BUILDING MATERIAL INTERRELATED TECHNOLOGICAL INNOVATION- HIGH-TECH ARCHITECTURE

A MASTER THESIS IN ARCHITECTURE

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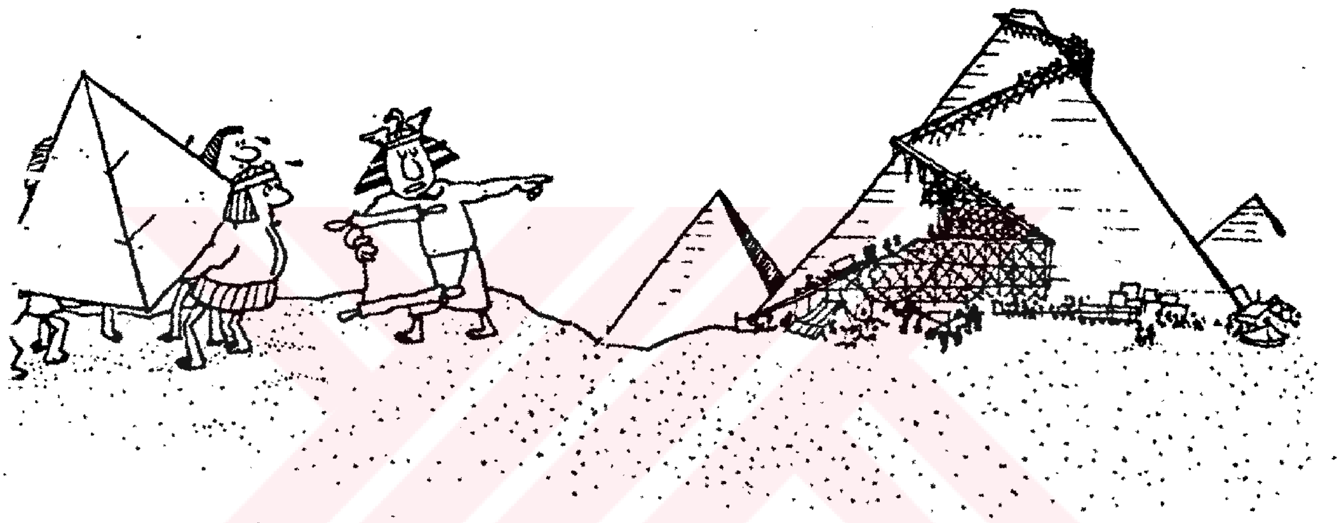

ABSTRACT

This study emphasizes on the importance of the building technology and its materials in architecture.It shows the inseperable relation of building material to architectural realizations through historical precedence,in acclaim of architecture of the future lies in the rational inventions of its materials.The intented aim of the thesis is the learning process of the building science,thus achieving a good command of its materials.

Finally,the study evaluates the form of thought in high-tech architecture -being a building mechanism of component parts in which the building materials and its structures' technological innovations play the leading role- to eventually demonstrate the benefits and opportunities this technology has to offer,in a proposal of a design project.

ÖZET

Bu çalışma,mimarlıkta,yapı teknolojisinin ve malzemelerinin önemini vurgulamaya yönlendirilmistir.Geleceğin mimarisinin yapı malzemelerinin rasyonel kullanımlarında olduguna inanan bir düşünce formunu karşılamak ve bunu sağlam bir temele oturtmak için,çalışmada tarih içinde yapı malzemesi ile mimari yapıtların gerçekleştirilmesi arasındaki bağ incelenmistir.Çalışmanın amaci yapı biliminin öğrenilmesi ve irdelenmesi ve bunun sonucununda tasarımlara daha verimli bir sekilde aktarılmasıdır.

Son olarak çalışmada,bir bütünlestirici parçalar sisteminden oluşan ve malzemelerin ve strüktürlerin teknolojik yeniliklerinin en önemli rolü oynadığı bir bina mekanizması olan High-Tech Mimarlık düşünce formu değerlendirilmiş ve bu sistemin getirdiği avantajlar ve imkanlar önerilen bir proje de sunulmuştur.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PICTURES

1. INTRODUCTION

Architecture, in the largest sense, is the total of all those spaces man has created for his own use. A building, as a product of architecture and as an object that defines and encloses space, reflects the society of its time more than any other art form. The meaning of a building is transmitted by the function it has to serve and the materials it is constructed in.

Isolated from society, man will instantly start repeating the architectural history whether he seeks a shelter in the cave, stretches a tent, fells a tree, or even burrows into the earth. But architecture is something beyond the necessity for elementary shelter. As primitive man developed, architecture had to develop in order to serve man's other requirements of spaces to meet his inner needs both as a complex psychological animal and as a creature whose ultimate values are of the spirit (1). Throughout the history, while the cultural and territorial transformations have resulted in todays' different building typologies, all built to satisfy the two basic human needs - the secular and the sacred, the technical transformations advanced the materials and introduced new ones.

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(1) JONES CRANSTON, Architecture Today and Tomorrow, London : McGraw Hill, 1961, p.1.

This thesis is an investigation into the new technologies and the new materials applicable to building industry starting from the so-called first machine age of the 18^{th} century, extending to our day. The final aim is to have an understanding of the materials and to find a rational system of building using the advantages of the 21^{st} century's technology to be eventually demonstrated in application in the design and project execution of a contemporary building type.

The study consists of three parts, in which the first investigates building materials such as iron, steel, concrete, glass and plastics and the design possibilities in these materials. It recalls history, to look into the correspondance between the architect's attitude to space and the choice of materials and techniques used to define and articulate it. In the second part, a certain system of building is decided on and explored further. The last part undertakes the application of this system to propose a building concept.

The author's opinion is that, architects must be technically knowledgeable or at least ought to have a clear understanding of modern building techniques. As all attempts to reconcile architecture with art will fail, so long as technology remains unrelated to the process of artistic design. There can be no architecture without technology to translate architectural concepts into physical reality.

2. TECHNOLOGICAL CHANGES AND EFFECTS ON ARCHITECTURE

Man, from the past to the present, has changed the form of the earth's resources to satisfy his wants. The way man makes these changes is called technology (2).

The term `technology´ is derived from the Greek technè meaning `art´ or `craft´, but it is generally used in either of two or more restricted senses. In the narrower sense, `technology´ refers only to the industrial processes that succeeded craft operations. In the wider sense the term `technology´ refers to all processes dealing with materials (3).

`Technology´ is rooted in the past. It dominates the present and tends into the future. It is a real historical movement - one of the great movements which shape and represent their epoch.

It can be compared only with the classic discovery as man as a person, the Roman will to power, and the religious movements of the Middle Ages.

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(2) G.DONALD LUX and E.WILLIS RAY, The World of Construction, Ill.U.S.A. : McKnight and McKnight, p.1.
(3) The Encyclopedia Americana, U.S.A. : Grolier Ltd., 1977, Vol.26, p.357.

Technology is far more than a method,it is a world in itself.As a method it is superior in almost every respect.But only where it is left to itself,as gigantic structures of engineering, there technology reveals its true nature...

Whenever technology reaches its real fulfillment,it trascends into architecture (4).

The revolutionary advances in technology,has provided a great initial stimulus for the architecture of our time.From an elementary shelter in a cave,to the building types characteristic of our age,the evolution of architectural forms have depended heavily upon the expenditure of technical and material resources.Architects of every era have derived inspiration from the technical mastery of the new materials that technology has brought.

While considering some abstract design parameters such as context,style,time and function,architects had to consider three factors in making their initial choices of the materials to be employed : availability,physical properties and cost.In a pre-industrial society the availability of natural materials has been of great importance in determining the style and scale of any building.The nature of buildings,were determined not only by

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(4) L.MIES VAN der ROHE,Technology and Architecture,Programs and Manifestos,Cambridge,Mass. : U.Conrads ed.,1970,154 Extract

qualities which may be described as social and spiritual,but also very much by the technical qualities (5).

However,the Industrial Revolution in the 18th century,brought in many additional factors such as technique,structure,geography and appropriateness,while also bringing new materials and construction systems for buildings.

In spite of the growth of mass transportation,particularly in the 19th and 20th centuries where materials could be moved from one side of the world to the other with more ease,through the constraints put by other factors,buildings of the same typology were realized in certain material types.Different techniques both for processing and assembly were developed in order to achieve the same building typologies.Geological conditions put their constraints particularly where height and weight were of concern. Climatic conditions have dictated different obligations and thus brought in their own different solutions.The demand for appropriateness and styles have developed certain material to become endowed with particular meaning through their continued use.

The problems of weight and mass that had limited architecture in the past were overcome when the industrial age provided us with two materials of great strength,both with the

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(5) J.J.P. OUD,Architecture and Standardization in Mass Construction,DE STIJL,1918,Vol 1 No.7,pp.77,79.

ability to be economically employed in tension and compression for continuous structures : steel and reinforced concrete.It became possible to achieve greater structural efficiency with less visible efforts,greater heights and spans,the enclosure of more space with less mass,and greater flexibility in the enclosure of that space (6).

There were other changes in architecture.The new general situation created by the industrial and social revolutions provided a multitude of new building tasks.The church and the palace lost their importance as leading powers and during the 19th century the monument,the museum,the dwelling,the theatre,the exhibition hall,the factory and the office building in turn took over their roles.Each of these tasks as well as their temporal succession,indicates the rise of a new form of life based on new existential meaning.The monument represents the wish for a return to original archetypal forms.The museum was conceived as an 'aesthetic church',where all the works of man were brought together.In the dwelling the small and commodious space of the private world was understood as a symbolization of the truth.The theatre was,where human feelings found their dramatic manifestation.The exhibition finally represented the economic values of the new capitalist society,and the factory and the office building its productive forces (7).

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(6) PAUL HEYER,<u>Architects on Architecture</u>,Toronto : McLeod Ltd.,1966,p.14.
(7) NORBERG CHRISTIAN SCHULZ,<u>Meaning in Western Architecture</u>,New York : McMillan Pub.Co.Inc.,1980,p.173.

2.1. BUILDING MATERIALS

2.1.1. IRON AND STEEL

2.1.1.1. THE MATERIAL

Iron,although it is an element,in commercial usage has other materials in small quantities in its constitution.Of the varying amount of these elements,its mostly carbon that forms cast iron,wrought iron or steel.Cast iron is the most resistent to corrosion and the easiest to make,so its major use in building predates steel : wrought iron is the easiest to work ; steel is the strongest but unfortunately the quickest to corrode.

As building materials,iron and steel were very different from the materials that the construction industry had used before.With the appearance of these new materials,for the first time a new architecture could be realized.The inseperable relation between material and shape,structure and form could be reinvestigated.Where in the past buildings had been essentially forms of compression,discontinuous structures of material,built by placing one element upon another,iron and steel were forcing for new techniques to be developed.Earlier changes such as the introduction of brick in late medieval England,had not implied a new architecture,as they could be used for load bearing walls in much the same way as the stone buildings that they superseeded.

Being much stronger and more expensive than any of the previous materials that had been used in the building industry, iron and its derivates resulted in being used as linear members, first as tie bars, then as columns and finally as complete frames.

2.1.1.2. EARLY USES AND DEVELOPMENTS

2.1.1.2.1. IRON

With iron, an artificial building material appeared for the first time in the history of architecture: It went through a development whose tempo accelerated during the course of the century. This received its decisive impulse when it turned out that the locomotive, with which experiments had been made since the end of the twenties : could only be utilized on iron rails. The rail was the first unit of construction, the forerunner of the girder. Iron was avoided for dwelling houses, and made use of for arcades, exhibition halls, railway stations, buildings which served transitory purposes (8).

BRIDGES :

Renaissance buildings made use of iron for the rods across arches and for chains around domes, but it was not until late in the 18^{th} century when Abraham Darby (1711-63) at Coalbrookdale, began smelting the ore with coke instead of charcoal and as a result increased dramatically the quality of iron, that the opportunity of

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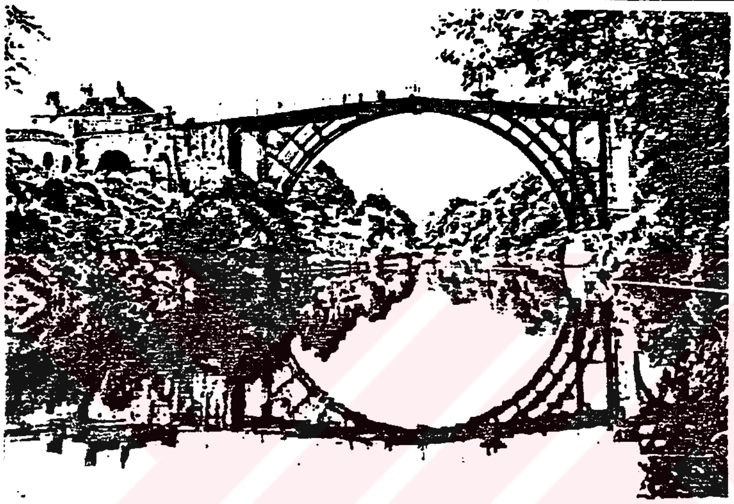
(8) WALTER BENJAMIN, `Paris : Capital of the 19^{th} Century, New Left Review, March - April 1968, No 48.

the structural use of the material arose.Between 1770 and 1772, St.Anne's Church in Liverpool was built with cast iron columns, and during next half century the material was developed first for the bridge over the Severn and then for nearby factories in Shrewbury and Derbyshire.Darby and his architect,T.F.Prichard, designed the first cast iron bridge,a 30.5 mt span,weighing 378 tons,built over the Severn near Coalbrookdale in 1779.



Picture (1) : Coalbrookdale Bridge over the Severn

In 1778,Thomas Telford,increased the structural efficiency of the material by far.His Buildwas Bridge of 39.5 mt erected over the Severn weighed only 173 tons.

FACTORIES :

In 1769,Richard Arkwright,patented his water frame,which set the British textile industry on a century of world superiority and produced a situation where small scale operations were no longer economic : from the time of his patent,work was increasingly concentrated and the factory,a new building type came onto the scene.This new type of building because of some of the specific functions associated to it,created new problems.Fire hazards,caused a stackle in the entire development of the Industrial Revolution in England.The first solution was presented in William Strutt's six storey Calico mill,1793 in Derby ; columns were cast-iron,of cruciform section to give maximum strength without the casting difficulties of hollow,round columns.Timber beams spanned between these columns and between these were vaults of hollow pot construction levelled with sand and paved with bricks.The underside of the beam which would otherwise have been exposed,was plastered and then covered with sheet metal for fire protection (9).

Another major step in technology was taken in 1797,by Charles Bage.His flax mill at Shrewsbury was constructed with an internal frame completely of metal.Fireproofing led to the use of stone stairs,cast iron window frames,voulted floors and roof.

It was in the year of 1840 that the first multistorey completely metal frame building came into being.William Fairbairn,built a prefabricated mill with outside walls of iron plates and shipped it to Istanbul for erection there.

Designing with heavier loads,and greater openings led

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(9) MICHAEL FOSTER,The Principals of Architecture,Style,Structure and Design,UK : Phaidon Press Ltd.,1983,p.112.

engineers to experiment with the standard wrought iron angles and plates that were then being used in ship-building.

In 1860, Naval Dockyard at Sheerness went up. This remarkable four-storey cast and wrought iron framed building was employing the I-sections in its rigid connections to take the wind loads. The Boat Store, clad with corrugated iron in its systematic use of iron I-sections throughout, anticipated both the standard section and the assembly method of a modern steel frame construction.

As the use of iron in building increased, the surface of glazed areas expanded. By mid-century, for the rapid prefabrication and erection of urban distribution centres - market halls, bourse exchanges and arcades - cast iron columns and wrought iron rails in conjunction with modular glazing had become the standard technique of building.

The prefabricated nature of these cast-iron systems guaranted not only a certain speed of assembly but also the possibility of transporting building kits over large distances : from mid-century on, the industrialized countries began to export prefabricated cast-iron structures to all over the world (10).

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(10) KENNETH FRAMPTON, Modern Architecture, a Critical History, London : Thames & Hudson, 1980, p. 33.

EXHIBITION HALLS :

This prefabricated cast-iron system,in the year of 1851, marked a turning point in the history of modern architecture. Paxton,commissioned to design Crystal Palace,was able to present, in just eight days,an enormous orthogonal three tiered glass house.It was the first great official building which omitted all references to past styles.His scheme,was a masterpiece of standardization.Iron columns,girders and glass panels were made with coordinated dimensions,and were prefabricated in three months.Afterwards it took another three months to erect the immense structure,and the finished plan was received with great acclaim.

Architecturally,the Exhibition Building was a novelty.It was called the Crystal Palace because of its lucidity.The contrast between light and shade,characteristic of stone architecture,was cast aside and a building of shadeless light created.The profound effect of the Industrial Age on architecture was dramatically demonstrated.Here was the first architectural expression of that age,using the means which industry provided.Like the railway buildings,to which it was related,it was a highly flexible kit of parts (11).

Its construction requirements included studies which indicated that for every handling no part should weigh more than

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(11) L.HILBERSHEIMER,Contemporary Architecture,its Roots and Trends,Chicago : Paul Theobald Co.,1964,p.34.

one ton and the greatest economies could be obtained by using glass panels of the largest possible size (12).

