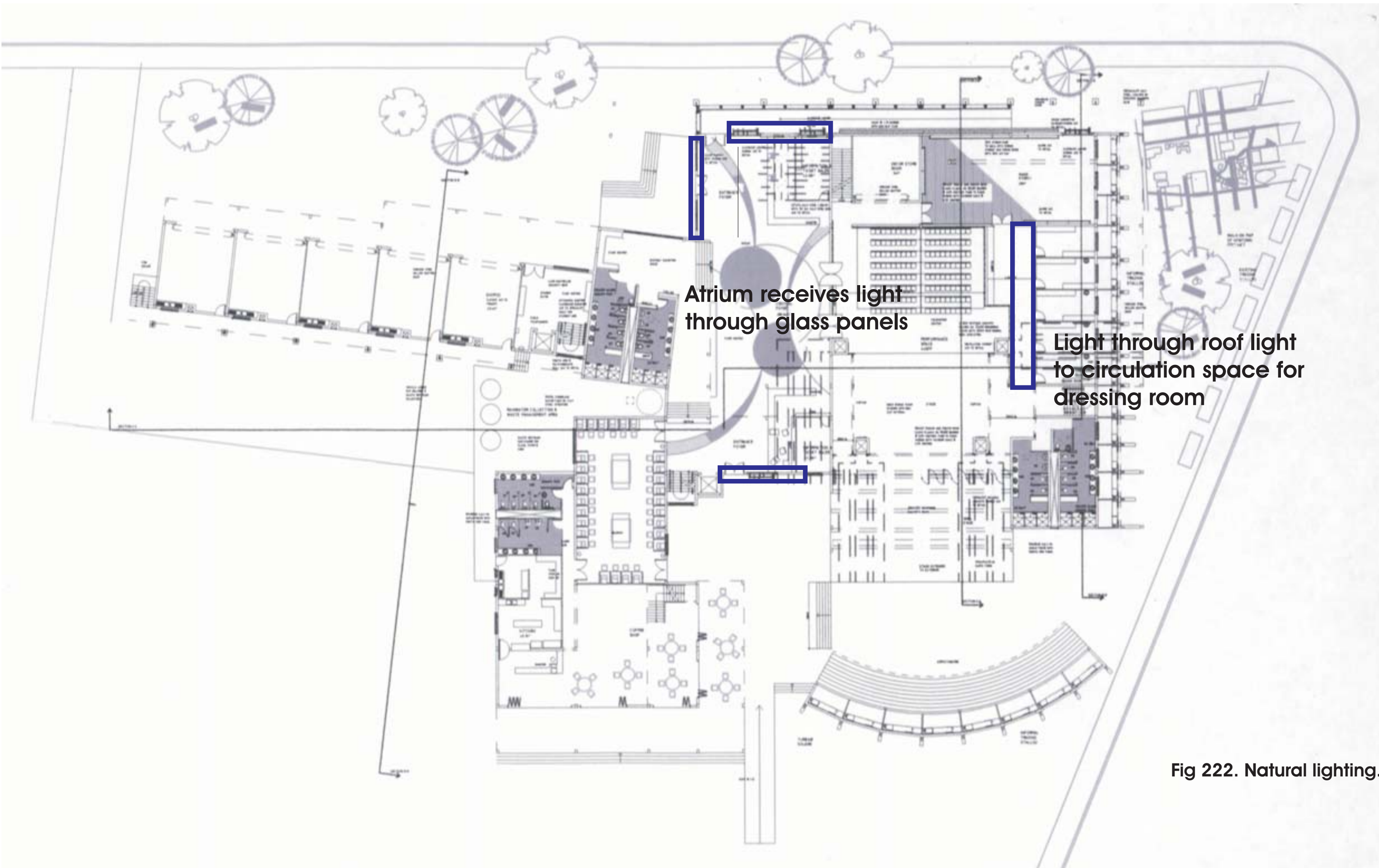


Fig 222. Natural lighting.

Fig 223. Rooflight

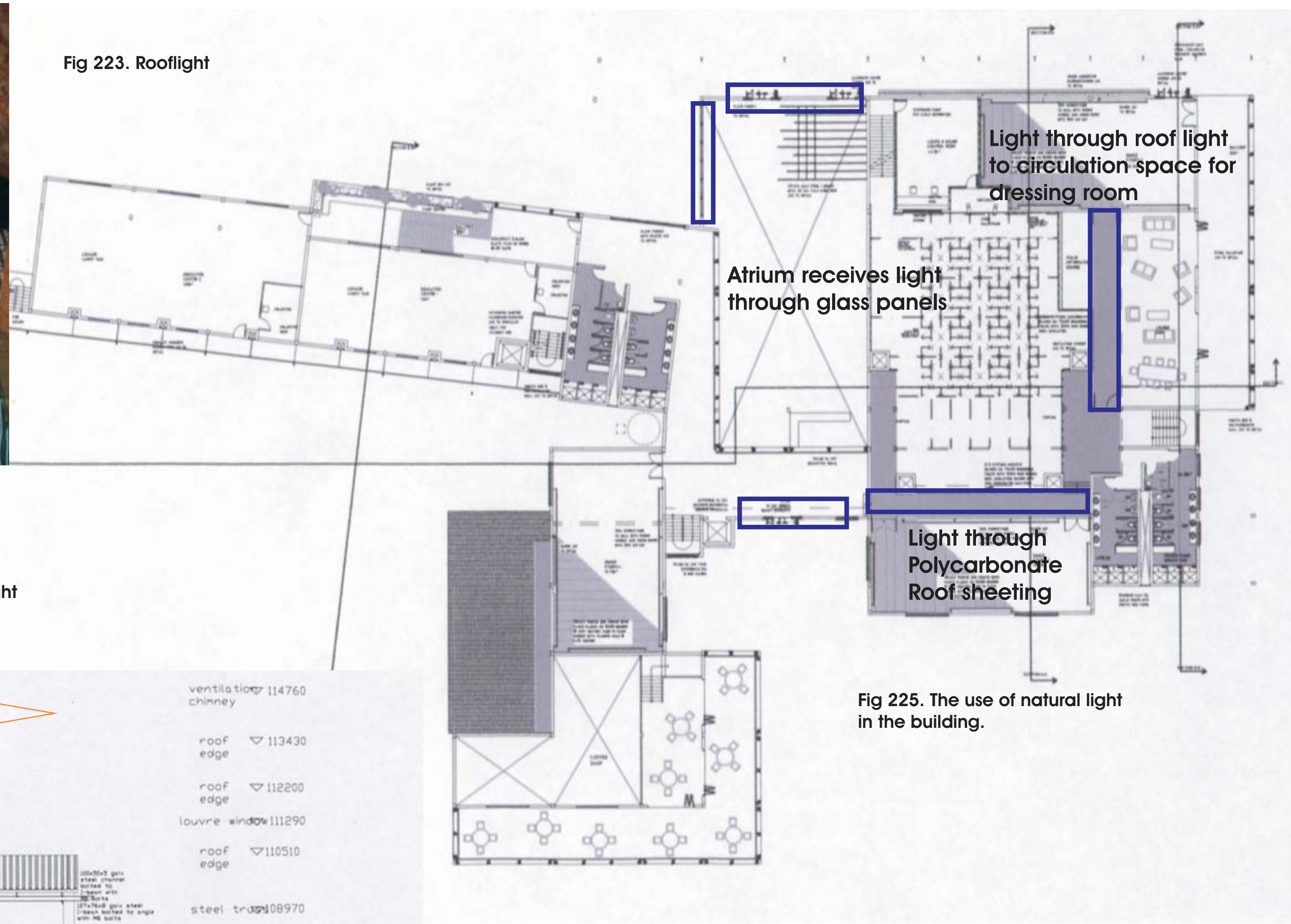


Fig 225. The use of natural light in the building.

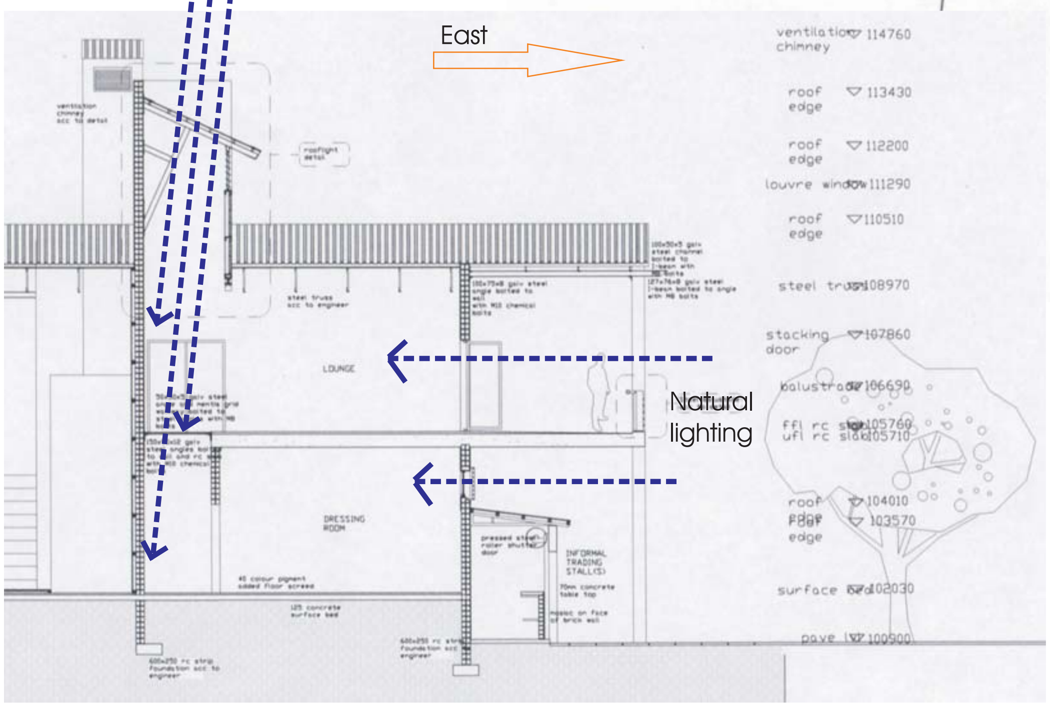


Fig 224. Light through roof light to circulation space for dressing room

Light control devices like movable aluminium louvre screens are used to Balance light patterns and distribute daylight throughout a space. They also provide privacy when required. Other exterior light control include louvres in front of windows. These louvres also function as burglar bars for security. An overhang decreases light levels near the window that makes light levels more uniform throughout a space.

Artificial lighting:

Artificial lighting includes the use of fluorescent lamps rather than incandescent lamps. Fluorescent lamps are more efficient than incandescent lamps and have up to 20 times longer life than incandescent lamps. More light is emitted by a 40-watt fluorescent tube than by a 100-watt incandescent bulb. The efficacy of fluorescent lamps depends on their color-rendering capabilities. The most efficient are warm white, cool white and white. These are best where economical light production is important. Deluxe warm white and deluxe cool white can be used where lower efficacies are acceptable. The lamp life of a fluorescent tube is dependant on the number of starts. The lumen output of a fluorescent lamp deteriorates rapidly during the first 100 hours of burning and thereafter much more slowly. The figures in table yy presents output after 100 hours of burning. At 40% of a bulb's average rated life, its output drops to approximately 85 90% of the 100-hour initial value. Fluorescent light have a life on average of 10 000 hours whereas incandescent light only offers 1000 hours. Fluorescent tubes give off far less heat than incandescent bulbs.

The shape of fluorescent lamps are tubular and straight. The standard 1.2 m tube is rated 40 watts. Energy-conserving reduced wattage lamps are available to decrease power consumption. A comparison between the wattages of a standard and energy-conserving 1.2 m and 2.4 m lamps are presented in Fig 20. The light output of the energy-conserving lamp is lower. The life of a 2.4 m lamp is shorter.

Fluorescent lamps are also available in U-shape for use in a 60 cm square fixture. The U-lamp is a standard 40-watt, 1.2 m fluorescent tube bent into this shape. Another fluorescent lamp light is a lamp that fits into an ordinary incandescent socket. The lamp uses 44 watts of power, but produces as much light as a 100-watt incandescent bulb (Bradshaw, 1993:270).

Lamp	Power Consumption (Wattage Range)	Rated Initial Lumens/Watt (Incl. Ballast)	Average Rated Life (hours)
Incandescent			
Standard	10–1,500	15–25	750–3,500
Tungsten halogen	100–1,500	15–25	2,000–12,000
Fluorescent			
Standard	15–100	40–95	9,000–20,000+
High-output	60–215	45–100	9,000–20,000+
High-intensity discharge (H.I.D.)			
Mercury vapor (standard)	40–1,000	24–60	12,000–24,000+
Mercury vapor (self-ballasted)	160–1,250	14–30	10,000–20,000
Metal halide	175–1,500	69–115	7,500–20,000
High-pressure sodium	35–1,000	51–130	12,000–24,000+
Low-pressure sodium	18–180	62–150	12,000–18,000

Fig 226. Fluorescent lights compared to incandescent bulbs.

Stage lighting:

There are a few factors governing the positions of lighting. There needs to be easy access to the lights. The access needs to be to the rear of the instrument with ample room for the staff to reach around the instrument to the front and also sufficient free space for the instrument to be readily demounted for repair. Over a third of the total number of instruments in a modern rig are likely to be located in the auditorium space (more to the front). The desired angle is normally between 42 and 44 degrees at an angle to a horizontal plane emanating at the stage front (Adler, 1994: 20-20). Lanterns are required at a high angle either side as well as across the main front area of the stage. Lanterns are either housed on bridges which cross the auditorium, or attached to the building structure itself.

Many people consider lanterns and their relevant bulky cabling and paraphernalia to be unsightly in the context of a formal auditorium. However, this performance space will carry a "high tech" design ethic and it will be acceptable to place lanterns in exposed positions, provided they are sympathetically arranged as they become part of the design integrity.. Lanterns themselves must not intrude into the audience's line of sight. Safe means of suspension must be provided.

One of the selling points for a multi-functional performance space is the speed and ease with which one can move from one production to another. Frequently this is serviced by having a grid made up of 50 mm steel tubing over the whole space from which lighting instruments can be hung in any location (Adler, 1994: 20-20). The grid can be accessed from below by a mobile access system.

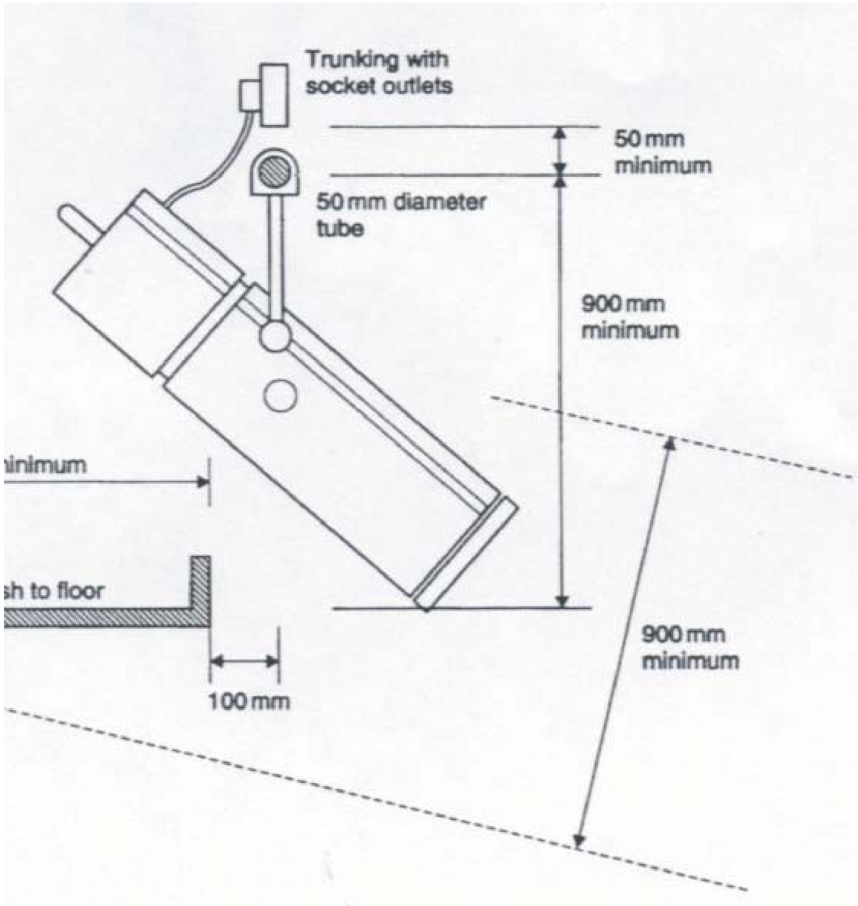


Fig 227. A lantern light which will be mounted on the lighting bridge grid.