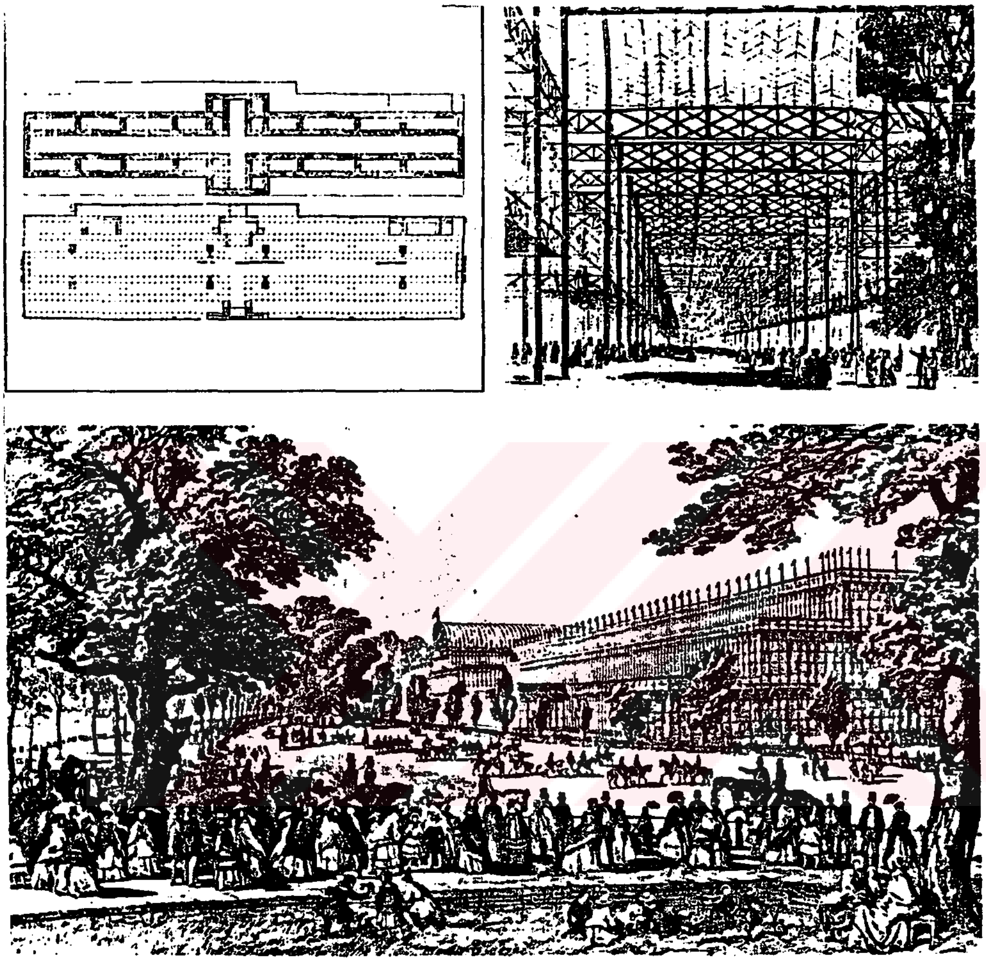


Figure (1) : Joseph Paxton,Crystal Palace,London
Ground floor plan,interior and
general view

(12) KONRAD WACHSMANN,Wendepunkt im Bauen,(The Turning Point of Building),1961.

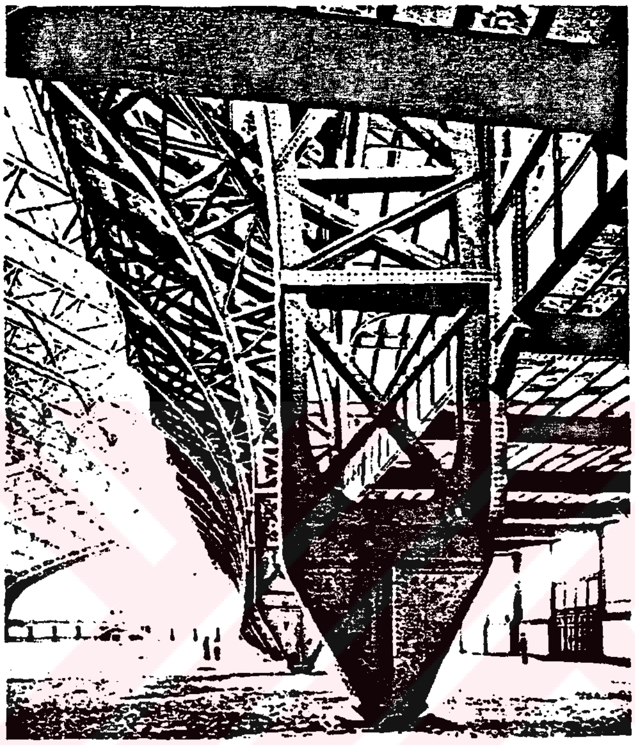
2.1.1.2.2. STEEL

Cast-iron,as a building material,had a rapid and indiscriminate spread.The spread of steel was a slow and carefully guided process,and thus mercifully free from disasters.

Structural steel,although it first appeared in Britain, through bureaucratic obstacles put by the Board of the Trade,had not been put into practice.It was in 1865,in Holland,that the first bridge using Bessemer steel was built.In 1874,Captain Eads fully demonstrated the qualities of the material,using chrome steel in his bridge over the Mississipi at St.Louis.In Britain,the Forth Bridge designed by J.Fowler and E.Baker,(1883-1890) was put up thus defeating the officials.

Steel was used likewise in the building of Exhibition Halls.After the British,the French launched five major international exhibitions between 1855 and 1900,which gave rise to the most remarkable structures that French engineering was ever to achieve : Victor Contamin's vast Galerie des Machines,107 mt in span,designed with the architect C.L.F.Dutert ; and the Eiffel Tower,300 mt high,designed in collaboration with the engineers Nougier and Koechlin and the architect Sauvestre.

The Galèrie des Machines,built in 1899,in Paris realized for the first time on a large scale the full innate possibilities of steel construction : the 107 mt were achieved by three-hinged girders.The functional shape of these girders reduced the height of the hall to less than half its width.The high enclosed space resulting from this construction was a great technical achievement.



Picture (2) : Victor Contamin,Galèrie des Machines,Paris,1899

2.1.1.3. AMERICAN USE OF IRON AND STEEL

SKY-SCRAPERS :

While in Europe iron and steel were being exploited through their continuous use in bridges,mills,exhibition structures, arcades,market halls and railway stations,in America the major contribution to building in iron and steel was made in high-rise buildings.

James Bogardus,as early as 1848,had worked out a system of prefabricated iron facades and columns that had spread the mode for iron store-fronts across the United States.These cast-iron pillars and other structural members proved to be highly vulnerable to fire,as one disaster after another demonstrated.But they did make iron and glass familiar construction materials for a whole generation of American architects.

The tall commercial building arose from the pressure of land prices,the land prices from pressure of population from economic pressure (13).In the decade 1880-1890 Chicago's population had doubled to reach one million and was still growing. Land in the central business district was extremely scarce,and the only way to expand was up.So pressing was this need that Chicago architects been attempting the seemingly impossible,mounting higher and higher with masonry walls whose immense weight caused some buildings to sink as much as 50 cms into the ground.But it was inherent in the nature of masonry construction to fix a new limit of height ; as its ever thickening walls ate up ground and floor space of ever increasing price (14).

So,the Chicago architects of the 1880 had no choice but to master the advanced modes of construction.The subsequent development of the fireproof steel frame with its ability to

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(13) LOUIS SULLIVAN,Essay,AIAJ,New York,1922-23
(14) Ibid

provide multistorey rentable space,enabled speculators to develop downtown sites to the absolute optimum.The desirability of natural light for commercial office buildings gave architects the initiative to reduce the structural members and their dimensions as much as possible,filling the voids of the slender structural cage with large horizontal expanses of glass sheets - the 'Chicago window' (15).

The first major use of steel in a conventional structure came up with William le Baron Jenny's Home Insurance Building in Chicago.Completed in 1885,it was also the first of the true metal framed high-rise buildings.The first five floors were built with cast-iron columns and wrought iron beams,but the next five floors were built with Carnegie steel beams.His Manhattan Building,of 1891 had a lighter structure accepting the wind loads through the frame by deep connections on the upper floors and by concealed steel diagonals at the groundlevel.

The sky-scraper building evolved,to introduce the riveted connections as in the Tacoma Building of 1899,and in the following Marquette Building by Holabird and Roche.

But the most skilled of all the architects of these American sky-scrapers was the firm of Adler and Sullivan.Their

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(15) PAUL HEYER,<u>Architects on Architecture</u>,Toronto : McLeod Ltd.,1966,p.20.

Auditorium Building of 1889 : a complex of an office block,a hotel and an auditorium,stood as a structure whose overall contribution to Chicago culture was to be as much conceptual as technological. The whole complex was housed in a massive masonry and iron structure,ingeniously ballasted during construction so as to compensate for the differential loading on its foundations.

Picture (3) : Louis Sullivan,Auditorium Building,Chicago,1886-1889

Likewise the Wainwright Building at St.Louis (1891) also of Sullivan,is credited with the evolution of an architectural language appropriate to the high-rise frame in addition to being a technological achievement.The facade which is no longer arcaded,is articulated by girdered piers clad by brick ; while transoms are recessed and faced in terracotta so as to fuse with the fenestration.The piers rise out of a sturdy looking two-storey stone base and terminate abruptly at a massive and ornate terracotta cornice (16).

Sullivan's Wainwright Building,followed by the Guaranty Building in New York (1895) and Carson-Pirie-Scott department store in Chicago (1898),all contributed towards a clear expression of the fire-proofed metal frame,as far as it was possible within the means of the time.

Jenney's Fair Department Store, opened in 1891 was employing all the structural features of the modern fire-proof high-rise building ; box columns,girders and beams of I-section, tile arches,portal bracing,riveted joints,fire-proofed tile cladding,and concrete subflooring (17).

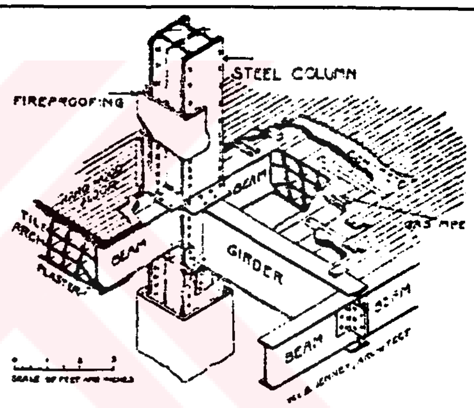

Figure (2) : Jenney,Fair Store,Chicago,1890-91 Detail of fire-proof steel frame construction

The first complete steel frame high-rise building in New York was probably the American Surety Building at Broadway designed by Bruce Price.

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(16) KENNETH FRAMPTON,Modern Architecture,a Critical History, London : Thames & Hudson,1980,p.55.
(17) W.CARL CONDIT,American Building,London : Chicago Press Ltd., 1968,p.127.

The success of steel in the sky-scrapers carried on with : Cass Cilbert's Woolworth Building reaching 60 storeys (1913), William Van Allen's Chrysler Building with 77 storeys (1929), Harmon's Empire State Building was completed in 1930,topping up 102 storeys.

2.1.1.4. USE OF STEEL IN CONTINENTAL EUROPE AND THE MODERN MOVEMENT

While the Americans developed the steel frame in daring sky-scrapers,and the English built their first tentative steel buildings,the continental Europeans,in early years of this century,were taking the first steps towards the creation of a new architecture.A faith in new technologies was a corner stone of the new modern movement.Steel and concrete were to be enjoyed for their own sakes.The cloaking of a steel frame in traditional stone work was seen as a crime (18).

However,the first use of iron was realized in the tenuous forms of the Art Nouveau.The Belgian Victor Horta treated iron as though it were an organic filament insinuated into the fabric to subvert the inertia of stone.In his project hotel Tassel,an octagonal vestibule on the ground floor rose upwards through a half level towards the garden,it expanded laterally into an

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(18) MICHAEL FOSTER,The Principles of Architecture,Style,Structure and Design,UK : Phaidon Press Ltd.,1983,p.119.

adjacent foyer space covered by an iron superstructure.The free standing columns of this space,embellished with iron tendrils,echo similar serpentine forms throughout the rest of metal work (19).In his Tassel house of 1897,masonry pillars had been replaced by an exposed metal frame work which is reinforced here and there by colonettes.

Guimard's Paris Metro stations entrances (1899-1904),were made of interchangeable standard iron pieces,cast in the form of naturalistic elements and framing enamelled steel and glass (20).

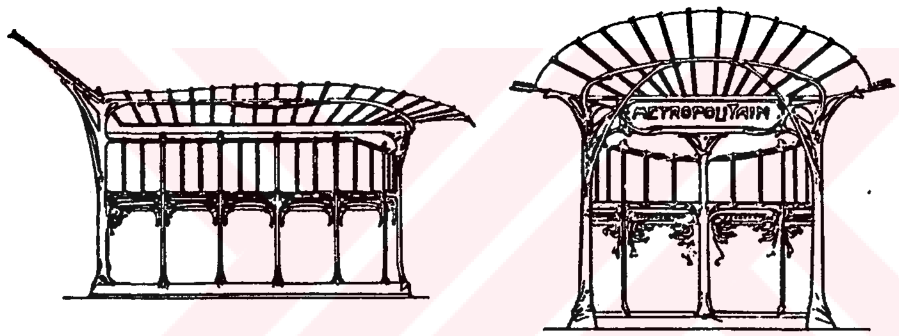

Figure (3) : Guimard,Iron and Glass Metro Entrances,Paris,1880-1904

Berlage's Amsterdam Stock Exchange Building completed in 1903,has exposed steel trusses in an expansive,sophisticated space.Berlage's passionte belief in revealing materials and construction led him to display the trusses as they were - undecorated and uncovered.

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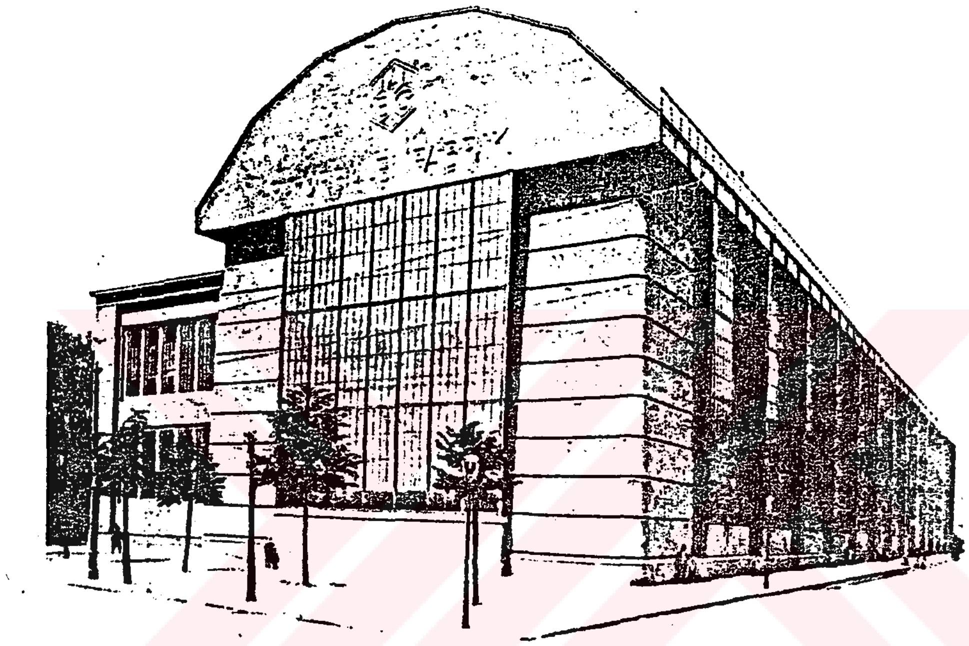
(19) SISSON THIBAULT,An Innovator : Victor Horta,<u>Art et Decoration</u>,Jan-June 1897,Vol 1,pp.11,18.
(20) KENNETH FRAMPTON,<u>Modern Architecture,a Critical History</u>, London : Thames & Hudson,1980,p.70.

Still another reverence to the nature of steel was shown in Peter Behrens' Turbine House for AEG (1909).The rivets,the glazing bars and the hinged bases to the frames are all treated towards the expression of the material,even though the massive concrete corners were a reminder of the masonry construction.



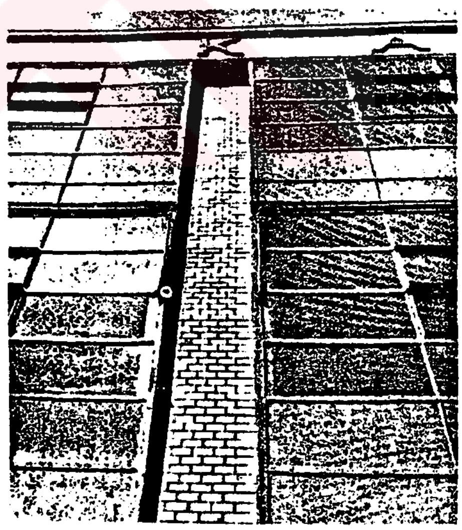
Picture (4) : Peter Behrens,AEG Turbine Factory,Berlin,1908-09

In the Faguswerk (1911) Gropius and Meyer,still keeping the corners to retain the same composition,were replacing masonry with glass.The vertical panels of glazing,set forward from the battered brick facing,gave the illusion of being miraculously suspended from the upstand at roof level.

Gropius said of the steel-framed building,"the role of the walls becomes restricted to that of mere screens,stretched between the upright columns of the frame to keep out rain,cold and noise" (21).

Arthur Korn and Ludwig Mies Van der Rohe are two,who broke away from the international style to explore the possibilities of expressing the steel structure.

The Fromm Rubber Factory (1930),of Arthur Korn's at Kopernick constructed of red painted steel with white glazed brick infill ; first building to express the steel frame as a regular cage,was taking the expression of multistorey steel structure as far as it could go until the acceptance of welding which was developed in Mies Van der Rohe's buildings.


Picture (5) : Gropius and Meyer,Faguswerke,1911

Mies' 1929 Barcelona Pavilion and his Tugenthat house (1930) in Brno - Czechoslovakia,used cross shaped columns and sheathed them in chromium-plated steel.In the Barcelona Pavilion,space defining screens were combined with a regular steel skeleton which gives order to the free plan,achieving a synthesis of the two main innovations of the 19^{th} century : the open,repetitive order of

(21) MICHAEL FOSTER,The Principles of Architecture,Style,Structure and Design,UK : Phaidon Press Ltd.,1983,p.120.

skeleton construction,and the fluid but articulated space.Eight columns supported a flat roof slab,beneath which non-structural walls,placed close to columns and continuing out beyond the roof slab to accentuate their fundamental difference,created a rich and dramatic space sequence (22).Mies was fully aware of the importance of his achievement and said : "The free plan and a clear construction cannot be kept apart.The structure is the backbone of the whole and makes the free plan possible.Without the backbone the plan would not be free and therefore constipated " (23).

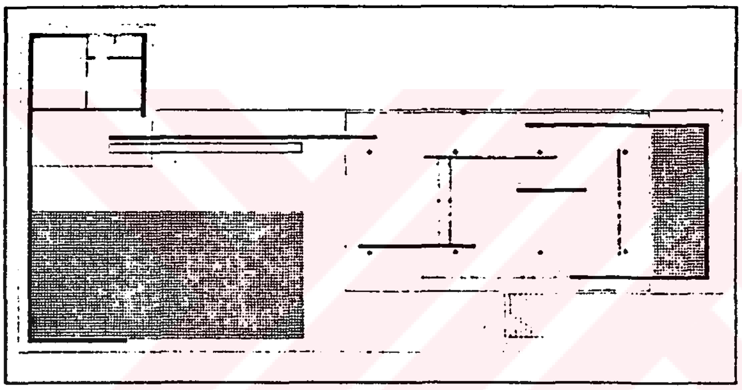


Figure (4) : Mies Van der Rohe,German Pavillon,Barcelona,1929

2.1.1.5. CONTEMPORARY REALIZATIONS

Mies Van der Rohe's entry for the Reichsbank competition of 1933 was the beginning of a transformation in his work,from informal asymmetry to symmetrical monumentality.This move towards

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(22) PAUL HEYER,Architects on Architecture,Toronto : McLeod Ltd.,1966,p.30.
(23) CHRISTIAN NORBERG SCHULZ,Talks with Mies Van der Rohe, L'Architecture d'Aujourd'hui,'79,p.100.

the monumental eventually culminated in the development of a highly rationalized building method that was widely adopted in the 1950's by the American building industry and its corporate clientele (24).For Mies,architecture was an expression of the essence of the 20^{th} century in terms of technology,science and economics (25).Mies speaks of his I.I.T. campus buildings : "Structural architecture was the obvious answer.It doesn't cost as much,and it lasts longer.It is based on logic,not impulses" (26).