Urban Citizenship

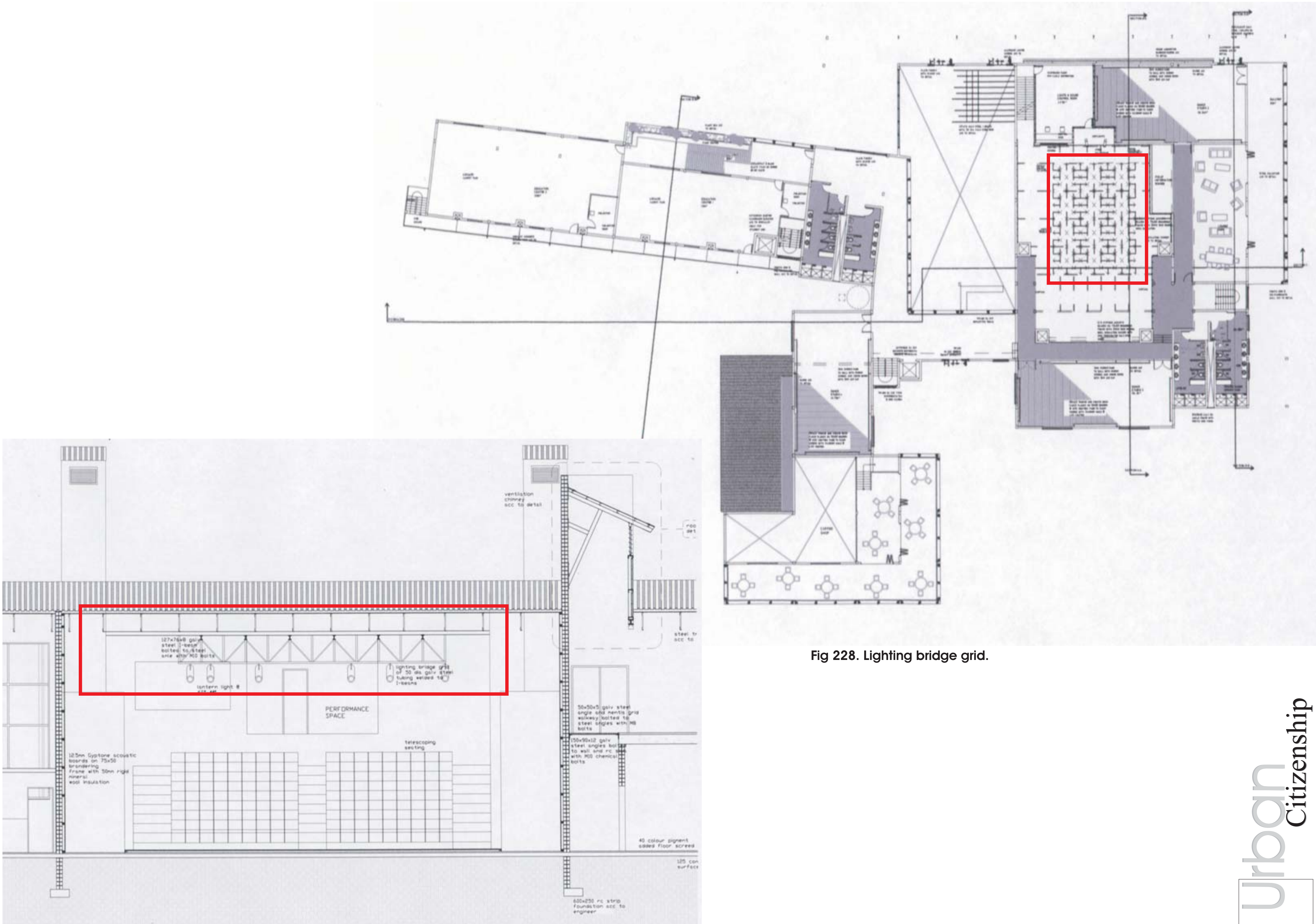


Fig 228. Lighting bridge grid.

Ventilation:

Natural ventilation is the movement of air into and out of a space through openings such as windows and doors intentionally provided for this purpose, or through non-powered ventilators. Natural ventilation provides fresh air as well as a cooling effect by replacing hot interior air with cool air outside. Prevailing wind directions can assist in the cooling of spaces. The quality of air in a space can affect occupant comfort. Under heavy occupancy of a space, the concentration of carbon dioxide can rise to unhealthy levels. Concentration of people in confined spaces, such as theatres, require the removal of carbon dioxide given of by respiration. At atmospheric pressure, oxygen concentrations of less than 12% or carbon dioxide concentration greater than 5% are dangerous. Other two major sources of low air quality are dust and tobacco smoke. Smokers and non-smokers need to be segregated in public spaces. Isolation of the smokers does not solve the problem: it only results in better dilution of the air. Two natural circulation techniques can be used:

- wind-induced cross ventilation;
- gravity ventilation.

Outdoor air ventilation requirements for various indoor spaces are given in litres per person. The ventilation rates are believed to provide a generally acceptable level of carbon dioxide, particles and odours. In bedrooms 15 l/person/room is needed. Retail stores need 1.5 l/person/square metre. Dressing rooms need 1.0 l/person/square metre. A ticket booth needs 10 l/person and an auditorium 8 l/person. A stage also needs 8 l/person. A lobby needs 10 l/person (Bradshaw, 1993:579). The ventilation rate needed to provide satisfactory air quality depends on ventilation effectiveness. Ventilation effectiveness depends on design, performance and location of supply outlet and return inlet. The supplied air needs to pass through an occupant zone before it passes out through the outlet. When spaces are unoccupied, ventilation is not required.

Natural ventilation usually occurs across operable windows. Windows may open by sliding vertically or horizontally. For cooling purposes, the outdoor stream should be directed towards where people are located. Personal manual control of openings is necessary to allow each occupant to control wind velocity and to establish occupant comfort.

Two openings are necessary for cross ventilation: one as an inlet on the windward side of a building; and the other as an outlet on the leeward side. Rooms most effectively ventilated by an inlet located near the bottom or middle of the windward wall, and an outlet in any position on the leeward wall. The inlets and outlets should be roughly the same size or the outlet can be larger. Obstacles upstream from intake openings or downstream near outlets can reduce wind velocity. Roof overhangs and the judicious location of trees can increase wind velocity at ground level and can improve air movement. For natural ventilation through operable windows, doors or louvres, the total openable area should be at least 1/25 of the floor area served. Toilets and bathrooms should have at least 0.3 m of window opening area. Air and sound are inseparable. Natural ventilation accompanies noise through an opening.

Gravity ventilation eliminates the need for window ventilation and allow for more flexibility. Gravity ventilation takes advantage of the thermal buoyancy of air. Vents at different levels in an interior space draw cool air in through a lower inlet, while forcing warm air out through the higher outlet. Ventilation chimneys will be used in the performance space, making use of the stack effect. The rate at which air circulates depends directly on the air temperature, the height difference between the two vents, and the size of the vents:

Q = 116 A sqrrt H T   Q = airflow rate (l/s)

A = free area of inlets/outlets, whichever is less (square m)

H = height difference between inlets/outlets (m)

T = temperature difference between incoming and outgoing air (C)

For one ventilation chimney:

A = 0.4 square m
H = 8 m
T = 30C - 21C = 9C

Q = 116 (0.4) sqrrt (8.9)
= 394 l/s

An auditorium needs 8 l/p. For 190 persons it is 1520 litres needed.

For 4 ventilation chimneys = 4 (394 l/s)
= 1574 l/s.

Air inlets should be located as low as possible in areas likely to have low temperatures. Drawing air through underground passageways before it enters a building will cool the air. The vents should be clear of obstruction. Outlets should be located as high as possible and preferably in areas where wind movement can be used to create a suction effect to aid in drawing air through the building. When air is heated it expands. It becomes less dense and more buoyant than colder air. In a space with a high ceiling, air near the ceiling are less dense than air at the bottom of the space. The less dense air rises higher than the more dense air. High density cooler air on the outside of the building envelope will tend to exert pressure against the building at its base, causing infiltration. When this infiltrating air is colder than room temperature, it will be warmed by room surfaces, internal sources of heat, or solar radiation entering through fenestration. As air is warmed, it will rise and escape near the ceiling under the pressure of the warm air behind it, overcoming the lower pressure exerted against the building by the low-density surrounding air.

An induced-draft system is a special kind of a gravity ventilator. A solar chimney is used that, when heated by sunlight, created an additional updraft that pulls a breeze through the chimney. The rate of airflow is proportionally to the intensity of the solar radiation striking the darkened upper part of the chimney.

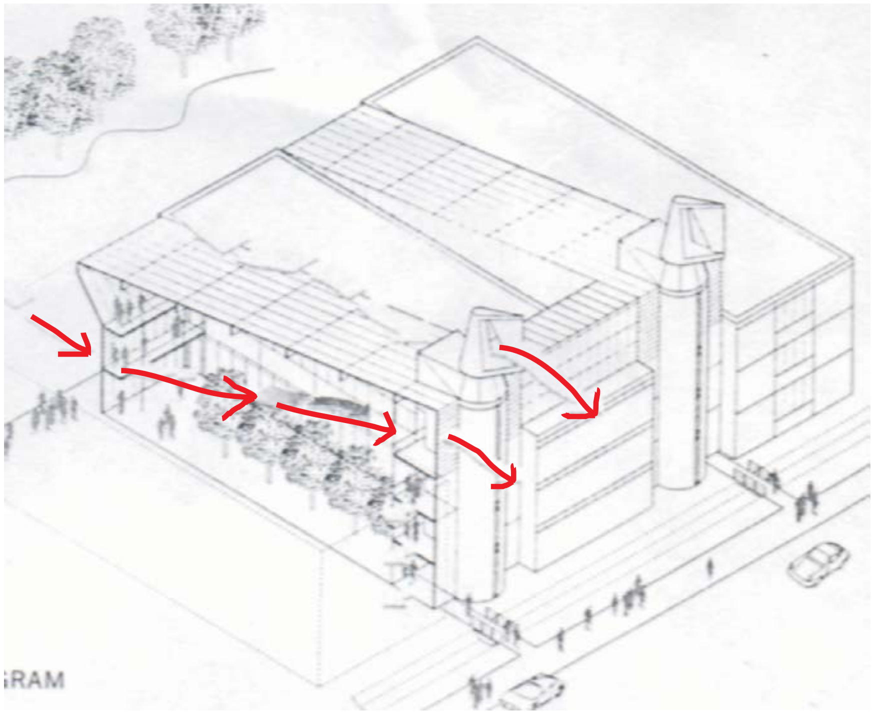


Fig 229. Ventilation chimneys used for ventilation.

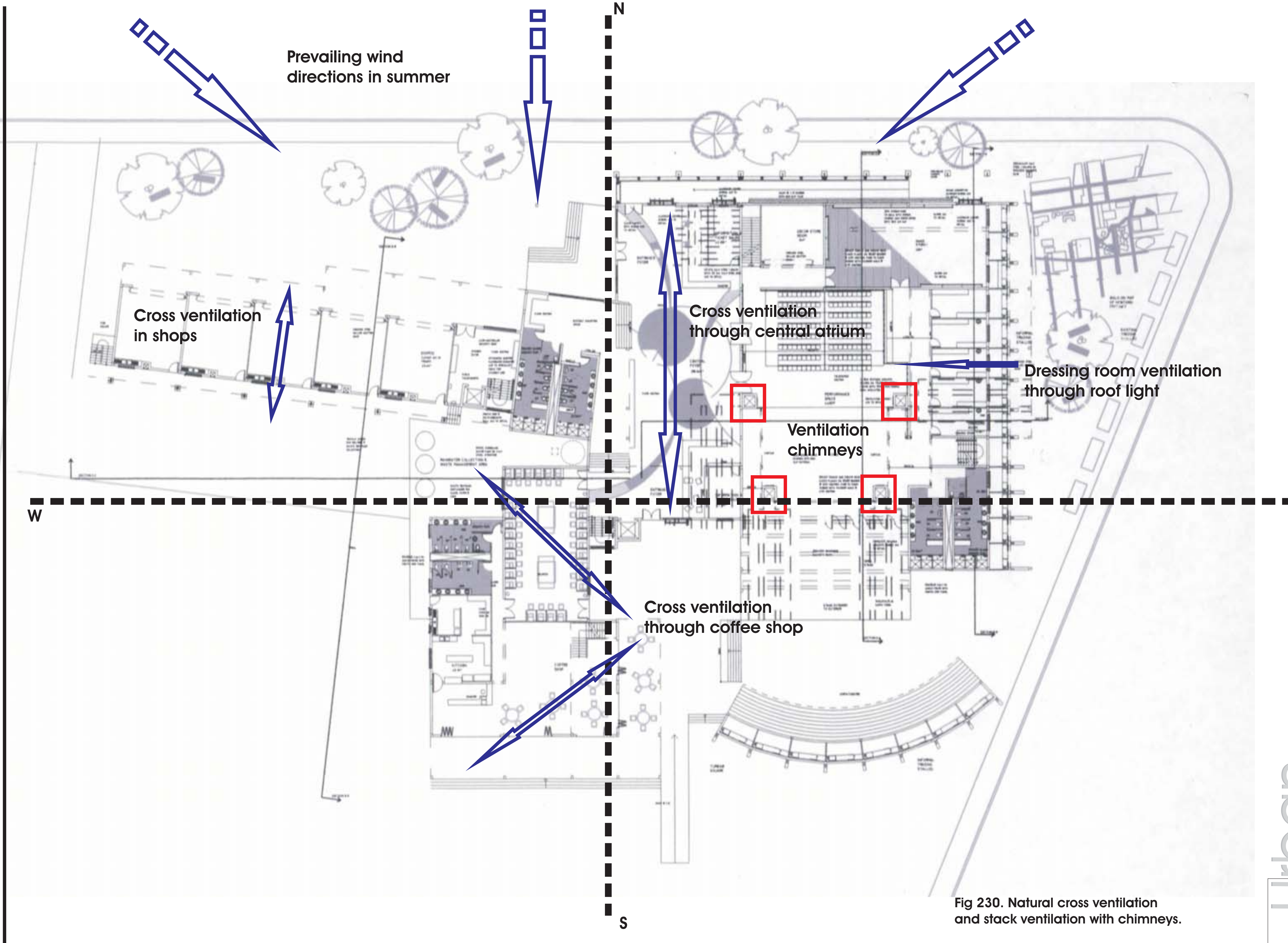


Fig 230. Natural cross ventilation and stack ventilation with chimneys.

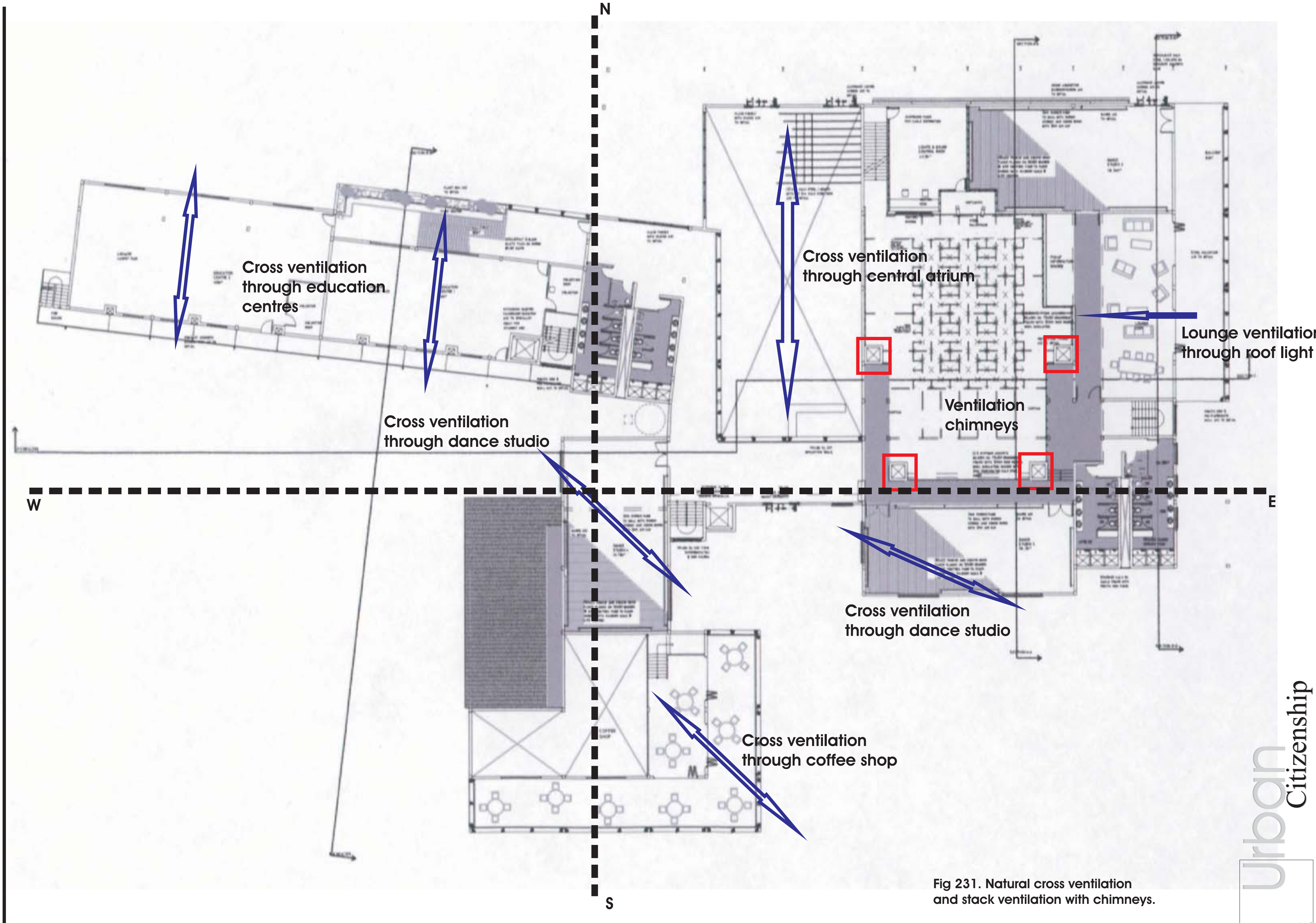


Fig 231. Natural cross ventilation and stack ventilation with chimneys.