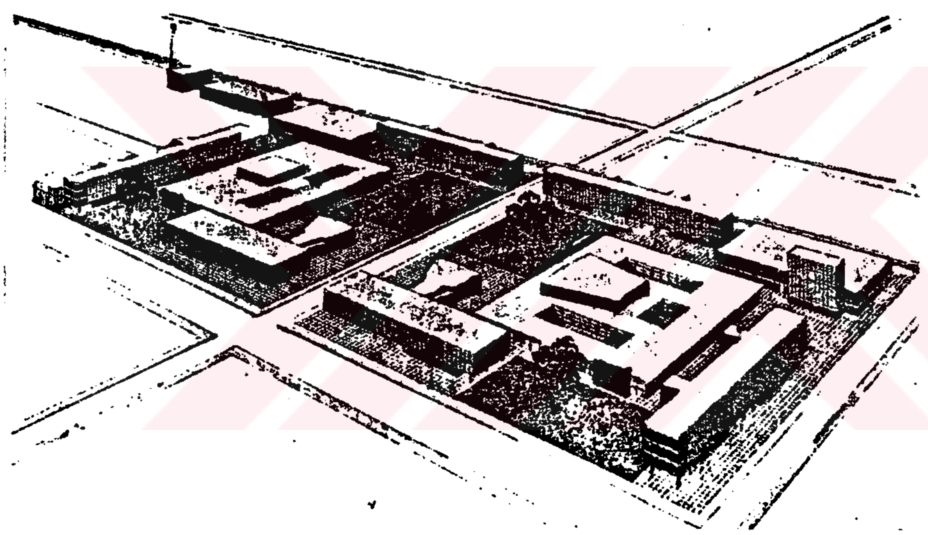

Figure (5) : Mies Van der Rohe,I.I.T. Campus, preliminary scheme,Chicago,1939

Illinois Institute of Technology (1939-58),most of which was built during the 1940's,was unified by a grid spread over the

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(24) KENNETH FRAMPTON,Modern Architecture,a Critical History, London : Thames & Hudson,1980,p.232.
(25) L.MIES VAN der ROHE,Address to the Illinois Institute of Technology,1950.
(26) L.MIES VAN der ROHE,Report,Time.

site.All the structures were four storey high and rendered as pure prisms,faced in graph paper curtain walls,their surfaces animated by skyscape reflections.Mies explains : "It is radical and conservative at once.It is radical in accepting the scientific and technological driving and sustaining forces of our time.It uses technological means but it is not technology" (27).

The design of exposed steel frame and brick infill dates from Arthur Korn's Kopernick factory,but in the intervening decade the all welded structure had become feasible.This meant that the detailing at I.I.T. could be neater and waterproof joints could be made,enabling rolled sections to be built up and exposed on the outside of the building.

The Minerals and Metals Research Building (1943) was the first to be completed and set the grammar of the structural frame both inside and outside.The structural system was the essential element : this,rather than craftsmanship,individual genius,or the function of the building,determined the form (28).

The library (1944),using the same design,had rolled sections joined by continuous welds to give members a complex profile,which held the brick infill clear of the columns,emphasizing the direction of span.The proposed clear structural span was 20 meters with glass panels measuring 5.5 x 3.7 meters and a single triple height volume 91 x 61 meters in

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(27) PAUL HEYER,Architects on Architecture,Toronto : McLeod Ltd.,1966,p.31.
(28) JONES CRANSTON,Architecture Today and Tomorrow,London : McGraw Hill,1961,p.64.

plan,broken only by a floor to floor book stack,an enclosed court and the suspended mezzanine (29).The Alumni Memorial Hall (1946) ,built with structural steel encased in concrete,presented the first fireproof steel building which looked like a steel building. This fireproofing concrete was faced with steel,which formed part of a light-steel framework on the outside of the columns (30).

Mies'Farnsworth house,860 Lake Shore Drive,and the Berlin National Gallery made steel a major architectural material and brought forth a language of its own.In his Farnworth house,which was finished in 1950,Mies set up eight 6.6 mt steel columns which are welded to the fascia beam above,achieving open,usable space, unhindered by columns,where function could be defined by flexible room dividers and furniture grouping.Mies also insisted that there be no difference between the principles of industrial and domestic construction.The all steel and glass sky-scrapers,the 860 Lake Shore Drive Apartments,erected in 1951,were arranged as two identical towers,set at right angles.Mies points out : "A clear block or tower is a clear shape,this was the strongest form : it made the clearest shadow.The strongest shape for a building is the best shape for communicating strength (31).The strength of the steel beams used,allowed for apparent lightness.Steel is apparent in the facade,with vertical I-beams welded to the steel frame

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(29) KENNETH FRAMPTON,Modern Architecture,a Critical History, London : Thames & Hudson,1980,p.233.
(30) MICHAEL FOSTER,The Principles of Architecture,Style,Structure and Design,UK : Phaidon Press Ltd.,1983,p.121.
(31) JONES CRANSTON,Architecture Today and Tomorrow,London : McGraw Hill,1961,p.66.

where they can act as stiffeners and also serve as mullions for the floor-to-ceiling glass. In effect, the esthetic from the vocabulary of standardized steel shapes, was borrowed to force steel to produce its own decorative motif. The structural frame and its glass infill become architecturally fused, each losing a part of its particular identity in establishing the new architectural reality. The mullion has acted as a kind of catalyst for this change. The columns and mullion dimensions determine the window widths (32).

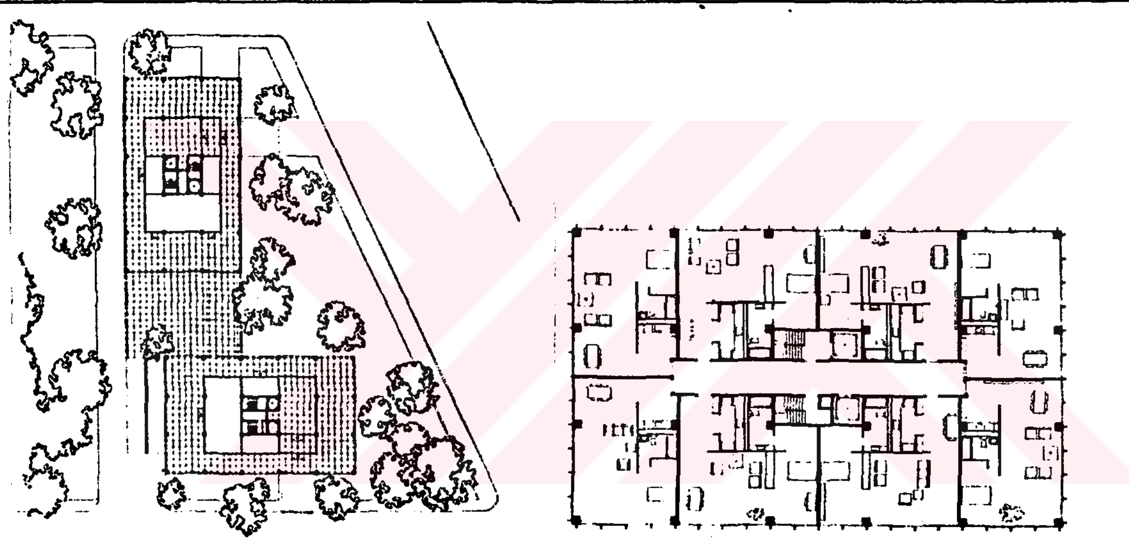


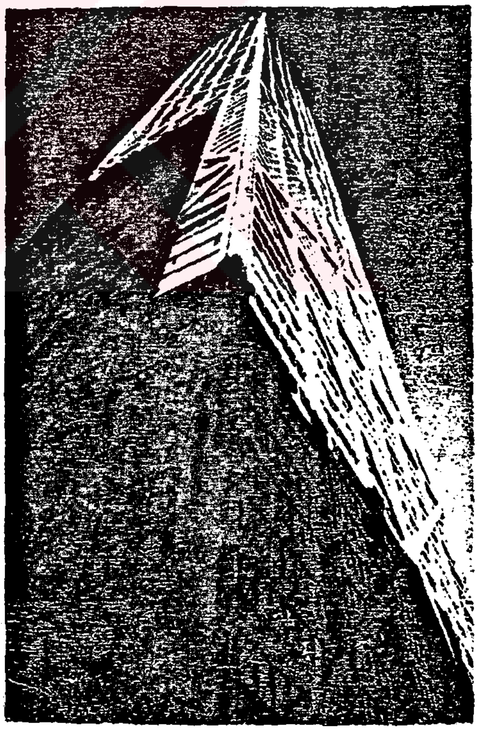
Figure (6) : Mies Van der Rohe, 860 Lake Shore Drive, Chicago, 1948-51, Ground plan of towers and typical floor plan

Mies moved steadily in the direction of creating an architecture that would be in essence an unobstructed space : "Universal Space". His plan for Chicago's Convention Hall, a project dated 1953, calls for a single space frame, square in plan 216 by

(32) PETER CARTER. <u>Mies Van der Rohe at Work</u>, London and New York : 1974.

216 meters,to provide an assembly area for 50.000 people without any interior columns.Mies' concept of "Universal Space" realized in steel,as a basic guiding principle,is one of the most influential in mid-twentieth century architecture.It also marks the halt of the theory of functionalism as one of the strongest determinants in modern building design.

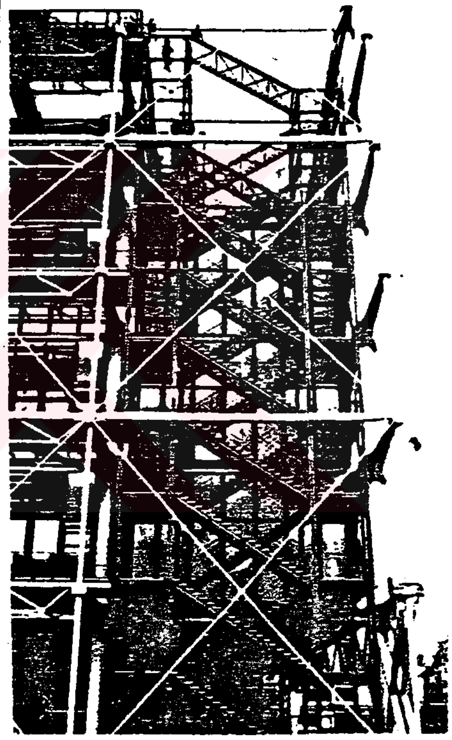
Ever since the Manhattan Building of Baron Jenney,steel-framed buildings had relied on diagonals to take the horizontal loads of wind and earthquake,but these diagonals had been hidden. In the 1960s Goldsmith and Fazler Khan,investigated the possibilities of very tall buildings ; and showed that lighter steel could be used if horizontal loads were taken by diagonals.Skidmore,Owings and Merril's Hancock building on Chicago's north side in 1972 was exposing the diagonal tubes to take the horizontal loads of wind,using an optimized column-diagonal truss tube.The tower for Sears,of the same architects,currently the tallest building at 110 storeys,was relying on a cluster of nine cellular tubes,giving it its structural efficiency.The completion of these two buildings has marked the culmination of Chicago's century of leadership in the techniques of high-rise steel construction.



Picture (6) : Skidmore, Owings and Merrill, Hancock Center, Chicago,1968-1970

The energy crisis of 1973,made some architects believe that only intelligent and highly sophisticated ways of building will allow the economic use of resources.Influenced by Mies,they aim towards machine made structures and the hard edge ; influenced by Eames they aim towards the use of a multitude of tiny parts : influenced by the space programme they show a love for services, pipes and high technology imagery ; adding all up to this color and sheer playfulness which is completely new to architecture.

Centre Pompidou,erected in 1977, in Paris,designed by Richard Roger and Renzo Piano,exemplifies this latter approach throughout its design.As opposed to the type of modern architecture that covered the whole structure with a curtain wall and suspended ceiling, Centre Pompidou displays all that goes on : brightly colored air handling pipes, circulation routes and a very complicated but clearly revealed steel frame.It is a brilliant de-tour-force in advanced technique,looking like the oil refinery whose technology it attempts to rival (33).



Picture (7) : Piano and Rogers,Centre Pompidou,Paris, 1975 - 1977

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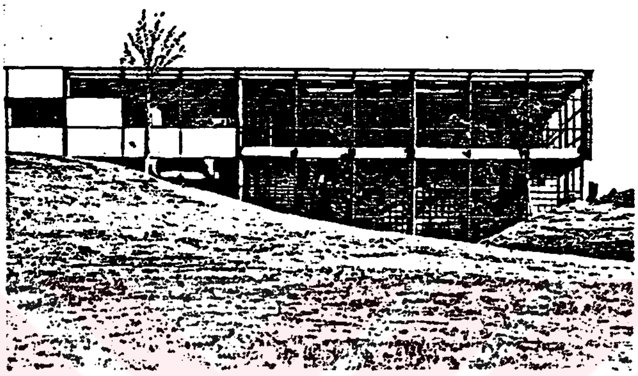
(33) KENNETH FRAMPTON,Modern Architecture,a Critical History, London : Thames & Hudson,1980,p.284.

The Pats centre in Melbourn-Cambridgeshire by the same architects, presents a system that was set up to accept and accommodate random changes. The light steel frame for the office floor, enables not only the rooms and the work patterns to change, but less usually, the exterior, too. A gasket can be unzipped to replace a glass panel for porcelain enamelled steel panels.



Picture (8) : Piano and Rogers, Pat's Centre, Melbourne-Cambridgeshire, 1976

Roger's former partner, Norman Foster has also produced fine buildings in the hard edge tradition. The Sainsbury Centre for Visual Arts, on the University of East Anglia Campus in Norwich (1976-77), is one of the most dramatic of modern steel buildings.

From the extraordinary accomplishment of Chicago : starting with Jenney's Home Insurance Building, to today's ultimate space structures, steel frame, offered unparalleled flexibility in dealing with the structural problems that were associated with buildings designed to house a diversity of functions. Steel technology continues to evolve, offering a lot of innovations to be made, not only as a technology but also in the way that technology is being expressed.

2.1.2. CONCRETE

2.1.2.1. THE MATERIAL

Concrete, is a composite material whose key ingredient is a binding medium in which small pieces of rock or other materials are embedded. The small pieces are called aggregate ; the binder is a cementing material (34). Like plastics, it is a composite ; unlike plastics, its constituents which are three basic components : cement, aggregate and water, are to be found in their natural state. The term "concrete" generally refers to the portland-cement concrete.

The essential feature of concrete is that, it has a great strength in compression, but very little in tension or shear. The modular elasticity of concrete is also exceedingly low and inconstant. However, the insertion of steel rods, wire or mesh into the concrete mix, completely transforms the performance of the material. Previous deficiencies in tension and shear are made good, so that the material is capable of spanning.

Concrete is the most versatile and widely used building material. It is used in dams, canals and aqueducts ; in highways, pavements and sidewalks ; and in buildings, bridges and other structures, both as a structural and as a decorative material. Where

(34) The Encyclopedia Americana, U.S.A. : Grolier Ltd., 1977, Vol.7, p.507.

concrete is not used as the primary structural material, it may be used for fireproofing or soundproofing. Concrete also acts as a shield against damaging nuclear radiation.

2.1.2.2. EARLY USES AND DEVELOPMENT

Concrete is the oldest synthetic material used in the building process, going back to some 2000 years. Reinforced concrete on the other hand, has a relatively short history and is quite a different sort of material. The Romans, who must be credited with inventing concrete, mixed an aggregate of broken stones or bricks with lime and sand ; allowed it to set, which process resulted with a strong and durable stone-like substance. With this early type of concrete, they built arches, domes and vaults that were often cast in one solid mass.

As iron technology developed through the exploitation of the earth's mineral wealth, so did concrete technology, too : a floor construction of concrete infilling and iron girders (Dr.Fox, 1844) ; "fireproof construction" in the form of concrete reinforced with wire rope (W.B.Wilkinson, 1854) ; and the basic principles of reinforced concrete (Francois Coignet, 1855) were the patents coming in towards the end of the Industrial Revolution. The first consequential use of this new material was made by Francois Coignet. In 1861, he developed a technique for strengthening concrete with metal mesh.

Setting out from Coignet's invention,Francois Hennebique, resulted with the systematic exploitation of modern reinforced concrete technique in 1879.Before Hennebique,the great problem in ferroconcrete had been the provision of a monolithic joint. Hennebique overcame this difficulty through the use of bars of cylindrical section which could be bent round and hooked together. Integral to his system alone was the cranking up of reinforcement bars and the building of joints with stirrup hoops in order to resist local stress (35).Hennebique's success of reinforced concrete boosted with the great acclaim it received in the Paris Exhibition of 1900 ; two years later his firm had grown into a large international concern.

In the United States,William Ward was building houses of reinforced concrete as early as 1870.In his own house the floor slabs rested on concrete beams massively reinforced with wrought-iron I-beams ranging in depth from 12.5 cms to 18 cms and located in the lower half of the concrete member,where the tensile stress is concentrated (36).In 1890,the engineer Cottancin,in France,was introducing a new system called the ciment armè,depending on the combined reinforcement of concrete and brick.The bricks

Figure (7) : Hennebique Francois, Monolithic reinforced concrete joints

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(35) KENNETH FRAMPTON,Modern Architecture,a Critical History, London : Thames & Hudson,1980,p.37.
(36) W.CARL CONDIT,American Building,London : Chicago Preee Ltd., 1968,p.170.

were bonded into the concrete with wire reinforcement ; while the ferroconcrete element was maintaining the structural continuity in areas of high tension,brick predominated in areas of compression. In 1902,E.L.Ransom,the inventor of twisted reinforcement,erected a 16-storey sky-scraper (91 meters) in Pennsylvania.In 1904,John Brodie,put up a three storey tenement block that anticipated "large panel" systems by nearly 50 years.Each of the six sides of the rooms was precast,conveyed to the side by traction engine and erected by block and tackle (37).