Urban Citizenship

The benefits of natural ventilation by means of towers are rediscovered to provide habitable spaces. During the Victorian era, the English became obsessed with clean air and chimneys and towers were not only used as part of ventilation systems, but served as observation points also. After World War II, the advent of central air conditioning and the sealed building, made natural ventilation an anachronism. The use of chimneys for ventilation minimizes rising energy costs. Chimneys and towers are key architectural elements for harnessing pressure differentials by employing the stack effect.

Chimneys are used in a great variety of spaces: from atriums to high-ceiling auditoriums. Chimneys should terminate above the ridge f the roof to prevent being located in a high pressure zone. Hot air may otherwise be pushed back into a space. The top parts of these chimneys are critical in ventilation design. Some towers absorb solar energy and others use tower-top cowlings that rotate in the wind. The four faces of a chimney can be designed to draw in wind regardless of the wind direction. Arup and Max Fordham have developed proprietary computer programmes to help determine tower and chimney parameters (Wilmert, 2000:138). A computer model of the proposed design, with weather data integrated into the program, can simulate the factors determining airflow. Wind-tunnel testing of scale models has proved to be an effective tool to analyze air movement through a building. These vertical gestures can become distinctive elements where architectural design and building service systems are integrated.

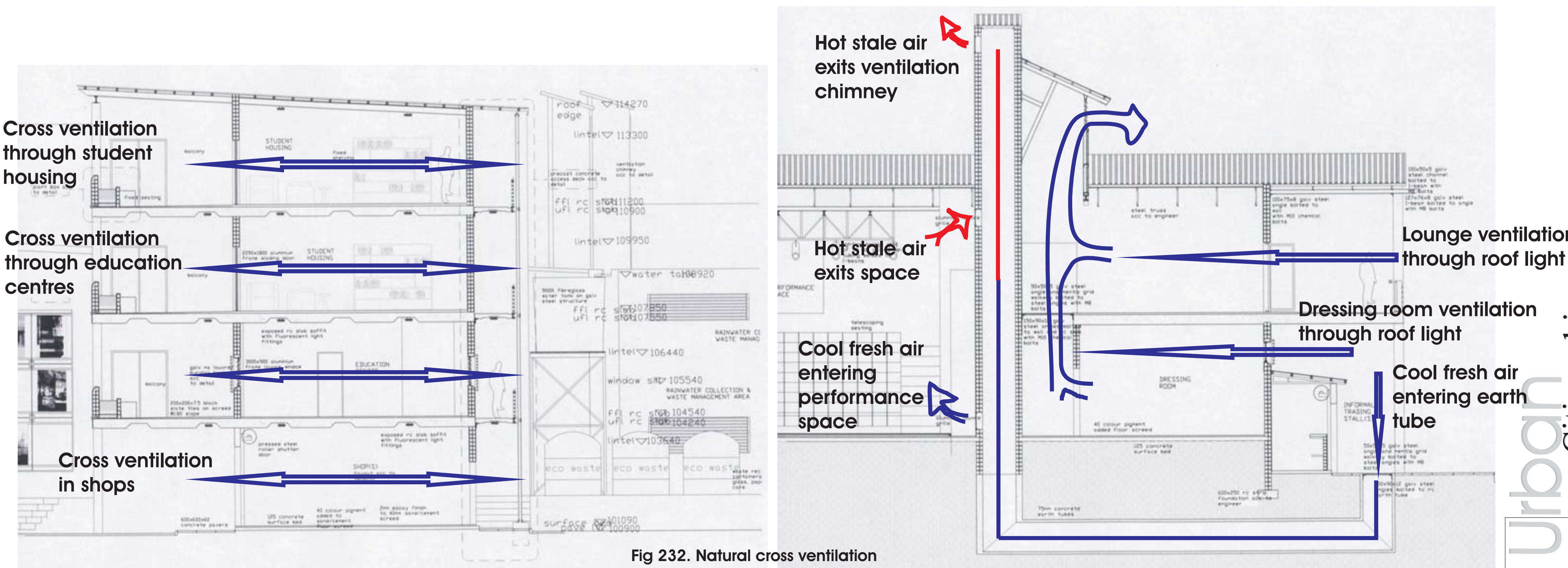


Fig 232. Natural cross ventilation and stack ventilation with chimneys.

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Noise:

Sound affects the occupants of a building in two ways:

- Annoyance with loud noise (unwanted sound)
- The quality of sounds generated within the building.

Vibrations from a source of sound set the surrounding air molecules into a similar physical motion. These vibrations can be transmitted through air or other "elastic" medium, including most building construction materials. Sound vibrations impinging upon the ear create similar vibrations of the eardrum. Sound travels at a velocity of 343 m/s in air at sea level, but much faster in solids. The velocity of sound in structural steel is about 5 000 m/s (Bradshaw, 1993: 430). Sound is identified by frequencies ranging from 20 Hz to about 20 000 Hz.

The range of sound pressures important to us is presented on a logarithmic scale, called the decibel scale. A decibel (dB) is the ratio of sound pressure to a base level chosen at the threshold of human hearing. A 3 dB sound pressure level is barely perceptible to the human ear. An increase in 10 dB is perceived as doubling of loudness (Bradshaw, 1993:434).

The accepted noise levels in dB are:

- Small auditoria, conference, lecture rooms: 45 dB 50 dB
- Bedrooms for sleeping and resting: 30 dB 40 dB (Krige, 200:28)

A source of noise, like a road, is considered as a linear source: the sound is generated along a line . For linear sources, the sound level falls off 3 dB with each doubling of the distance from the line source (Brown,1982 :14.3). The linear sources of noise on the site are the elevated M1 freeway which forms the western boundary of Newtown and Jeppe and West streets north and east to the site.

The average noise level next to the M1 = 73.0 dB (Kirchchofer, 1980:6)

According to the 3 dB fall standard, the noise level from the M1 at the site will be approximately 48 dB. The site is protected by the bulky structure of the Turbine Hall to the west of the site, creating a barrier between the freeway noise and the site.

The noise level is approximately 75 dB alongside a kerbside of a fairly busy street. A rate of 10 vehicles/minute produces 63 dB (Humphrey, 1978,143). These values relate to the traffic circulation around the site. Jeppe Street acts as a linear source of noise to the northern edge of the site. Traffic will rarely travel faster than 50 km/h, because of the pedestrian orientated environment with integrated road surfaces. The performance space will be located on the public corner along Jeppe Street and additional insulation along the northern façade will be necessary.

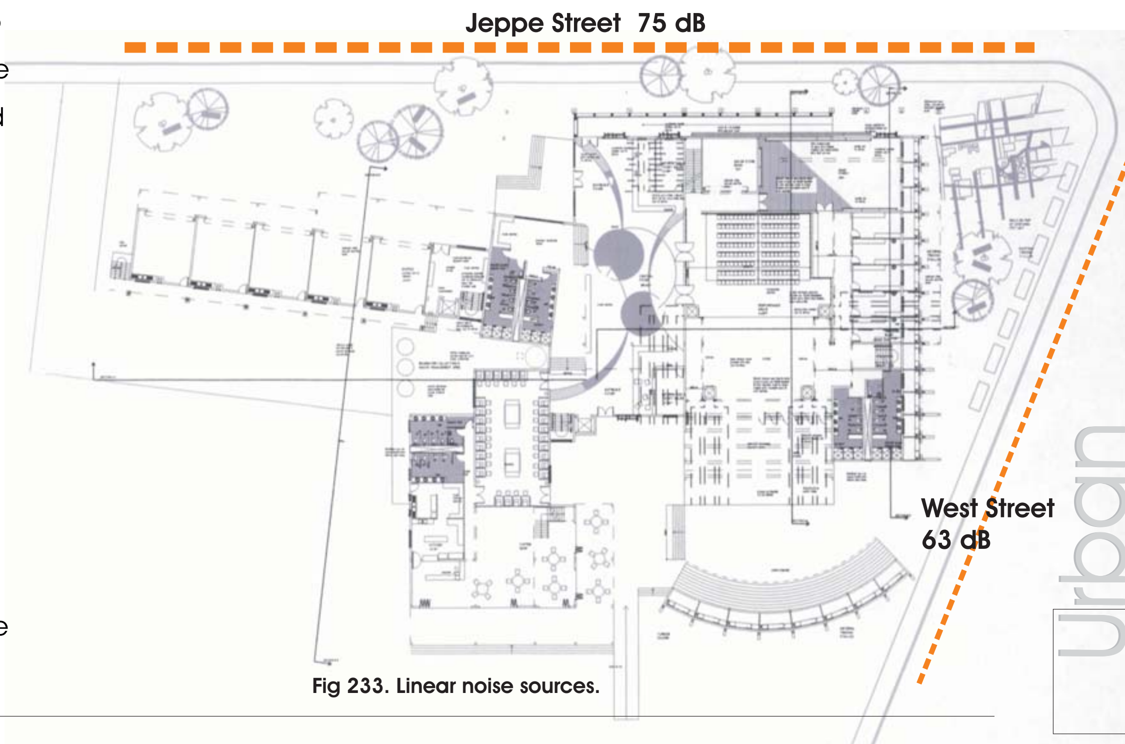

Fig 233. Linear noise sources.