2.1.2.3. THE USAGE OF CONCRETE IN THE MODERN MOVEMENT

After the achievement of the great engineers,a new generation of engineers and architects exploited the potential of the new material : Perret and Le Corbusier in France,Frank Lloyd Wright in America,Behrens,Gropius,Steiner and Mendelsohn in Germany,Loos in Austria,Maillart in Switzerland,Torroga in Spain,Candela in Mexico,Niemeyer in Brazil,and Nervi in Italy. Although the earliest forms of reinforced concrete had followed the pattern of iron and timber construction,these master-builders brought structural solutions and shapes,stretching the performance of the new material to its limits.

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(37) MICHAEL FOSTER,The Principals of Architecture,Style,Structure and Design,UK : Phaidon Press Ltd.,1983,p.128.

2.1.2.3.1. IN ENGINEERING

Robert Maillart,a great Swiss engineer,was demonstrating his characteristic bridge form at Tavanasa built in 1905 : consisting of a three hinged arch of a hollow box section with triangular openings cut,into its sides to reduce unnecessary weight and to give a light and expressive character to the overall form.

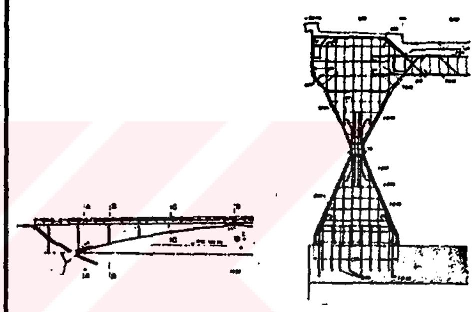

Figure (8) : R.Maillart, Aare Bridge,Vessey 1936

Maillart,realizing the secret of reinforced concrete : that steel rods and bulk concrete both expand and contract at the same coefficient, thus creating a monolithic material, experimented with laying the reinforcing rods in a crisscross fashion,resulting in a slab so strong that it could be used without the supporting beams.He also considered that,bending the rods through the junction between the top of the column and the slab,made an extraordinarily strong connection (38).

His beamless floor slab system,first used in Europe in 1912 in his five storey warehouse in Altford,was an advancement over the mushroom slab construction developed slightly earlier by the American engineer,C.A.P. Turner.In Turner's "four-way" reinforcement,the bars were required to pass all column heads,

(38) JONES CRANSTON,Architecture Today and Tomorrow,London : McGraw Hill,1961,p.205.

resulting in an uneconomical depth for the floor slab to accommodate the steel and to resist the tendency of the column pinching through.Maillart's "two-way" system was reducing the shear and the dimensions of both the slab and column heads,thus resulting in a lighter structure.

In his Aare Bridge at Aarburg,built in 1911,the bridge platform was articulated from its supporting arch while the platform was stiffened through transverse frames set into the haunch of the arch.In all his bridges,the platform was designed as a box section so that,as far as possible,the road bed was self-supportive.

In 1916,the French engineer Freysinet,built two gigantic airship hangars at Orly which unfortunately,were destroyed in the last war (39).These vast structures,each 62.5 meters high and 300 meters long,were one of the first attempts to design monolithic structures whose assembled elements were capable of supporting themselves.The problem of the intense compressive and tensile stresses induced in the curing and loading of large parabolic arches,led Freysinet by the mid 1920's to experiment with the artificial inducement of stress in the reinforcement before casting (40).

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(39) MICHAEL FOSTER,The Principals of Architecture,Style,Structure and Design,UK. : Phaidon Press,1983,p.140.

(40) KENNETH FRAMPTON,Modern Architecture,a Critical History, London : Thames & Hudson,1980,p.40.

Within a few years, in 1939, Freysinet invented the prestressed concrete : the extremely economical system for large spans where the beam depth was reduced about half, for the same concrete section.

The thin beamless slab transformed into the even thinner shell, in warped, curved and undulating structures of Pier Luigi Nervi, realized in his invention of "ferrocemento", a mixture of fine concrete mortar strengthened by several layers of fine steel mesh and bars of small diameter (41).

Nervi was an innovator of a very high order. His idea was that : in any building, esthetic perfection derives from technical perfection, that, "beauty" does not come from decorative effects, but from structural coherence. His structures have raised many questions, both for engineering and architecture. He explained "It is obvious that engineering and the mental make-up produced by engineering do not suffice to create architecture. But it is just as obvious that without realizing the techniques of engineering, any architectural conception is as non-existent as an unwritten poem in the mind on the poet (42)". His continuing search for greater efficiency in structure and erection methods led to

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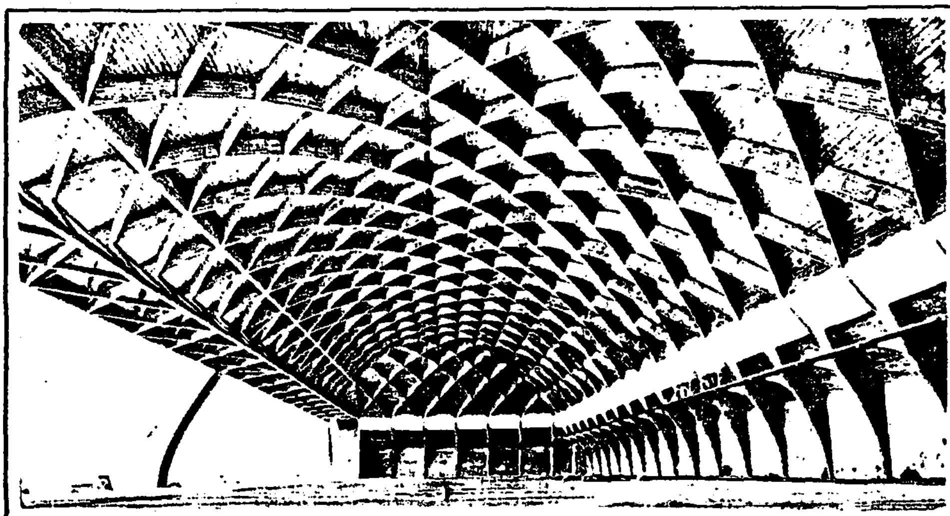
(41) A. FREDERICK PRAEGER, The Works of Pier Luigi Nervi, New York : 1957, p.VIII.
(42) PIER LUIGI NERVI, Nervi's View on Architecture, "Education and Structure", Architectural Review, Dec. 1958, p.118.

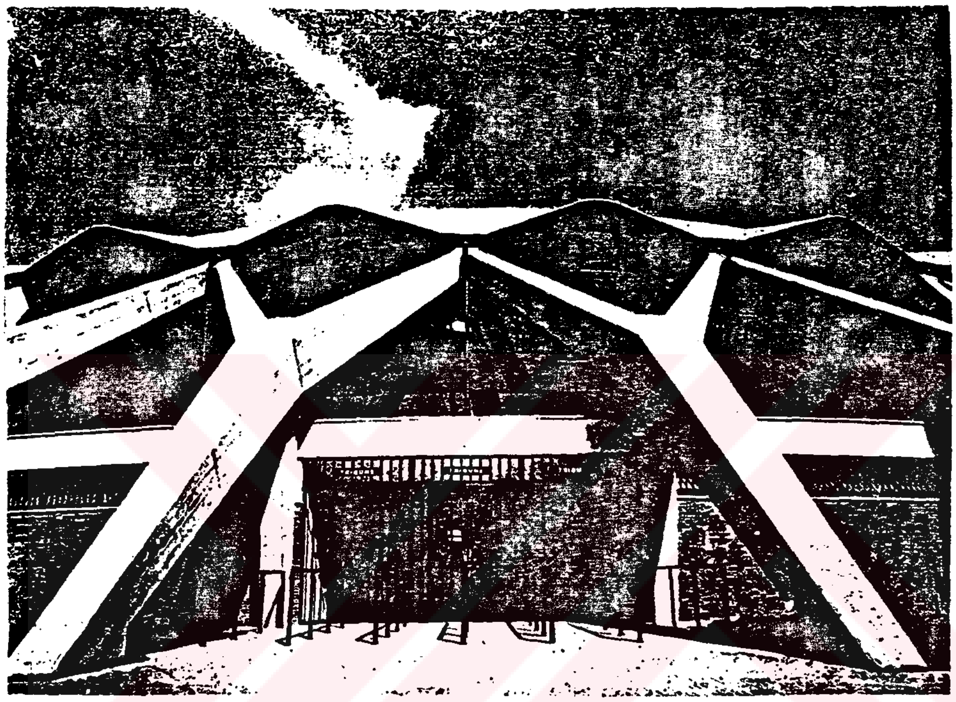
economies in material,cost and time,in his hangars,factories, exhibition and sports halls.

His first important technical innovation : two large hangars for the air force at Orvieto,was built in 1935,a structure of a basket-weave of reinforced concrete ribs supporting a 5 cm thick shell of reinforced concrete covered with asbestos.To hold this gigantic covering aloft,and to compensate for lifting forces of the wind,he designed huge diagonal columns which also served to support the sliding hangar doors.Four further hangars designed by Nervi between 1939 and 1941,were making use of prefabricated units of reinforced concrete.The whole sections of the roof were precast and were lifted into place by huge cranes,resulting in excess savings in steel reinforcement,in concrete and in form-work lumber.Of his greatest monuments,the three-structure complex : two domes and a stadium built for the 1960 Olympics,the smaller Palazetto dello Sport,rises effortlessly on its Y-shaped supports and spans some sixty meters to seat 5400 people.



Picture (9) : Nervi,Air Force Hangar,Orvieto,1935

The greater Palazzo dello Sport, surpasses this to seat 15000 people. The final structure, the Flaminio Stadium, a magnificient achievement of engineering, built of 7652 precast concrete elements, seats 46250 spectators, of which 8000 are beneath the cantilevered concrete canopy.



Picture (10) : Nervi, Palazetto dello Sport, Rome, 1956

2.1.2.3.2. IN ARCHITECTURE

Auguste Perret, who had a great part in making reinforced concrete a major building element in modern architecture, was putting up his first all-concrete structure with the Rue Franklin appartment block, in 1903, in Paris. For Perret, structure was the essence of good building. He explained, "if the structure is not worthy to remain visible, the architect has badly fulfilled his mission" (43). His Thèatre des Champs Elysèes of 1931, defiantly announced that reinforced concrete was a modern material of monumental effects.

At about the same time, Henri Sauvage's set-back apartments in the Rue Vavin, built in 1912, was exploring the expressive "plastic" potential of this new monolithic material. By this date the reinforced-concrete frame had become a normative technique, and from now on most of the development was to lie in the scale of its application and in its assimilation as an expressive element. While its first use on megastructural scale was in Matte Trucco's 40 hectare FIAT works, begun in Turin in 1915, its application as the primary expressive element of an architectural language came with Le Corbusier's "Maison Dom-Ino" proposal of around the same date (44).

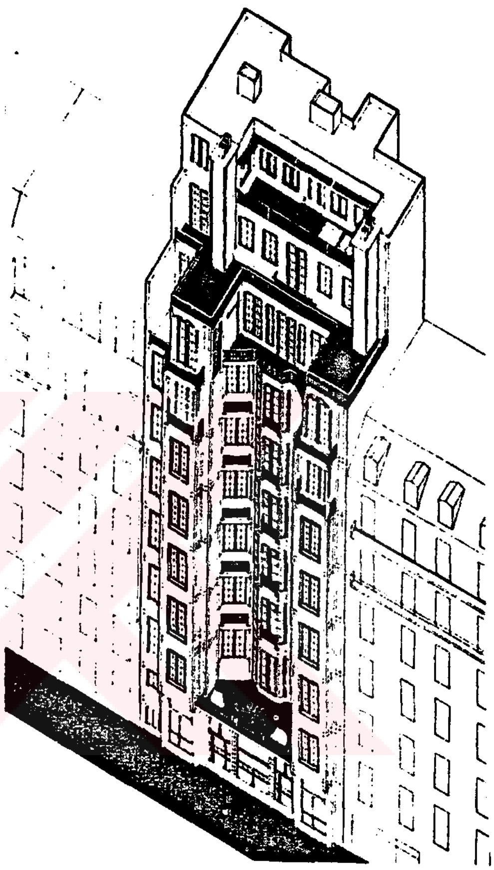


Figure (9) : Perret, 25 Rue Franklin, Paris, 1903

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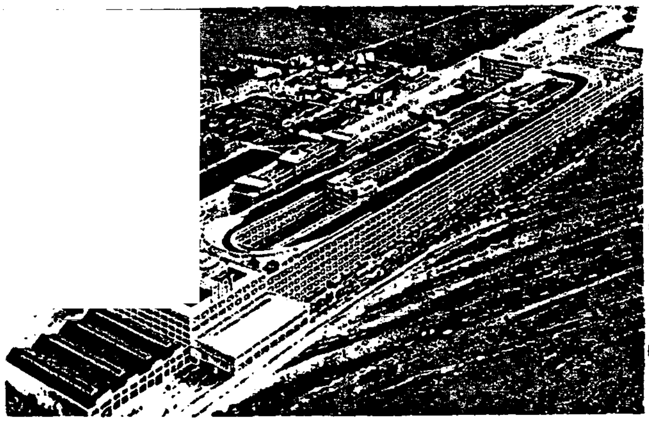
(43) AUGUSTE PERRET, La Construction Moderne, 1936.
(44) KENNETH FRAMPTON, Modern Architecture, a Critical History, London : Thames & Hudson, 1980, p. 39.



Picture (11) : Trucco,FIAT works, Torino,1915-21

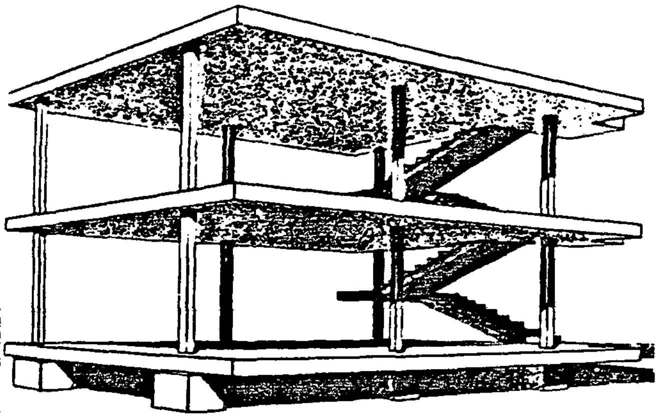


Figure (10) : Le Corbusier, Dom-Ino,1914,framework

Where the one clearly demonstrated that the flat concrete roofs could sustain the vibration of dynamic moving loads -the FIAT factory has a test track on its roof-,the other postulated the Hennebique system as a "patent" primal structure to which, after the manner of Laugier's primitive hut,(four tree trunks supporting a rustic pitched roof) the development of the new architecture would refer.

The architect to whom the discovery of the new material : reinforced concrete meant most,however,and who in turn contributed to its entrenchment as the prime building material and aesthetic of the century,was Le Corbusier.His writings,notably "Vers une Architecture",1923,and theoretical projects had immense impact.The so-called International Style and the machine aesthetic was largely his creation.He wrote : "If we eliminate from our hearts and minds all dead concepts in regard to the houses and look at the question from a critical and objective point of view,we shall arrive at the "House-Machine",the mass production house,healthy (and morally so,too) and beautiful in the same way that the working tools and instruments which accompany our existence are beautiful (45).

In his Dom-Ino principle of supporting homogeneous floor and roof concrete slabs with concrete pillars,thus freeing the internal spaces from any supporting walls and earning a large space which could be left open or be seperated by light-weight partitions,he laid by the idea of creating the spirit of constructing mass-production houses.Dom-Ino was aiming at the fixings of standards in order to face the problem of perfection.The word denoting a house as standardized as a domino. It was a piece of equipment,a technical device of construction, which aside from the framework and the steel reinforcement,was designed to be built by unskilled labour.

The qualities of the new material,combined with Le Corbusier's genius led to his famous five points d'une architecture nouvelle,which were first published in 1926 : (1) the pilotis elevating the mass off the ground, (2) the free plan, achieved through the separation of the load bearing columns from the walls subdividing the space, (3) the free facade,the corollary of the free plan in the vertical plane, (4) the long horizontal sliding window -"fenètre en longueur"- and finally (5) the roof

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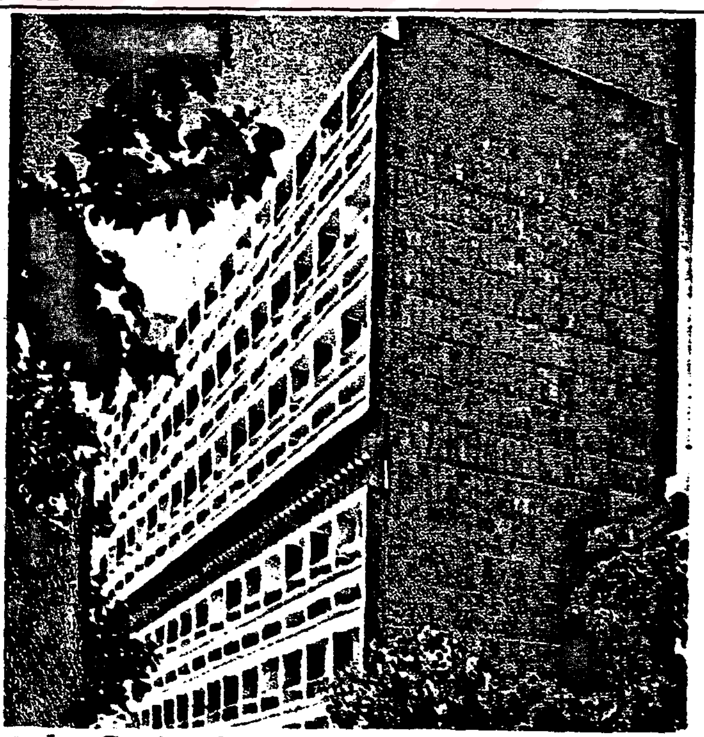
(45) LE CORBUSIER,<u>Towards a New Architecture</u>,London : The Architectural Press,1982,pp.12,13.

garden,restoring,supposedly,the area of ground covered by the house.These points were demonstrated in his projects - Maison Cook,in Paris (1926),Villa de Monzier,at Garches (1927),and Villa Savoie at Poissy,(1929) - all of these buildings presenting the puristic phase of Le Corbusier,where he made use of this material for its plastic,white,pure and clean effects.As he explained in his words "architecture is the masterly,correct and magnificient play of masses brought together in light".

In his later works,such as the Unitè d'Habitation,a large apartment house block in Marseilles,built at the end of the Second World War ; the Chapel at Ronchamps ; and the State Building for Chandigarh,concrete was exploited for its drawback of taking on the marks of the wooden forms that mold it,to achieve a purposefully brutal texture.Today whenever reinforced concrete is the prime material for building,Le Corbusier remains to be the presiding genius.



Picture (12) : Le Corbusier,Unitè d'Habitation,Marseilles

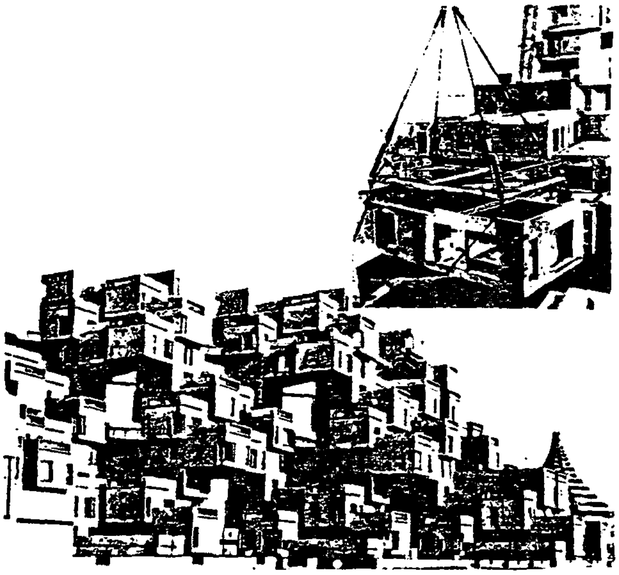
2.1.2.4. THE CONTEMPORARY REALIZATIONS

By the 1950s,almost every possible shape suitable to the qualities of reinforced concrete had been accomplished,challenging the strength and behaviour of the material further and further. Although innovations still continue especially in higher structures,such as in telecommunication towers,all the major technical advances have been made 20 years ago.

Of the two supreme achievements of reinforced concrete ; the Sydney Opera House (1957-73),which faced with immense problems in the engineering design process and also in the fabrication and erection of the great shells,represented a more individual and poetic approach in the architecture. The second of the two : Moshe Safdie's Habitat,built as a permanent housing complex at the Montreal Expo of 1967 consists of 400 box precact units,

Picture (13) : Utson, Sydney Opera House, 1957-1973

rising up to 12 levels which presented a prototype for a fully mass-produced building system.The construction called for the most sophisticated techniques of precasting and transportation,together with engineering expertise of the highest order.The prestressed rods and post-tensioned cables,structurally knit the boxes and the straight girders together which service,stiffen and partially support the units.Although this rational,disciplined assembly remains in use,there have been no comparable schemes,possibly because of the large costs of transporting the units and lifting them into position.



Picture (14) : Moshe Safdie, Habitat,Montreal Exhibition,1967

In the future,the designers,being fully aware of factors such as design overreach,inflexibility,irrevocable cost,will have to back up further innovations in this material whose formal and technical potentials cannot have been exhausted .

2.1.3. GLASS

2.1.3.1. THE MATERIAL

Glass,is a hard non-crystalline material that is usually clear and transparent.Almost all glass contains three types of constituents - formers,fluxes and stabilizers.The former is silica,which is the principal ingredient of almost all glasses. The flux,which has a lower melting point than silica itself,acts to form a mixture with silica.Common fluxes include the oxides of sodium,barium,and lithium.The stabilizer,added to the water glass, gives the product a chemical stability.The most common stabilizer are the oxides of calcium,aluminium and zinc.All glasses have som common properties - they are hard,perfectly elastic,brittle,non-conductors of electricity and are chemically stable (46).The principal products made of glass are containers,windows,fiber products,food service ware,industrial products,electronic components,and architectural panels,lighting fixtures.

2.1.3.2. EARLY USES AND DEVELOPMENT

The first use of glass,originating from the Middle East, sometime before 1500 B.C. had been confined to more decorative purposes,jewellery,small bottles and jars.Although glass was well known to the Egyptians,they were aloof from the float glass suitable for glazing.The first use of the material in buildings came with the Romans,where it had found a particularly useful application in the hot baths for its value in transmitting the natural light indoors,while preventing the heat from escaping. Later on Byzantines used glass mozaics to evoke transcedental qualities (47) in interiors.The mozaic pictures depicted religious scenes for the education of the people,in much the same way as stained glass was later used in Gothic churches.With the Renaissance,Gothic's tall,pointed window was gradually replaced by the more practical flat arched or square-headed window,especially

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(46) <u>The Encyclopedia Americana</u>,U.S.A. : Grolier Ltd.,1977,Vol.12, p.784.
(47) CHRISTIAN NORBERG SCHULZ,<u>Meaning in Western Architecture</u>, New York : McMillan Pub.Co.Inc.,1980,p.58.

in domestic buildings where the height of rooms was restricted. Window glass,was still limited in size to small panes which were set in lead frames and its effectiveness for lighting interiors was hindered by relatively low transparency.To effect these limitations,in Northern Europe,the windows were projected out from the face of the building in the form of oriel or bay windows, keeping them as wide as practical.The increase in width made transoms more necessary and brought a structural and aesthetic integration between the windows and the walls in timber framed houses.In Southern Europe this problem of maximizing available light did not arise.The window,remaining as a puncture in an otherwise solid mass,was used as an element of surface modelling where its form was now more determined by aesthetic rules of proportion and massing,than by functional necessities.

However,as the influence of the Renaissance spread through Northern Europe,it underwent considerable change as it was modified to meet local conditions.In particular,the window area again gradually increased in proportion to the wall by the 18th century,the town houses of the nearly affluent English middle class had elegant windows of some considerable size : these windows had a sliding sash operated by counterweight (48).The sash window and crown glass together predominated through the 18th century.It was a period of perfection rather than innovation (49).

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(48) MICHAEL FOSTER,<u>The Principles of Architecture.Style.Structure and Design</u>,UK. : Phaidon Press,1983,p.153.
(49) RAYMOND MC GRATH,<u>Glass in Architecture and Decoration</u>,The Architectural Press : London,1961,p.108.

Towards the end of the 18th century, it became possible to obtain crown glass of good quality of a reasonable size and price, which gave way to larger panels thus admitting a large amount of light from suco windows. The reveals were often splayed, and the glazing bars turned into mullions consisting of fine timber sections. The resultant window had a delicacy and refinement and has proved to be popular to this day.

In England, by the middle of the 1820s the increase in industrial production together with social and land reforms, caused a drift of population from rural areas to the new industrial townships (50). The demand for new housing and factories and the growth of railways in the 1830s led to a building boom. Glass became one of the most important elements in those new building types, alongside iron. James Hartley's patent of 1847, succeeded in making sheets of thin cast-plate by ladling metal from the founding pot directly onto the casting table, the glass thus cast, being unlimited to any size desired (51). These sheets were very suitable for skylights and glass roofing for the new railway station roofs, covered markets and green houses. Further improvements in manufacturing processes led to further savings on cost, enabling glass to be a practical alternative to other panelling materials.

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(50) JACK BOYER, History of Building, London : Granada Publishing Ltd., 1973, p. 194.
(51) RAYMOND MC GRATH, Glass in Architecture and Decoration, London : The Architectural Press, 1961, p. 46.

Throughout the 18th century, glass had already been quite widely used for horticultural purposes, to exploit the "greenhouse" effects. This is the effect whereby a high proportion of incident shortwave solar radiation is transmitted through clear glass and heats up objects, walls and floors. These then reradiate energy as a longwave radiation to which the glass is opaque, causing a built-up of heat (52). By 1817, J.C. Loudon had carried out a number of experiments with these structures in the search for an optimum angle for glass roofs to make the use of this effect. A form of roof construction of his, which he called "ridge and furrow" led to the best results. Glazing was used subsequently by Sir Joseph Paxton in the great glass house at Chatsworth, and later for the Crystal Palace.

Ever since the Elizabethan times, the new technology of glass and iron made the glazed galleries a popular building form : a place outside yet protected from the bad weather. The Royal Opera Arcade (1800), the Burlington Arcade (1819) and the Lowther Arcade (1831) in London were making use of their small glazed lanterns for natural lighting. The idea was extended, allowing house and garden to merge. From conservatories, it was a short step to the glazed courtyard, and to immense structures enclosing landscape and people under one cover. Winter gardens, railway stations, exhibition halls and museums emerged, making the glass roof the hallmark of the Victorian era.

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(52) MICHAEL FOSTER, The Principles of Architecture, Style, Structure and Design, UK. : Phaidon Press Ltd., 1983, p. 156.

2.1.3.3. THE CONTEMPORARY REALIZATIONS

In the 20^{th} century with the developing techniques in the manufacturing process,while the cost of glass decreased,the size of the glass sheet and the quality of the material increased dramatically.The availability of the large glass sheet had a great influence on the design process and its possibilities,was exploited by a whole new generation of architects.The transparent wall thus far eased and developed over and over,finally arrived with Paxton's Crystal Palace ; while it found an expressionist architectural character in the glass chain led by Bruno Taut (1880-1938) ; also found an essential role in industrial buildings such as ; Peter Behrens AEG Turbine Factory in Berlin (1909) and Gropius' and Meyer's Fagus Shoe Factory at Aalfeld (1911-13).These were followed,in the 20s by Gropius monumental glass-walled machine shops for the Bauhaus,at Dessau (1926),and the Van Nelle Factory in Rotterdam (1924) by J.A. Brinkmann and L.C. Van der Vluccht.

By the beginning of the century,Frank Lloyd Wright was building houses around Chicago where the traditional subdivision of the home into seperate rooms was challenged.Each space was linked together and integrated with the landscape outside. Influenced by the Japanese architecture this concept gained ground (53).

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(53) MICHAEL FOSTER,The Principles of Architecture,Style,Structure and Design,UK. : Phaidon Press,1983,p.158.

As it became possible to build large frameless glass walls,glass lost its horizontal associations and became a symbol of the clean fresh lines of modernity.Frank Lloyd Wright,the master of masonry,acclaimed glass as the modern material par excellence in his famous Kahn lectures in 1933 ; he stated : "Glass has now a perfect visibility,thin sheets of air crystallized to keep air currents outside or inside.Glass surfaces too,may be modified to let the vision sweep through any extent up to perfection.Tradition left no orders concerning this material as a means of perfect visibility ; hence the sense of glass as crystal has not,as poetry,entered yet into architecture.All the dignity of colour and material available in any other material may be discounted with permanence.Shadows were the "brushwork" of the ancient architect.Let the modern now work with light,light diffused,light reflected - light for its own sake,shadows gratuitous.It is the machine that makes modern these rare new opportunities in glass" (54).

In Mies Van der Rohe's Barcelona Pavilion of 1929,dark glass and polished materials extend and define its disposition of space : where the inside and outside are being the continuations of the same space,the hovering roof and open plan is a reflection of Wright's houses.The design is simultaneously simple and complex

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(54) FRANK LLOYD WRIGHT,Modern Architecture,Princeton : 1931,Style in Industry - The Kahn Lectures

its ingredients are merely steel columns and independent rectangular planes of various materials placed vertically as walls or horizontally as roofs : but they are disposed in such a way that space is chanelled rather than confined (55) - it is never stopped,but it is allowed to flow continuously.In his Farnsworth House (1950),he used large sheets of clear glass for the entire enclosure,in effect making the walls invisible.

At the turn of the century,with the Chicago development engineers had already developed the principles of steel frame for construction,which,allied with the introduction of electric lifts and central heating,made high-rise buildings possible.In 1919,Mies suggested that glass be used as an infilling material for the surfaces of these new framed structures which did not need walls for support.His proposals for an office building of 1921 to 1925 in Berlin marked him as the first to recognize the importance of the role which glass could play in the new architecture.The freely curved surfaces of these buildings were determined by three major factors : "sufficient illumination of the interior,the massing of the building viewed from the street,and lastly the play of reflections" (56).Describing them Mies wrote : "Skyscrapers reveal their bold structural pattern during construction.Only then does the gigantic steel web seem impressive.When the outer walls are

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(55) PHILIP JOHNSON,Mies Van der Rohe,New York : Museum of Modern Art,1947.
(56) DENNIS SHARP,Glass Architecture by Paul Scheerbart and Alpine Architecture by Bruno Taut,New York : Praeger Pub.,1972,p.27.

put in place,the structural system which is the basis of all artistic design is hidden in a chaos of meaningless and trivial forms.When finished,these buildings are impressive only because of their size.Yet they could surely be more than mere examples of our technical ability.Instead of trying to solve their new problems with old forms,we should develop the new forms from the very nature of the new problem.We can see the structural principles most clearly when we use glass in place of the outer walls ; this is feasible today,since in a skeleton building these outer walls do not actually carry weight.The use of glass imposes new solutions" (57).

Mies' idea for the "curtain wall" was a logical extension of metal window technique.As the development of the curtain wall has not been based purely upon considerations of design,but equally upon considerations of economy and structural technique,it took several decades for the architects to realize this design. They produced steel framed structures composed of rectangular bays,with the columns on the outer edges.Many buildings of this type have been sheathed in glass,but the clarity of Mies'idea of the "curtain wall" depended on the floor planes being free of such structural restraints and independent of the columns.Le Corbusier's Dom-Ino design,stating clearly the column and slab principle,had shown the way ahead using the newly developed technique of reinforced constructions.His projects such as,Plan

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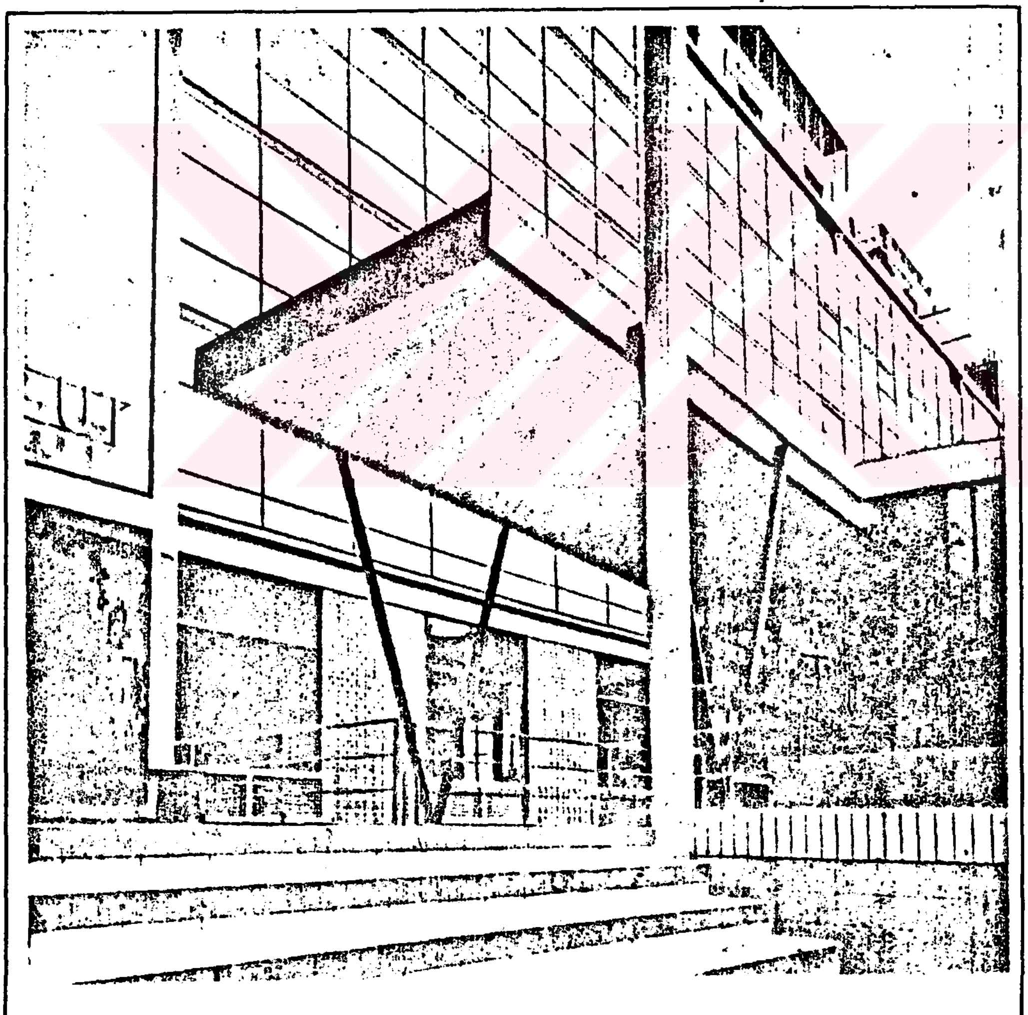
(57) JOHN PETER,<u>Design With Glass</u>,U.S.A. : Materials in Modern Architecture Series,Vol.1,1964,p.10.

Voisin sky-scrapers for Paris,the Villa Savoie,the Pavillon Suisse and the Citè de Refuge uses glass generously ; but,from the point of view of later architectural developments,the Citè de Refuge (1933) is the most interesting.The entire south facade of the building is a glass curtain wall (measuring 1000 m^2) except for the refectory floor which has the bays of fixed concrete and glass,alternating with sliding plate glass windows.The building being air conditioned,the main curtain wall has no light openings.



Picture (15) : Le Corbusier,Citè de Refuge,Paris,1933

Unfortunately at this time,although glass was available in quite large sheets,it still required mullions and transoms both for support and also to resist the high wind loads imposed on tall buildings (58).These mullions were so thick that they became small frames themselves,serving the interior only by being useful as convenient posts against which to abut the internal partitions. Despite all the technical improvements that the advent of steel and aluminium had made in reducing the size of such components,the image of the totally transparent wall,free of mullions and transoms that gives rigidity was still some way off in the 1950s.

Overcoming the problems such as jointing,waterproofing,air conditioning,condensation and fireproofing was fiftysix years later from Mies' 1919 design for the all glass building.In 1975 Foster Associates completed the Willis Faber building in Ipswich a building which matched the clarity of structure and elegance of that early design,making use of the fact that,technology had by now solved all the practical shortcomings.

2.1.4. PLASTIC

2.1.4.1. THE MATERIAL

Plastic is a polymer based material that is formed in the liquid state and then hardens,providing an article with a degree

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(58) MICHAEL FOSTER,The Principles of Architecture,Style,Structure and Design,UK. : Phaidon Press Ltd.,1983,p.162.

of structural rigidity (59).Plastics,as opposed to brick,stone and timber and even metal,glass and concrete which are natural raw materials or processed from natural materials,are man-made substances which do not exist in nature.They are generally organic materials - that is,they are based with some exceptions on carbon chemistry.They are high polymers - giant molecules made of numerous small relatively simple repeating units combined into very large aggregations.They are synthetic materials,products of the chemical industry,which converts raw materials into radically different forms (60).As their name implies,they are plastic at some stage of their production,and at that stage can be moulded in shape by a variety of techniques.