When sound strikes a boundary or surface, part of its energy is absorbed, part is reflected, and part is transmitted through the construction. The sum of all three components is equal to the total incident sound energy. Soft, porous materials, such as wood, fabrics, furnishings and people absorb a large part of the energy striking them.

Sound absorption and sound isolation are two different phenomena. Fiberboard and acoustic tile may reduce the sound energy level within a space, but they do not prevent sound transmission between spaces: they are not good insulators.

The ratio of sound energy absorbed to the sound energy impinging upon a surface is called the absorption coefficient. A sound absorption coefficient of 1 represents total absorption by a material.

Sound transmission from space to space depends on the sound-insulative qualities of the construction between them. The property of the construction materials is known as transmission loss (dB), which represents the difference in sound pressure level between the incident side and the opposite side of the construction. Transmission losses are greater for a more dense, heavy construction. It is more difficult for sound energy to set in motion a heavy partition than a light one. The heavy partition is a better insulator.

Two types of sound absorbers were looked at for the design of the building: dissipative absorbers and panel absorbers. Dissipative absorbers are glass wool, mineral wool, open-cell polyurethane foam and underfelt. These materials have small passages and air-filled cavities that are penetrated by sound energy through the surface of the material. Surface porosity of the material is a requirement to allow sound wave penetration, along with internal porosity. The material must consist of elastic particles or thin fibres, connected to small air passages or cavities for sound to enter and to set these fibres into motion. These materials consist of soft, resilient blankets or panels. Because of finite material thickness, part of the sound energy still pass through the material without being converted into heat. Dissipative absorbers are effective over a wide frequency range and therefore are the most useful and common type of sound absorber with the widest application. These materials are used in acoustic design for the control of reverberation time and noise. They are used in conjunction with insulating materials to construct walls and panels. Semi-open protective covers have no detrimental effect on absorption if the percentage open area is at least 20% (Van Zyl, 2000, 6.2). Acoustically transculant protective covers include:

- Perforated vinyl
- Perforated steel
- Woven cloth
- Shade netting
- Wooden slats with openings
- Expanded metal

The other type of sound absorber is a panel absorber. A sound wave incident on a panel will set it into vibration. A panel over an air gap creates a resonating system with resonance frequency determined by the panel's mass, and air stiffness. If the panel resonates from sound energy, it absorbs energy from the sound wave. Discontinuity in construction is an effective way of improving sound insulation. The wall must be divided into two separate skins. If a wall consists of two layers with an air space between them, both layers must be set into motion in order to transmit sound across the construction. It is very difficult to achieve complete discontinuity: structural connections between solid walls and screens will transmit sound between the surfaces across the space. Typical of such a panel is a plywood panel on a wooden framework or gypsum ceiling boards on brandering.

Description	Frequency [Hz] 125	250	500	1 k	2 k	4k
Hard Finishes						
Brick unplastered	0.02	0.03	0.03	0.04	0.05	0.07
Brick plastered	0.01	0.02	0.02	0.02	0.03	0.03
Concrete smooth unpainted	0.01	0.01	0.02	0.02	0.02	0.03
Concrete smooth painted	0.01	0.01	0.01	0.02	0.02	0.02
Plastered wall unpainted	0.03	0.03	0.02	0.03	0.04	0.05
Tiling glazed	0.01	0.01	0.01	0.01	0.02	0.02
Marble	0.01	0.01	0.01	0.01	0.02	0.02
Steel solid	0.01	0.01	0.01	0.01	0.01	0.01
Steel (1 mm plate) over air space with glass wool	0.20	0.20	0.10	0.02	0.01	0.01
Water	0.01	0.01	0.01	0.01	0.15	0.20
Floors & Floor Coverings						
Floor concrete smooth	0.01	0.01	0.01	0.02	0.02	0.02
Floor tiles glazed	0.01	0.01	0.01	0.01	0.02	0.02
20 mm thick plank floor on joists	0.15	0.12	0.11	0.10	0.08	0.08
Wood block floor on concrete	0.02	0.04	0.05	0.05	0.10	0.05
5mm Cork on concrete	0.05	0.02	0.05	0.15	0.08	0.02
Vinyl on concrete	0.02	0.04	0.05	0.05	0.07	0.04
6 mm Carpet tiles on concrete	0.06	0.06	0.05	0.07	0.10	0.17
10 mm Carpet on concrete	0.02	0.08	0.16	0.35	0.55	0.70
6 mm Carpet on 10 mm Under-felt	0.08	0.24	0.57	0.69	0.71	0.73
10 mm Carpet on wooden floor on joists	0.20	0.25	0.30	0.30	0.50	0.60

Room Contents	Unit	Amount of absorption [m^2] 125	250	500	1 k	2 k	4 k
Air	Per m^3	0.000	0.001	0.003	0.006	0.011	0.029
Seat hard empty	Per seat	0.01	0.02	0.03	0.03	0.04	0.04
Seat hard occupied	Per seat	0.20	0.25	0.38	0.30	0.35	0.30
Seat leatherette upholstered empty	Per seat	0.03	0.05	0.05	0.10	0.15	0.10
Seat leatherette upholstered occupied	Per seat	0.20	0.32	0.38	0.35	0.38	0.38
Seat open weave upholstered empty	Per seat	0.12	0.25	0.28	0.30	0.35	0.36
Seat open weave upholstered occupied	Per seat	0.23	0.37	0.42	0.46	0.45	0.47
Orchestra player with instrument	Per person	0.35	0.75	1.10	1.30	1.20	1.10

Description	Frequency [Hz] 125	250	500	1 k	2 k	4k
Glazing & Curtains						
4 mm Glazing	0.35	0.25	0.18	0.12	0.07	0.04
6 mm Glazing	0.18	0.06	0.04	0.03	0.02	0.02
300 gm/ m^2 Curtain straightened and 100 mm from window	0.03	0.04	0.12	0.15	0.22	0.31
300 gm/ m^2 Curtain 50 % draped and 100 mm from window	0.05	0.20	0.35	0.43	0.50	0.60
Ceilings						
12,7 mm Gypsum on brandering under pitched roof	0.33	0.15	0.08	0.04	0.07	0.09
12,7 mm Gypsum on 38 mm brandering against concrete	0.29	0.10	0.05	0.04	0.07	0.09
Acoustic Tiles and Treatments						
25 mm 40 kg/m^3 Fibretone (perforated vinyl facing) Against concrete	0.08	0.24	0.66	1.12	1.00	0.83
40 mm 40 kg/m^3 Fibretone (perforated vinyl facing) Against concrete	0.20	0.62	1.08	1.19	1.03	1.06
25 mm 40 kg/m^3 Fibretone (perforated vinyl facing) In T-Hangers with 300 mm air space	0.44	0.62	1.00	1.00	1.00	1.00
15 mm_Acoustone In T-hangers with 300 mm air space	0.26	0.20	0.30	0.44	0.55	0.69
6 mm Plywood over 60 mm empty air-space	0.30	0.22	0.15	0.09	0.05	0.02
6 mm Plywood over 60 mm air-space filled with glass wool	0.40	0.25	0.15	0.09	0.05	0.02
Glass wool						
50 mm Aerolite against solid backing	0.36	0.34	0.74	0.87	0.85	0.95
50 mm 24 kg/m^3 Glass wool against solid backing	0.27	0.37	0.89	0.98	0.94	0.97
100 mm 24 kg/m^3 Glass wool against solid backing	0.74	0.40	1.11	1.11	1.06	1.04
50 mm 48 kg/m^3 Glass wool against solid backing	0.23	0.47	1.09	1.05	1.02	1.08
100 mm 48 kg/m^3 Glass wool against solid backing	0.83	0.78	1.20	1.09	1.07	1.15
Mineral wool						
50 mm 60 kg/m^3 Mineral wool against solid backing	0.28	0.60	0.99	1.06	1.02	1.02
100 mm 60 kg/m^3 Mineral wool against solid backing	0.69	1.13	1.08	1.04	1.05	1.02
50 mm 80 kg/m^3 Mineral wool against solid backing	0.24	0.57	0.93	1.00	0.96	0.93
100 mm 80 kg/m^3 Mineral wool against solid backing	0.65	1.13	1.08	1.02	0.99	0.99

Fig 234. Sound absorptive materials.