There are two main categories of plastics,classed by their behaviour when heated.The first category "thermosetting" plastics become soft when heated and can be shaped ; but upon further heating,they become stiff and solid and cannot then be softened again.The second category,called simply "thermoplastics",soften when heated and become stiff and solid again when cooled.While the thermoplastics can be processed into more complex shapes,the thermosets are less sensitive to temperature ; they have better resistance to stress,better fire endurance,and can be made rigid.

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(59) The Encyclopedia Americana,U.S.A. : Grolier Ltd.,1977,Vol.22, p.216.
(60) ARTHUR QUARMBY,Plastics and Architecture,New York : Praeger Pub.,1974,p.18.

Both categories have many different applications in building.

2.1.4.2. EARLY USES AND DEVELOPMENT

The first truly manmade plastic was invented in 1907, called phenol formaldehyde, or bakelite after its discoverer. It was only available in its natural darkbrown color and was rather brittle. In 1929, William Chalmers, working on a substitude for glass, found out that a hard clear material was produced by the polymers of methacrylic ethylester and methacrylic nitrite (61), and his discovery was rapidly taken up by major companies in the USA and Britain, to be developed as a synthetic glazing material. The first World War emphasized the essential nature of a large scale chemical industry, and by the 1920s and 1930s, a raid of other plastic materials had been invented, including acrylic, polysterene, nylon, polyethelene PVC - bringing with them the development of new forming techniques, such as injection moulding. The second World War brought the plastics industry to full stature. The material finding a use in a wide variety of products.

Without doubt, that the dramatic expansion in the availability of plastic materials for buildings is very recent. Although the first applications of plastic were supplementary to traditional materials such as : better paints for wood, protective

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(61) <u>The Encyclopedia Americana</u>, U.S.A. : Grolier Ltd., 1977, Vol.22, p.217.

coatings for metals,insulants for brick and concrete,damp proof membranes for roofs,sealants for stone and so on,with the massive increase in building output and the development of mass industry coinciding in the 1950 and 1960s led to a demand for cheaper and faster construction with better physical performance,which then resulted in plastic being a replacement to the traditional materials.The first acceptance of the material came in as the imitations of the old ones : the decorative laminate panels,plastic fencing and wall claddings were all made to look as much as like timber as possible.But today,through the variety of forms of raw plastic,that the polymerization process gives us,the use of plastics in building became so numerous.These products - in basic forms such as powders,granulates and liquids or in semi-finished forms,such as sheets,films,rods or tubes by different shaping techniques processed into final products that are applicable in building industry.

2.1.4.2.1. PLASTIC SHEETS AND FILMS

Sheet and films widely used in building as vapour barriers, temporary enclosures,flashing,glazing,illumination,flooring sheet and tiles and many other applications,are made by a variety of processes (62).Plastics,such as acrylic can be transformed by

(62) ALBERT H. DIETZ,Plastics for Architects and Builders,U.S.A. : The Kingsport Press,1969,p.37.

heating the raw material with a catalyst to form a viscous liquid which is then poured between two polished surfaces,such as glass, and allowed to cool to an even,smooth,transparent sheet which is widely used as an alternative to glass.These sheets although they are flammable,can scratch easily and are not good insulators and cost more,though their lightness and resistance to breakage can be an advantage in some cases.They have been used primarily as a replacement for glass windows,walkway covers,ballustrade panels and so on,in areas vulnerable to damage by vandalism,particularly in schools,shopping centres,stations and other public places.

Flexible films of PVC and polythene sheets,apart from usual operations,such as shower curtains or chain covers,show main uses for damp proofing,as waterproof membranes,and as protective covers. They are commonly used concrete slabs on-grade and show reasonable resistance to puncturing and is insert to most still conditions.

2.1.4.2.2. DRAWN AND MOULDED SHAPES

To make drawn shapes or extrusions in plastic,thermoplastic moulding powder or granules are fed by a hopper into one end of a heated chamber.Inside this chamber,a rotating screw forces the softened plastic out through a die which is shaped to give required cross section.Extrusion provides continuous profiles, including edgings,architectural mouldings,pipes and tubing.

Extruded PVC,for being relatively cheap,unbreakable and not needing repainting for its smooth finish which helps water flow, replaces metal and clay products in cold water plumbing,rainwater and underground drainage systems.Hollow sections with moulded connectors,which were used to make fences and posts,were used to benefit from their contained air space as an effective heat barrier ; insulated window shutters and the many transparent or translucent extrusions for roof glazing present examples for this usage.

A heated,flat thermoplastic such as acrylic,formed by extrusion or casting,can then be remoulded to take up the shape of mould on cooling.A domed or a pyramidal form,achieving strength by means of double curvature will defy the tendency of plastic to expand and deform when subjected to heat.Since the plastics are far lighter than glass and development in engineering have led to spaceframe and geodesic structures,long-span trusses and cable suspension systems,it is possible to construct scale and delicacy (63).

The geodesic domes of Buckminster Fuller,such as the Expo 67 dome,in Montreal,Canada,which makes use of baloon acrylic panels,investigates the possibilities that the material has to

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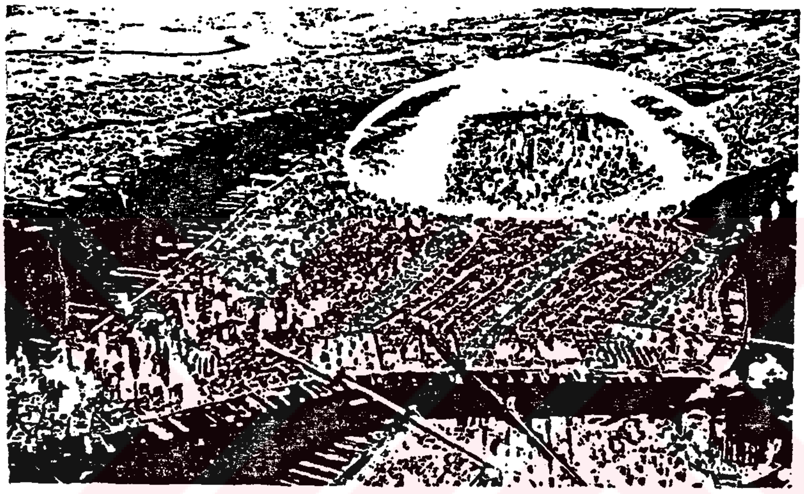
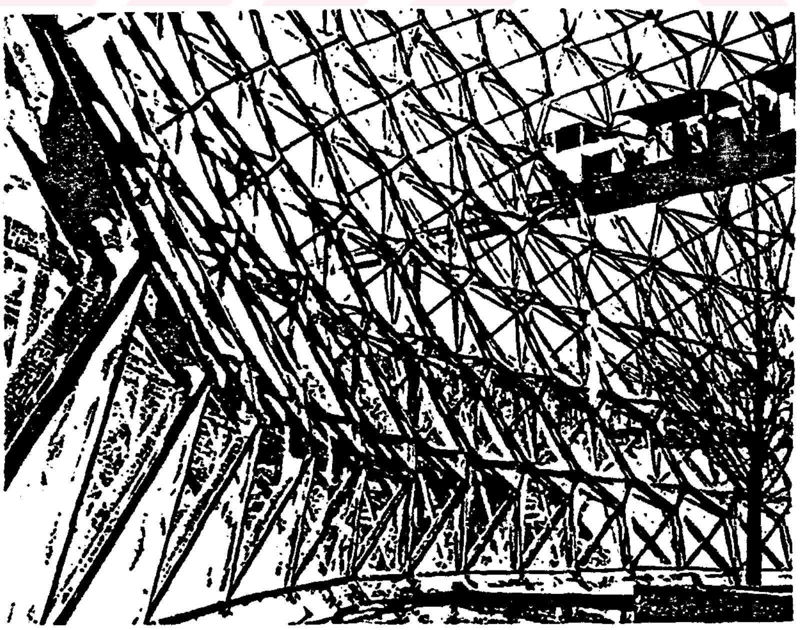
(63) MICHAEL FOSTER,<u>The Principles of Architecture,Style,Structure and Design</u>,UK. : Phaidon Press Ltd.,1983,p.174.

offer and clearly demonstrates that the metal frame and acrylic panels,made of standardized parts are capable of covering large areas efficiently.This idea took Fuller even to conceive a scheme whereby a large area of Manhattan would be encapsulated by a giant dome - providing a weather-proof controlled environment,implying that the buildings within would not have to cope with exterior weather conditions.

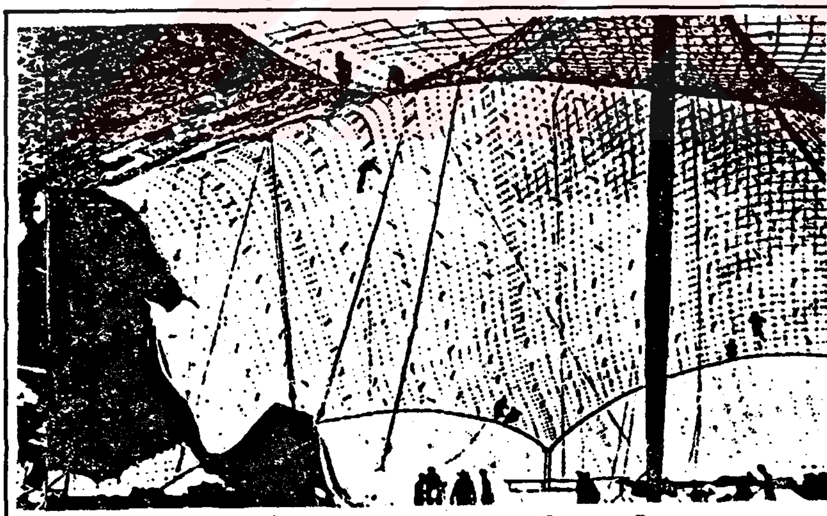


Picture (16) : B.Fuller,Two-mile dome for Manhattan



Picture (17) : B.Fuller,Detail of dome at Expo'67, Montreal

Frei Otto's West German Pavilion for the same exhibition in Montreal,in 1967,was an equally powerful statement : almost anything could have been placed in this vast tent structure.His Olympic Stadium in Munich in 1972,like Fuller's dome,is an example of the potential of lightweight plastic panels used in conjunction with steel - in this case steel in tension.Otto's work ; progressing from very simple tents to projects for skinning over whole cities,stands as the definite example of skin-work.He has also been one of the leaders of investigation into pneumatic structures.His work has a strong link to the notion of an ultimate in skins : a membrane which is not there.The skin which can be seen through ; the skin which can be parent to all within ; the skin which can be regularized ; the skin which can be treated as an environmental totality (64).



Picture (18) : Frei Otto,West German Pavilion,1967,Montreal

(64) PETER COOK,Experimental Architecture,New York : Universe Books,1970,p.105.

2.1.4.2.3. GLASS REINFORCED PLASTICS

A larger group of components used in building,are more commonly moulded from the rigid thermosetting resins.Polyester resin in conjunction with glassfibre reinforcements produces a material called glass reinforced plastics which is used in roof and wall panels and other structural or semi-structural applications.Reinforced plastics are composites of polyester or epoxies reinforced with fiber,almost always glass but not exclusively so.It was the first practical plastic material that could be used for making sizeable building components.However,GRP was not short of problems : the fire-resistance was a problem which was hoped could be cured by modifying the resins or adding fillers,but as these were found to affect the curing,mechanical and weathering properties of the material,other techniques had to be devised.In some cases,but elsewhere,it was necessary to add incombustible linings (65).

GRP is also not entirely impervious to water,moreover the strength of this material reduces in time and with temperature increase.However,for being a light material,saving on structure and foundation costs,and for being shaped easily,it offers some advantages.It had been widely used to make the shiny finishes,

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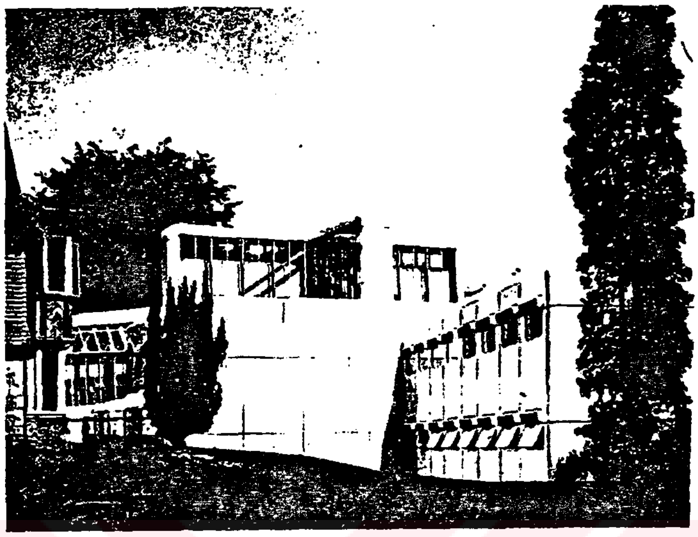
(65) G.H.ALBERT DIETZ,Plastics for Architects and Builders,U.S.A. The Kingsport Press Ltd.,1969,p.103.

round cornered window inserts and ribbed surfaces.Today,most moulded cladding panels are of this type.



Picture (19) : James Stirling,Olivetti Training Crntre,Haslemere, Employing GRP panels

The Water Research Centre,in Swindon by architects Design Partnership,illustrates the variety of applications of the material in construction.Neoprene gaskets seal the glazing on the front elevation,plastic-based paints cover the external steelwork, and complex profiled GRP panels are used for cladding.

The idea of capsule,a complete structural enclosure of plastic heavily moulded for rigidity,presented an impetus to exploit the advantages of plastic,particularly for its lightness, while overcoming problems for poor sound and fire insulation and lack of permanence.In the 1960's,the proposal of a group of

British architects known as Archigram, for a "plug in architecture" which consists of housing capsules that could be lifted up by crane onto a support structure, and then detached and removed when they had outlived their usefulness, have had a powerful influence upon designers over the world (66).

2.1.4.2.4. FABRICS

Few building materials impact a completed building like the fabric of a fabric structure. The nomad tent skin is now replaced with the extruded filaments of nylon, polyester, or glass fiber, spun into threads and woven into through fabrics, which are strong in tension, light and translucent. When such fabrics are coated with other, more durable plastics such as PVC, neoprene, hypalon, or PTFE, a useful life of some twentyfive years becomes possible.

Fabric structures are at the same time structure and envelope, building sculpture and architectural space, lighting system and acoustical environment (67). However, of all the roles fabric plays its structural function is the most important. To assume and maintain an intended shape, architectural fabrics must withstand an initial load, which may be induced by air or vacuum or air supported structures, and one or more masts, frames, or arches

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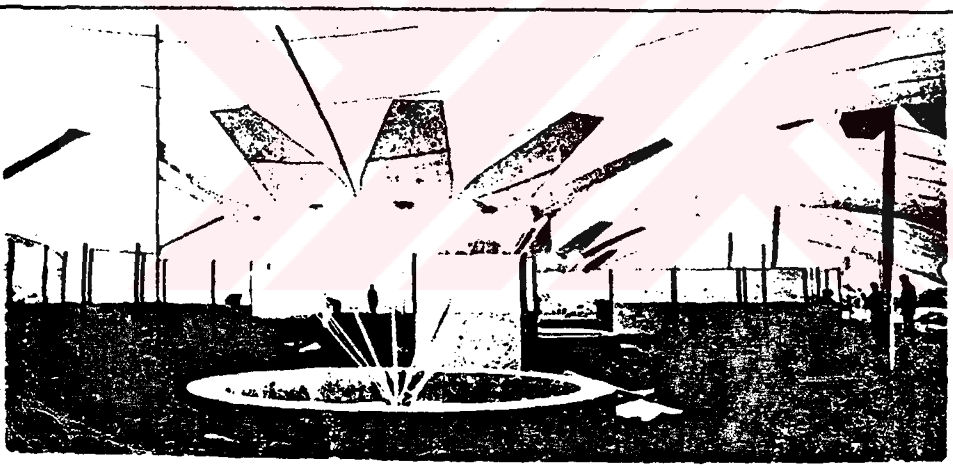
(66) PETER COOK, Experimental Architecture, New York : Universe Books, 1970, p. 105.
(67) JAMES GARDNER, The Nature of Architectural Fabrics, Architectural Record, March 1985, p. 157.

for tension structures.Superimposed loads from snow,wind,or construction workers walking on the roof must be handled as well. The only way the fabric membrane can withstand loads and channel them to the ground is through tension or more accurately,the ability to withstand tension through tensile strength.

In the tension structures ; the traditional tent system of the fabric carrying the tension stresses to a pole or compression strut while still,stays to be the main principle.The advanced high strength steel cables available today support the fabric and make vast tented structures possible.



Picture (20) : Frei Otto,Fabric structure

Air supported structures,"inflatables",may be supported without struts by compressing the air which it encloses.There are two basic types,of which the first contains the air in compression between two skins of fabric much like a baloon,and then the baloon itself transfers the load to the ground.The advantages are that, the collapse of one cell does not cause the collapse of the whole system and the structure does not need to be tightly sealed to the ground. The disadvantage is that, the span is limited. The second type requires a constant input of air to maintain the internal air pressure, slightly higher than outside, and supports the flexible membrane in tension by compressing the air which it encloses, the air itself transferring the load to the ground.

2.1.4.2.5. FOAMS

The principal foams used in building are polyurethane and polysterene, and these are employed for the thermal and acoustical insulation and most importantly as the structural cores of sandwich panels (68). These panels have a tough skin and a lightweight core which makes them very strong for their weight. They can be worked out like wood but, unlike wood they do not rot, warp, split ; and can be coloured.

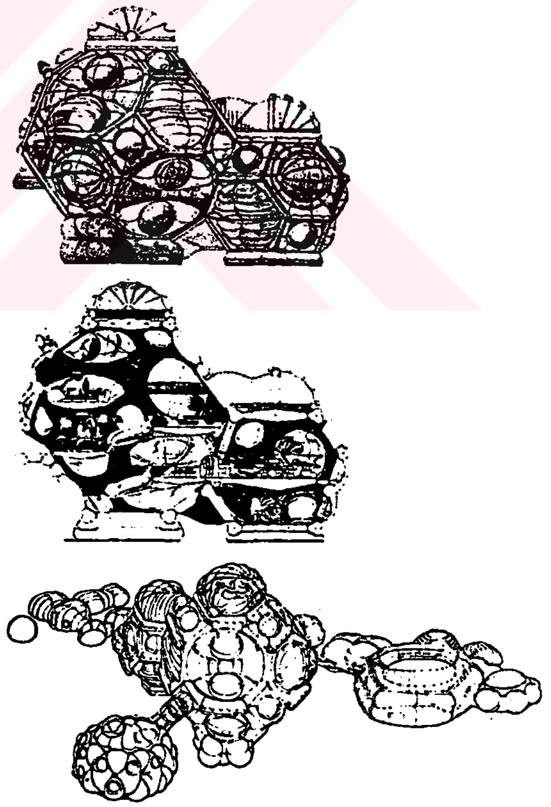


Figure (11) : Jean Paul Jungmann, Pneumatic living cells, 1967

In 1967-68, the architects, E.H.Brenner and Associates, working with plastic engineers in the United States, produced plans for buildings to be spun from foam. The

(68) ARTHUR QUARMBY, Plastics and Architecture, New York : Praeger Pub., p.27.

foam employed an epoxy resin with a forming agent which resulted with a hard finish on the outside to form a tough double skin, instant to its mixture coming into contact with the cold surface of a mobile,rotating conveyor mould.The mould,as it moved on,left a ribbon of a structural walling system laid vertically in the same way as conventional walling and carried over to form roofs.

The same year Jean-Paul Jungmann designed his "pneumatic living cells" presenting a true use of plastic material where voluminous foam cushions liberated from the traditional constraints construction,anchored in place for stability.

In future such kind of developments,offering freedom of design,arrangement and total flexibility,where the cells could take on any form,is likely to change the understanding of hitherto normal building practice.

3. CONCLUSION OF THE DISCUSSION OF THE ADVANCE OF BUILDING TECHNOLOGY AND BUILDING MATERIALS : THE ADVENT OF AN ARCHITECTURE THAT MAKES USE OF HIGH LEVEL TECHNOLOGY

Architecture is a synthetic process,and one which is considerably dependent on the technical.characteristics of raw and manufactured materials,their specific historical precedents and their future potential.Today,well into the 21st century,into the so-called computer or the space age,architects have been provided with more materials with which to build as it ever has been. Traditional materials have new capabilities.New materials offer challenging potentials.The architects must keep pace with scientific theory and must keep ahead of technology to an extent which enables them to control the latter creatively.Designers, only by grasping technology and its means as a great driving force for a new architecture,and only by keeping in the forefront of technical innovation and advancing the technical mastery of its materials,will succeed to produce a fresh response to current social attitudes and requirements.

Two thousand years ago,the Roman architect Vitruvius' "five points of architecture" recognized three different requirements of architecture : utilitas,firmitas,venustas (commodity,firmness,delight).Vitruvius' writings are not primarily concerned with "commodity" which take in the role of buildings in containing and ordering social activities and thereby reflecting society.The emphasis has been on "firmness",the soundness of structures through the use of materials."Delight" has only been discussed as it come out,through the sensibility of designers in their usage of these materials.Since the principal concrete fact of relevance to every project is its construction,architects require a broad command of the building science,which means thinking first and foremost in structural terms.Structural techniques,throughout the history,have been the most determinant factor on the evolution of the building forms.The architecture of the pre-industrialization era,depended for its execution on the work of the crafts,and the crafts in return influenced architecture.Today the traditional pattern of building has been radically altered,with frames of concrete and metal,tents and inflatable fabrics,rigid plastics and transparent sheets,offering utterly new architectural possibilities.Thus our age has different means ; they are based on technology and industrial methods of production.These,too,have their influence on architecture.Since, architecture necessarily includes a technological component which can be encompassed within a rational system,the said influence is positive.Industrial production is based on standards and objectivity.Architecture should also be so based.

Today, the pressing need for mass construction and the savings required on time and economy has brought the building process close to being something industrial. New building systems bringing new technologies have been overlaid on the older ones, and the notion of prefabrication has emerged as an inevitable technique. As a component of industriallized building systems, prefabrication has been put forward by each successive generation as the solution for building and has gradually become one of the main approaches.

Contemporary industrialized systems include : the panel system, the skeletal system, and the box system which mainly uses reinforced concrete, employs manufactured pieces which are then put together on the site. Another building system which uses the manufactured components, benefits from the steel technology and its metal alloys, glass and plastic. This system, currently called "high-tech", for the quick assembly and erection of finely detailed buildings, makes use of the highest and most sophisticated technologies available, serving the construction industry whether be in structure, cladding, mechanical equipment, services and so on.

Being the culminatory expression of the manipulation of the highest level of technological achievements towards the making of architectural spaces, this form of thought is most challenging for the professionals.

4. THE CONCEPT OF HIGH-TECH

The term high-tech is used to characterize a particular approach in architecture in which high-technology inspires the imagery of building as much as being used in its production and assembly process.This form of thought is not very widely spread and familiar,which fact results in the rejection of its resultant products.In supporting the values of this vein of building obligates to examine the background that prepared for it and its precedent realizations.

4.1. ORIGINS AND INFLUENTIAL PRECEDENTS

This science based approach,using components of all the latest of their kind,functioning and mechanistic as an image (69) is an outcome of our particular age in which the development of science and its related technologies has been experienced very powerfully by the populace of this last century.The great technical inventions and social developments of the last hundred years has set off a stream of changes in people's way of living and gradually established new habits and new standards (70).Banham,in his book "Theory and Design in the First Machine Age",talks about the transformations of science and technology of this era as

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(69) PETER COOK,Experimental Architecture,New York : Universe Books,1970,p.27.
(70) WALTER GROPIUS,Apollo in the Democracy,the Cultural Obligation of the Architect,New York : McGraw Hill,1968,p.14.

having had extreme effects on human life.While the strongest impact came in the form of small machinery for domestic usage,such as washing machines,printed-circuit radios,television,telephone, automatic cookers and refrigerators (71) and so on,it also caused a growth of feeling that the traditional architecture of the styles did not fully represent the new technical age.There were pressing needs,particularly in housing,which could not possibly be tackled by conventional technology.

Le Corbusier's persuasive call in the opening words of "Towards a New Architecture" in 1923,hails engineering as governed by laws : "The engineer,inspired by the law of economy and governed by mathematical calculation,puts us in accord with universal law.He achieves harmony"(72).By reestablishing the validity of an engineering view of architecture,Le Corbusier brought into the arena something which stood outside the trap of formalism.Formalistic architecture lacked the single dominating space which had been the chief characteristic of much of 19th century engineering work and its resultant transparency (73). It was a premonition of simple industrial service shed which permits a flexible plan and a concentration of service elements and structure in the membrane.For Le Corbusier and his generation,

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(71) BENHAM REYNER,<u>Theory and Origin in the First Machine Age</u>, London : The Architectural Press,1960,p.10.
(72) LE CORBUSIER,<u>Towards a New Architecture</u>,London : The Arch. Press,1982,p.7.
(73) DENNIS SHARP,Une Architecture de la Technologie,<u>Architecture d'Aujourd'hui</u>,Dec 1980,No 212,p.2.

it was a model for modern appearance, technological symbolism, a directional strictness, functional planning and decorative restraint.

Walter Gropius made a more specific claim for the rationality of architecture and its technology in "The New Architecture and the Bauhaus" : "The outward forms of the New Architecture ... are ... simply the inevitable logical product of the intellectual, social and technical conditions of our age ... . In the progress of our advance from the vagaries of mere architectural caprice to the dictates of structural logic we have learnt to seek concrete expression of the life of our epoch in clear and crisply simplified forms (74)."

Thus, the "dictates of structural logic" represented a belief in the capacity of technology, to provide new "correct" solutions to new problems, and a feeling that buildings should represent technology of its age as one of the principal conditions (75). It is in this form of thought which led to the machine aestetic of the 1920 - although should not be mixed either with the functionalism of the Modern Movement or with the productivist wing of the Russian Constructivist Movement - that lies the roots of the origins of today's high-tech or mechanical architecture.

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(74) WALTER GROPIUS, The New Architecture and the Bauhaus, London : Faber and Faber, 1935, p. 47.
(75) ANDREW SMITH, Across the Technological Fracture, Architects Journal, Jan 1984, pp. 54-55.

However it is possible to see some common aesthetic principles that are valid both in the Modern Movement and in high-tech ; emphasis upon volume - space enclosed by thin planes or surfaces as opposed to the suggestion of mass and solidity (76) ; expression of lightness inherent in tensile structure and synthetic materials ; and lastly,technical perfection,and the fine proportions,as opposed to applied ornament.

The Modern Movement presented two products of important influences on today's high-tech architecture ; Bijvoet and Chareau's Maison de Verre,particularly the design of the bathrooms and storage fittings ; and Le Corbusier's comparisons in Towards a New Architecture,of architecture with the most advanced machines, ships,cars and planes.

In the second half of the 19th century the work of the three men : Ludwig Mies Van der Rohe,his aesthetic cult of "less is more" ; Buckminster Fuller,his theories and projects ; and Konrad Wachsmann,his concern for the actual processes of machine tool production ; provide the historical chain with further links,as well as giving a note of more recent perspective to this continuing idea.

Mies puritanical use of steel and glass and his concept of

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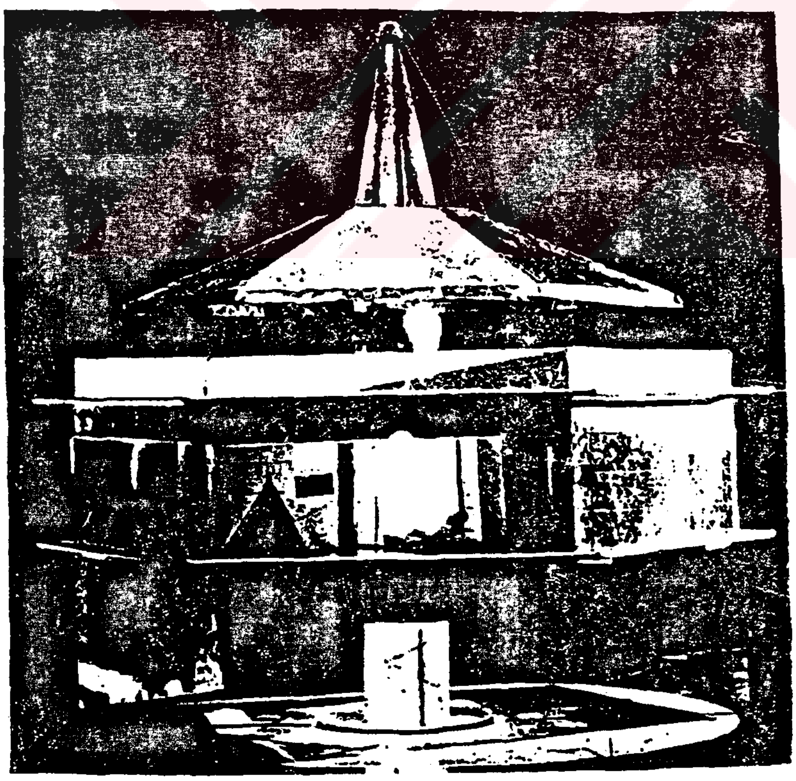
(76) HENRY RUSSEL HITCHCOCK,PHILIP JOHNSON,The International Style,New York : W.W.Norton,1966,p.13.

"universal space" (77),minimizing the building so as to be composed of just an envelope,thus freeing the interior space for a maximum flexibility and enabling future alterations on use with minimal cost,are the determinant factors in today's structures of "hardware architecture".

Buckminster Fuller's "Dymaxion" principle of design (1927) developed of corrugated sheet metal tacked around a central pole structure - consists of components that can be put together in very much the same way as current furniture kits or etc.,implying the fact that the components have to be produced industrially for increased efficiency.



Picture (21) : Buckminster Fuller,Dymaxion House,1927

(77) JONES CRANSTON,Architecture Today and Tomorrow,London : McGraw Hill,1961,p.66.

Another major contribution came from Jean Prouve's development of pressed metal components and his ingenious curtain walls (78).Prouve has turned panels of steel into beautiful buildings by virtue of the finesse with which he is able to resolve the structural potential of pressed metal,its production and its jointing.

Picture (22) : Claude and Jean Prouve, Palais des Expositions,Exterior and Interior detail of glass wall, Grenoble,1968

High-tech architecture,as a building system which is composed of only prefabricated components,has benefited from the works of Konrad Wachsmann who in the 1940s started to produce beautiful prototypes,joints and working parts.Wachsmann,has probably brought the idea of fabric prefabrication further than anyone else from its more primitive aspects through to the sophisticated package house system which he designed in 1942 with Walter Gropius,where there was the interface of a very rational system and a brilliant joint (79).From there on he moved to

(78) MICHAEL VERNES,Jean Prouve,Arch Review,July 1983,p.38.
(79) PETER COOK,Experimental Architecture,New York : Universe Books,1970,p.33.

experiment with minimal structures supporting maximal space. In the 1940s and 1950s, he made projects for space frame structures of gigantic dimension and sophisticated profile. Particularly as a result of industrial needs and the necessary incorporation of services, good lighting and the alternative profiles of roofing, the idea of the space frame roof as the parent structure emerged as a very strong notion.

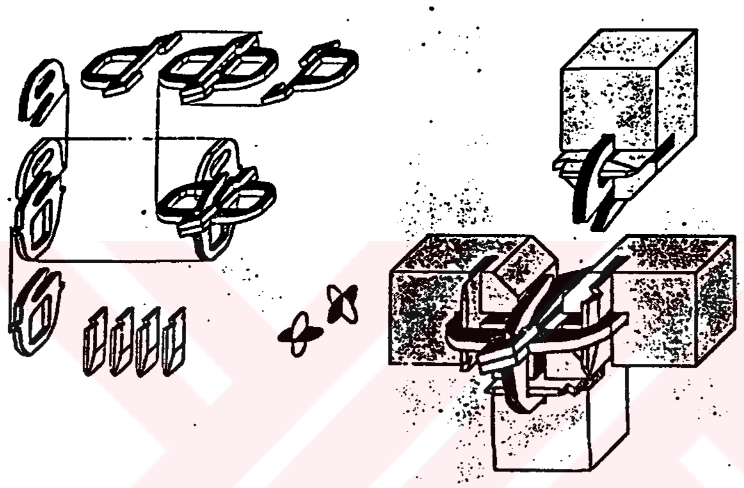


Figure (12) : Konrad Wachsmann, jointing detail for the general panel system

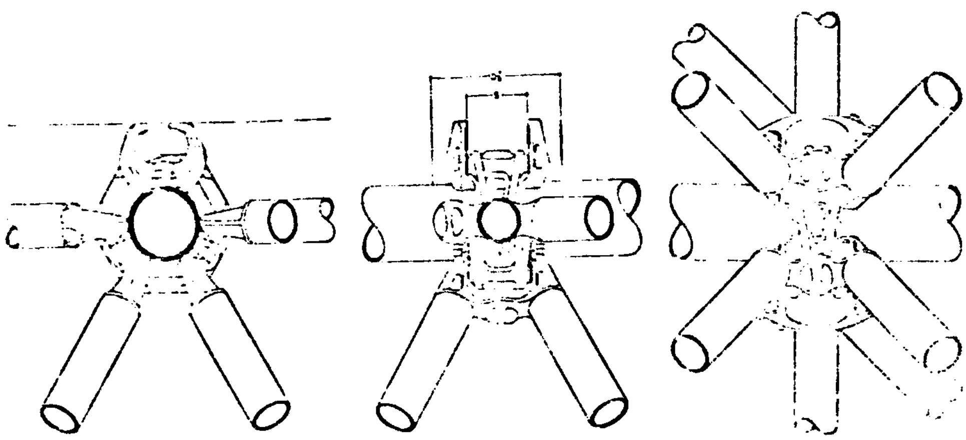
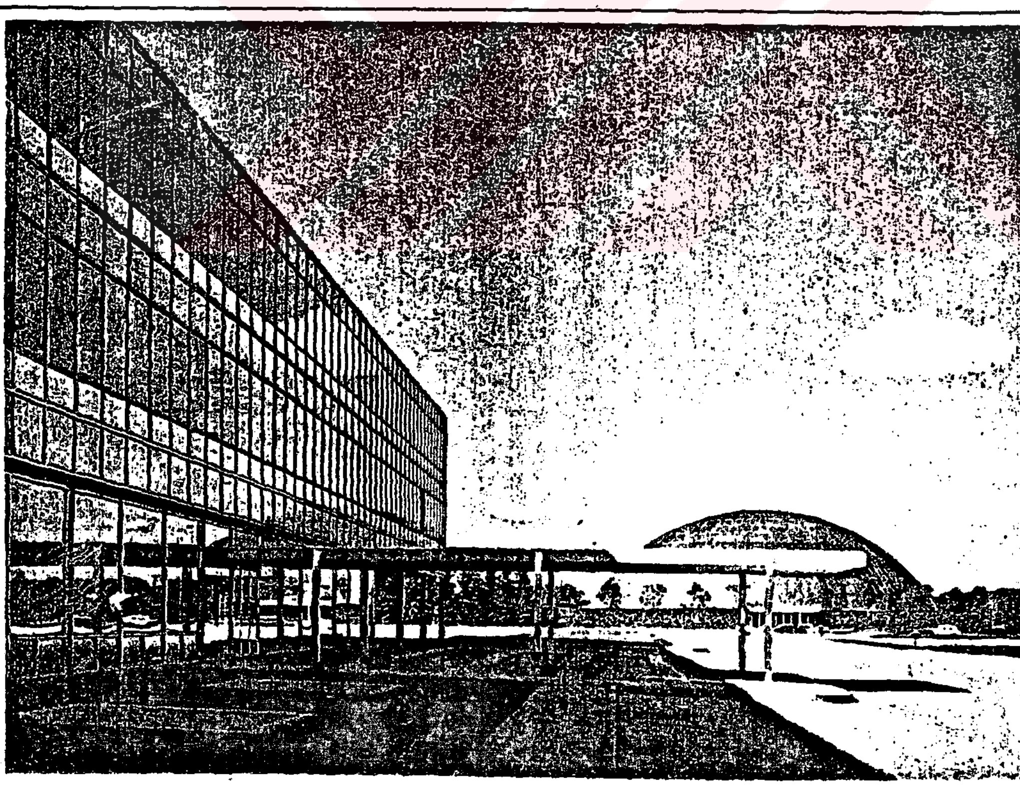


Figure (13) : Konrad Wachsmann, views of the connectors between the modular pipe sections

Other influences include ; Eero Saarinen's General Motors building in Detroit where the gasket glazing techniques of the car industry were first adapted to buildings ; Max Bill's demountable exhibition pavilion for the Swiss Landesasstellung (1963), corresponding to his own notion Produktform ; where in all structural and architectonic order is seen to derive directly from the processes of production and assembly ; Ezra Ehrenkratz's SCSD school systems in which space framed roofs packed with air conditioning plant and ducts hovered over flexibly partitioned teaching areas ; Charles Eames' beautiful use of new materials and assembly processes in his furniture,and his house assembled from catalogue industrial components.