A sound-absorptive barrier will be needed along Jeppe Street. A double-perforated sheet metal barrier or screen filled with insulative material fixed unto the northern façade of the building, and adjoining the performance space, works as a combination of the above principles. Perforated sheet metal can be used for the front layer and a solid panel for the back layer. Light, rust-free materials will be best. The internal space contains mineral wool or any other noise-absorbing material. This type of barrier is the best suited for the urban context. Close inspection should be made of the urban fabric, materials and cultural context, seeing that such a barrier will be a visual feature along Jeppe Street. The barrier can reflect the proportions of the Turbine Halls broken windows, which are a recognizable trait of the old building. The most effective design will respect the integrity of the materials used. A bold, visually coherent solution can be created by keeping lines simple and strong. The simplicity of form and line may be enlivened by using contrasting materials and colours to accent and punctuate the overall design. Metal surfaces can contrast with off-shutter concrete and bright painted steel supports.

Other factors were considered in the design of the sound screen or barrier:

- In urban areas, where there is often a jumble of built forms and a clutter of urban paraphernalia, such as signage, poles and lighting, with a juxtaposition of often discordant materials, a screen with strength of form and a simple design, may be better suited.
- An angled barrier tends to have a more dynamic and designed appearance and makes more of a visual statement. Most barriers are tilted 3 to 15 degrees (Kotzen and English,1999:76) from the vertical, depending on the materials and supports used and the height of the barrier.
- The structure of the barrier may be used as a functional as well as an aesthetic element. The structure may have an important visual function, which defines the character of the barrier. The structure can be either emphasized or down-played, or concealed within the façade to give a seamless appearance to the barrier.
- Where more than one layer of material is used on a barrier, the visual transition between the two layers are important. The first layer can be more visually penetrable than the second layer.
- Barrier design is generally based on the repetition of panel and structure. This strategy is important in keeping down cost and providing visual continuity. Such a surface can become visually boring. This can be prevented by using layering, periodic focal points along the length of the barrier or the rhythmic patterns such as staggered openings punched into layers.
- Patterns of light and shade create a vibrant surface. Patterns should be bold and an integral part of the overall design of the building. The barrier faces north and will receive direct sunlight at different angles. Light falling unto the barrier can create pleasing effects, which alter according to the strength of the changing light, the weather, the angle of the sun and time of the day. This allows a barrier to become more visually complex and interesting, especially when placed in an urban context where views are most likely to be from close up for longer periods of time, like the people slowly moving up the ramp and becoming aware of surfaces an textures around them. Visual complexity is important in these locations in order to avoid visual sterility.
- The texture of the barrier is defined by the material make-up. People moving up the ramp should become aware of the texture of materials.
- Colour are also determined by material, but can be altered with paint, stains or anodizing. A metallic colour gives a high-tech engineered appearance. A surface that gives the appearance of older, stained metal will show its respect to the urban context, seeing that the design will also reflect the proportions of the Turbine Hall's broken windows. Bright colours imply conscious design and the making of a statement. Colouring posts of a barrier red, states that the barrier has some visual or architectural merit. Off-shutter concrete colours, greys, red brick and earthy colours and metallic sheens fit in well with the urban context of Newtown.

Architectural acoustics is concerned with the behavior of sound in closed spaces, where sound is acted upon by the room boundaries. The acoustical objective for an auditorium space is low background noise so that music can be heard clearly. The performance space is insulated against external noise with 12.5mm gyptone acoustic board backed with 50mm rigid mineral wool insulation material. Absorbent materials can be used on surfaces to control echoes. Gyptone acoustic board control echoes. Absorptive materials should not be used inside auditoriums to lower background noise. Absorbent materials should only be used to control reverberation time and echoes. The surrounding construction must be able to exclude enough unwanted background noise by means of absorbent treatment.

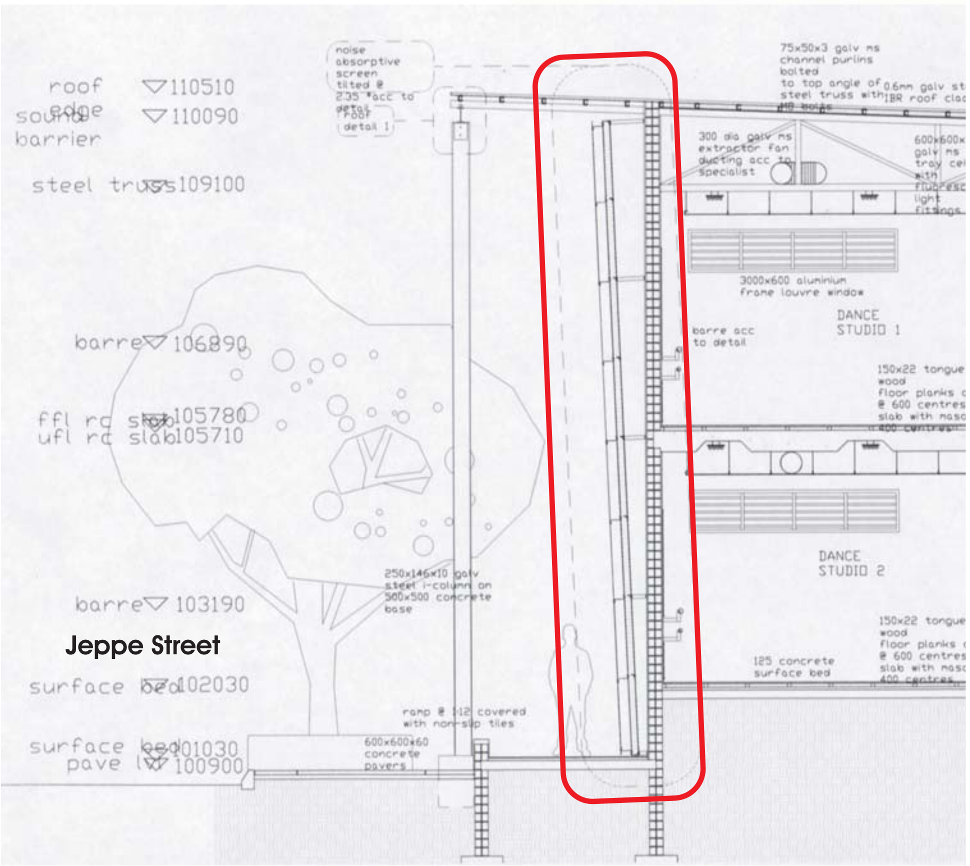

Fig 235. Noise absorptive screen

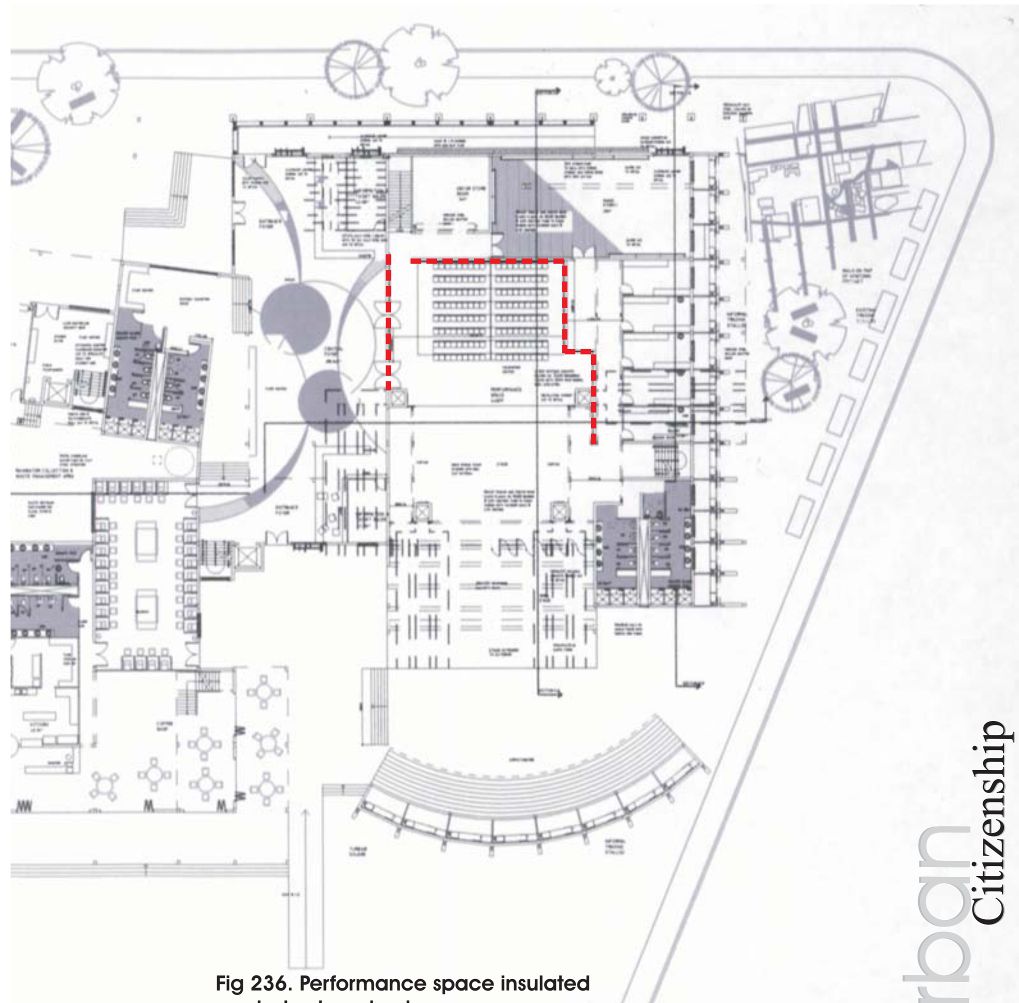

Fig 236. Performance space insulated against external noise

Views:

All living, working and circulation areas have access to a view outside. The student housing units and education center have balconies facing north, looking out onto Jeppe Street. The southern side of these units comprise of an access corridor that look out unto the Turbine Square. The central atrium is highly open to views towards Jeppe Street to the north and to the amphitheatre and Turbine Square towards the south. The northern façade adjoining the performance space is a solid wall that conceals the activities inside the building to the visitor moving up the ramp to the entrance. This creates anticipation to a point of focus where the interior of the atrium space is revealed. The Turbine Square can also be seen right through this space. The southern wall of the building opens up towards the public environment of the Turbine Square. The amphitheatre integrates the public environment into the atrium space of the building. A progressive flow from inside to the outside of the building is created. All users are situated not more than 6 m from a window with a view.

Access to green outside:

The public will have access to green outside spaces that integrates and form part of the public environment. Tree-lined streets like Jeppe and West Streets provide cool comfortable spaces during hot summer months. Shade will also be provided in the amphitheatre during summer where visitors can socialize while enjoying the outside dance performances.

Inclusive environment:

Buildings should be designed to accommodate a wide variety of activities, users and times of usage.

Public transport:

There has to be a focus on public transportation for two main reasons. Firstly, a vast percentage of residents will never be able to afford a private car. Secondly, it is more efficient to move a number of people in one public vehicle than having numerous, usually single occupant, private vehicles clog the roads. The building is located within 100 metres of a disabled accessible public transport system. A bus stop is located in West Street adjoining the Turbine Square. This stop is located within 50 metre of the building. The minibus-taxi routes are as pervasive in the area as the bus services. The minibus routes converge on the CBD as the major interchange center for their services, and many ranking facilities, such as the Metro Mall, are within one city block of the site.

Fig 237. View out unto Jeppe Street from balconies

Fig 238. Amphitheatre space as transitional link between interior of building and public square.

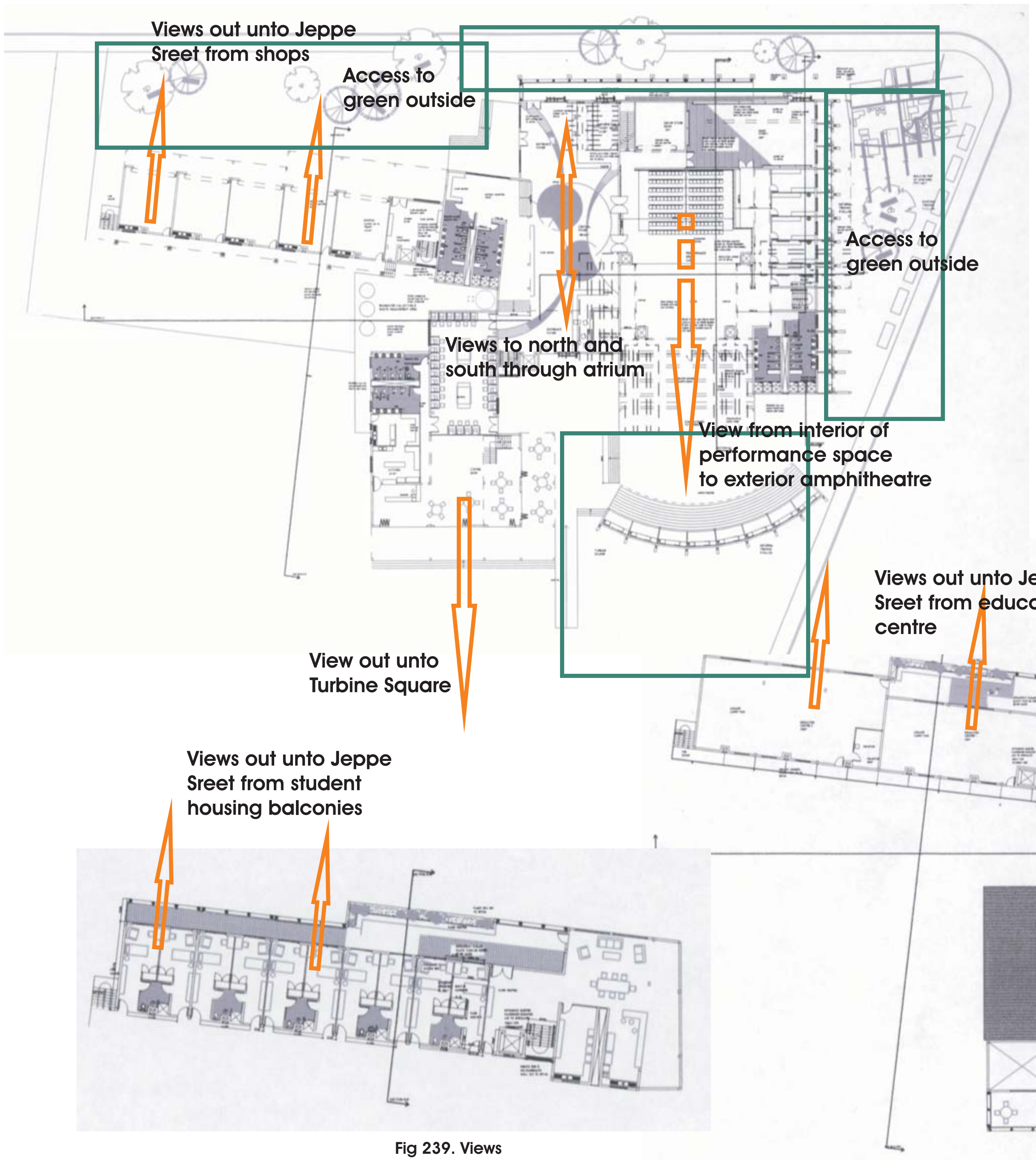
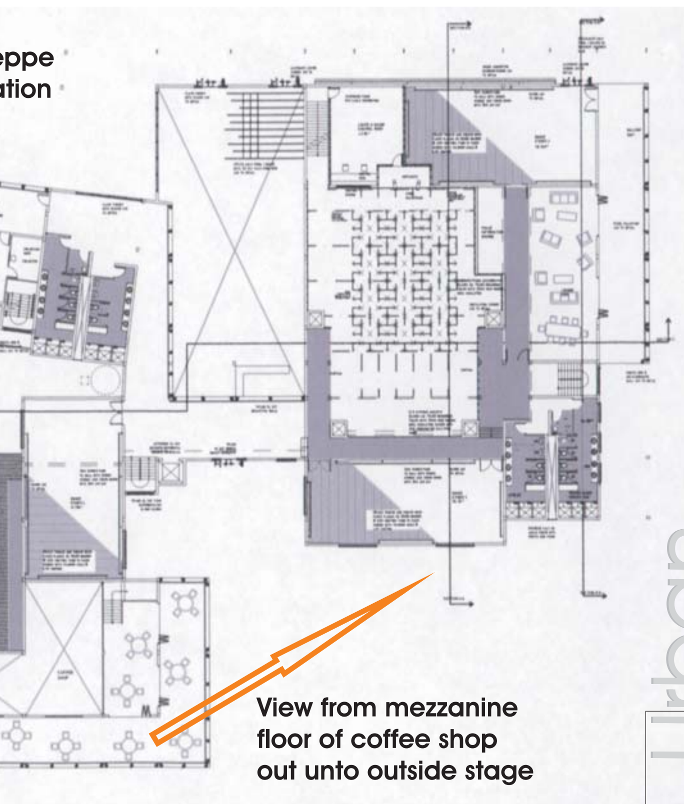

Fig 239. Views

Fig 240. View out unto Turbine Square from coffee shop