Picture (23) : Eero Saarinen,General Motors,
Technical Center,Michigan,1950-57

Another important antecedent to high-tech was the increasing role of structural engineers,or structural forms,in shaping some well known modern buildings like those by P.L.Nervi, Eduardo Torroja,Felix Candela and Owen Williams.

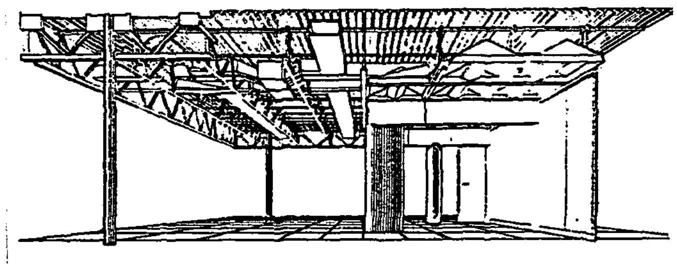


Figure (14) : Ezra Ehrenkrantz,SCSD prototype school building 1960

4.2. PHILOSOPHY

In high-tech,the words technology and art are rolled into one ; as Greeks used it where the word technè - a root word for technology meant art.The argument is that,technology is simply the making of things and the making of things can't by its own nature be ugly or there would be no possibility for beauty in the arts, which also include the making of the things (80).Greeks never seperated art from manufacture in their minds,and so never developed seperate words for them.The way to solve the conflict between human values and technological needs is not to run away from technology.That is impossible.Thus building mechanisms and architecture are united into one.

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(80) JOHN MC KEEN,Gold Standard,<u>Architectural Journal</u>,March 83, p.12.

High-tech architecture bases its rules on the methods and products of manufacturing industry.Buildings are seen as being mere industrial products.Influenced by the super high-technology gadgetery of the space programme,architects want to bring building into line with the rest of the industry ; to make it more like the production of motor cars,aeroplanes,refrigerators and television sets (81),products which are in closer touch with the realities of the 20th century.

The basic guiding principles of high-tech may be listed as follows ; firstly,as far as possible all building tasks should be reduced to the provision of a well-serviced "shed or hangar" space ; this hangar should be planned as flexibly as possible after the open plan model established in the early fifties by the "office landscape" movement ; the adaptability of this space should be assumed through the provision of a homogeneous,integrated network of services ; power,light,heat and ventilation,etc. ; wherever possible a clear separation should be maintained between servant spaces such as lavatories and kitchens,and the served areas such as auditoria and dining halls ; as far as possible the hangar or shed space should be a self-supporting basic shelter tending towards "ideal" space forms such as the geodesic dome (Fuller) or the inflated bubble (Victor Lundy) or the suspended tent (Frei Otto) ; finally,there remains the moral principle that the expressive elements in any structure should be reduced to nothing more than the production of its component parts.

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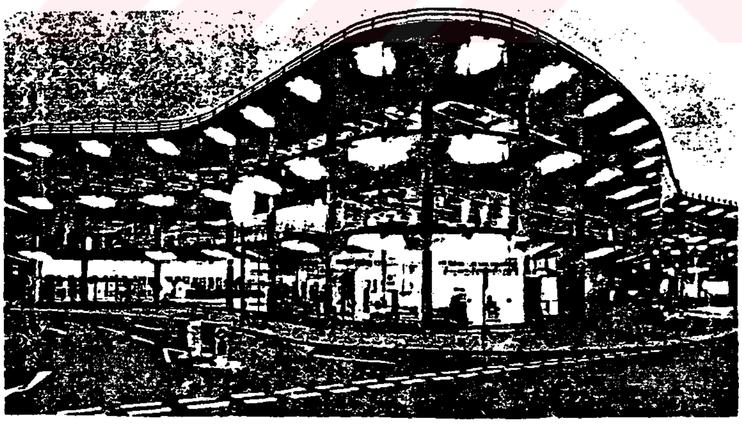
(81) DAVIES COLIN,Hopkin's Rules,Architectural Review,May 1984, p.54.

4.3. CONTEMPORARY REALIZATIONS

Of all the projects completed in high-tech it is without argument that the British architects practice this approach with a degree of seductive finesse found nowhere else.This is not to say that the British buildings are more rational,economic,efficient or even innovative in their use of high-technology than others elsewhere.Indeed B.Fuller's,Prouve's,Piano's and Otto's and his collaborators buildings succeed in these terms better than anybody's.

From the Seminal Reliance Control Factory of 1966,designed by team 4 (Norman and Wendy Foster,Richard and Su Rogers),to the turning points of Foster associates'Willis,Faber,Dumas and Piano and Rogers' Pompidou Centre,high-tech has evolved from being an anti-art into the representation of art in its lightest form.

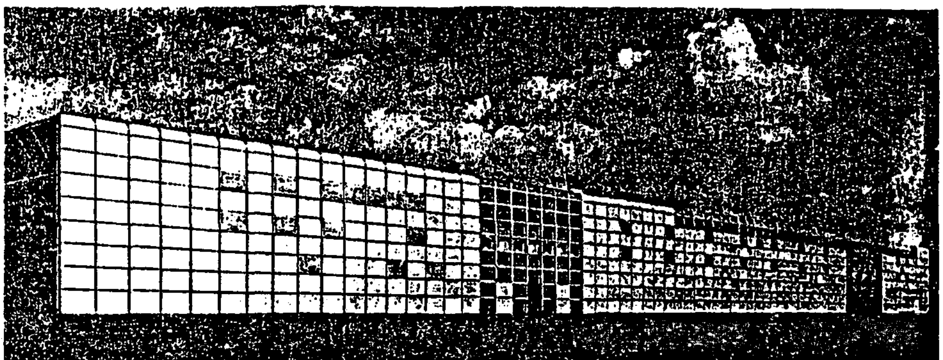


Picture (24) : Norman Foster Associates,
Willis,Faber and Dumas Offices,
Ipswich,1975

Willis,Faber and Dumas offices in Ipswich (1974-1975), employes a suspended glass wall which makes use of the high tensile strength of toughened plate glass in suspension.The joints between the glass are translucent silicon sealing and the only visible connections are the patch fittings (82).The structural members are seperated from the enclosing glass.

The quality of lightness and penetrability is a general feature of Piano and Roger's Centre Pompidou (1977) (83).The frame is generally expressed as a slender net work and both external walls and internal partitions are seen as light and provisional.

Foster Associates' Sainsbury Centre for Visual Arts (1977) ,in Norwich of England,a museum to house a collection of art,takes the skin structure,and services and integrates them into the double membrane shell wrapping around a 33x120 meters clear span 7.5 meter high. The same exterior cladding,sheathing walls and roof



Picture (25) : Norman Foster Associates,Sainsbury Center for Visual Arts,1977

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(82) MICHAEL FOSTER,The Principles of Architecture,Style,Structure and Design,UK. : Phaidon Press Ltd.,1983,p.160.
(83) ALAN COLQUHOUN,Essay,Symbolic and Literal Aspects of Technology,Architectural Design,Nov 1962,pp.508-509.

in one continuous surface of aluminium,glass and grill panels (84) generates an innovation in gasketery,panel fabrication and attachment.

The RENAULT Centre,in Swindon,of the same architect envisions a decorated architecture that stems solely from the expression of structure (the same sort of thought as in Modern Movement).The building is organized in a series of 25 meter square bays,whose corners are defined by 16 meter high tubular steel poles poking up through the roof to carry the tension rods from which hang the undulating (85) internal structure of the roof.In essence the structure is a portal frame,tensioned at 24 meter centres from its steel masts.Two systems of arched beams meet the masts at right angle and on the diagonal,with purlins spanning between them (86).

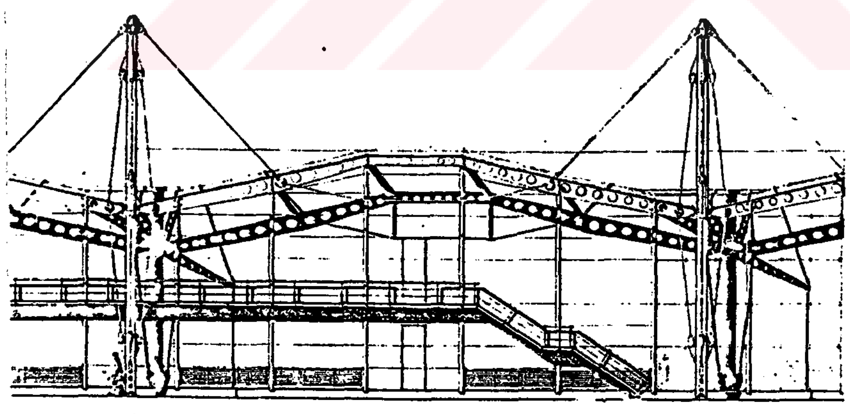
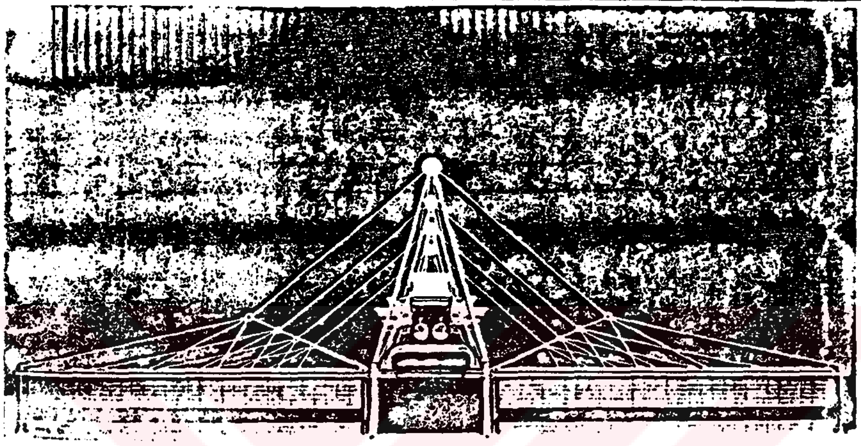


Figure (15) : Foster Associates,Renault Centre, Swindon

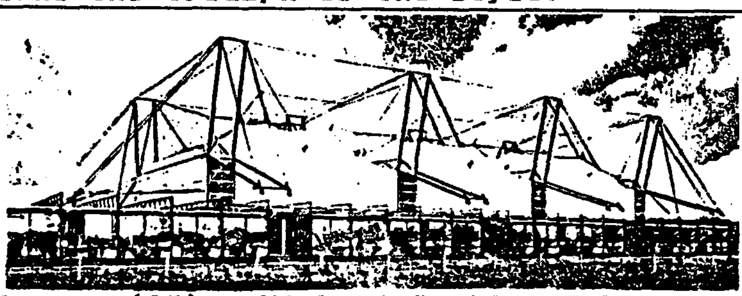
(84) SUZANNE STEPHENS,Modernism Reconstituted,Progressive Arch, Feb 1979,pp.49-50.
(85) MICHAEL VERNES,Jean Prouve,Arch Review,July 83,p.38.
(86) ALASTAIR BEST,Foster at Play,Architects Journal,Dec 82,p.40.

Pat's Centre Princeton,a high-tech building of a high-technology research facility in New Jersey,by Rogers and partners, uses a suspended structure to achieve column free open space arranged on either side of a central spine from which the suspended beams are supported and which also accommodates the mechanical plant.



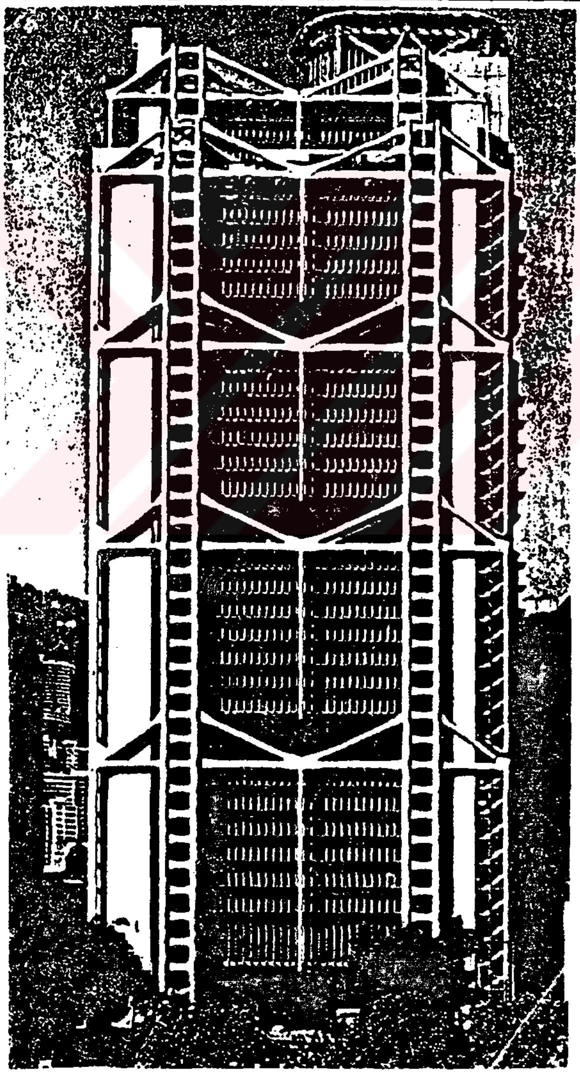
Picture (26) : Rogers and Partners,Pat's Centre Princeton,New Jersey

Whereas the Schlumberger Research Centre in Cambridge, architect Michael Hopkins,working with designer Tony Hunt,secured his position as high-tech's heir apparent,the two most recent buildings,just completed,which come in the form of high-rise : the Lloyds Buildings of Rogers in London and the Hong-Kong Bank of Fosters crowns the triumph of the style.



Picture (27) : Michael Hopkins,Schlumberger Research Centre,Cambridge,1977

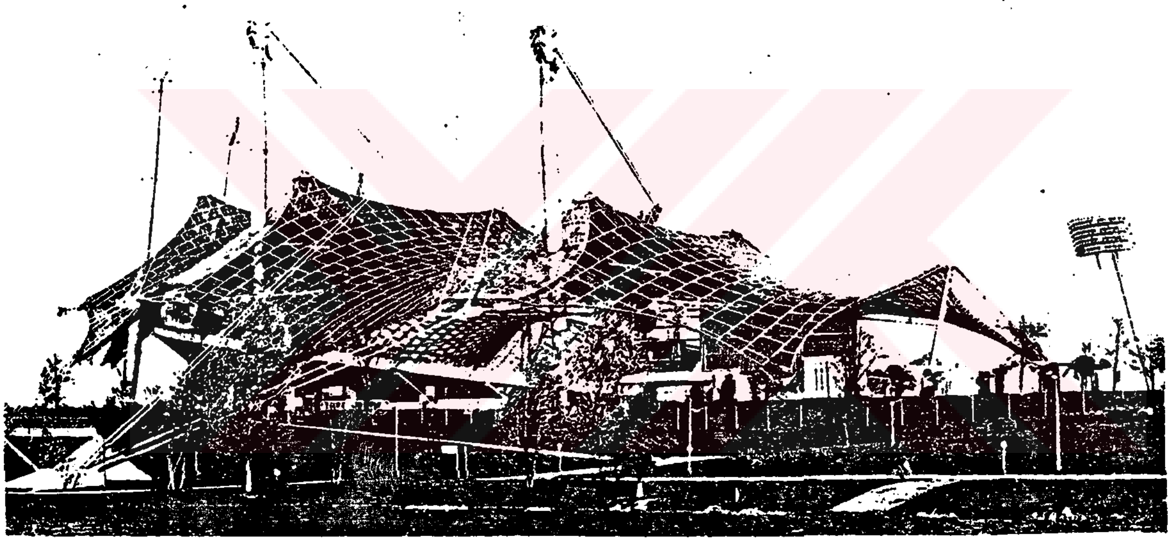
Lloyds office building is a reinforced concrete structure where the columns,floor edges,toilet modules,the vertical circulation elements and most of the air-handling ducts are fully exposed external elements.The floor structure is also fully exposed (87).The building is of particular interest that it moves away from the building industry for the prefabricated stainless steel toilet capsules,which are manufactured by suppliers from the process engineering,aircraft and offshore industries.



Picture (28) : Foster Associates,
Hongkong Bank,1987

(87) Design for Better Assembly,Case Study : Rogers' and Arup's, Architectural Journal,September 1984,p.88.

Hongkong Bank, is significantly more efficient in achieving usable office space - over 73% efficiency for the entire building compared to 63 - 65% average in comparable buildings around the world (88). This is achieved by concentrating the main structure into eight steel pylons ranged along two sides, from which the floors are suspended in tiers for the main office and banking activities, seperated by transfer spaces of higher ceiling height where social and public activites occur, and where the main structural bracing is located.



Picture (29) : Frei Otto, Olympic Stadium, Munich, 1972

Parallel development has taken place in space technology and building engineering. Frei Otto, taking the concept of envelope further with his use of minimal structures has developed a building from quite outside architectural fashion. Otto's expressed interest was not just to build more fabric structures, but to

(88) Investing in High-Tech, <u>Architectural Journal</u>, February 1981, p.342.

explore the "dramatic potential of naturally occuring materials and forms" (89).With his single storey light-weight structures, Otto sought to extend the boundaries of engineering possibilities far beyond the limits of conventional materials,structural systems and established methods of construction.Otto was able to extend the vocabulary of tensile forms and begin to operate on a large scale.Thus he was inventing new forms as well as new technical methods that put it under the title of high-tech.

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(89) JAMES CARDNER,The Nature of Architectural Fabrics, Architectural Record,March 1985,p.157.

5. APPLICABILITY OF HIGH-TECH AND A PROJECT PROPOSAL

Commissioners, whether be in private or in the state sector, want to benefit from the most efficient use of space and the allowance for their alterations in their organizations. Especially where the land prices are extremely high in those concentrated areas of the city, this point becomes of utmost importance.

So, a new approach to building design is evolving which is aimed at creating as much space as possible for future change without disproportionate increase in cost; the cost being represented in terms of structure, cladding and services. High-tech has produced: wider spans to cover space more economically, with less material and fewer supports, more sophisticated cladding materials, and repetitive forms of design for the production of structural systems. Long span structures are seen by some developers as providing one such mechanism for space operation. The efficient use of space is clearly displayed as in the case of the Hongkong Bank, in which the increase of fifteen percent cannot be neglected.

Building programme pressure of city developments have led to an increased use of fast track design and construction where site works overlap design. Because of its programming advantages, steel frame has become synonymous with fast track. Patrons benefit from the quicker erection allowing earlier completion of fit out and subsequent occupation,thus enabling an early return of investment.

Another factor,is the fact that the requirements of modern life are so complex and changeable that any attempt on the part of the designer has to come in the same terms with flexibility.The expected frequency of refurbishment and change of use in building also favours the steel frame,compared to reinforced concrete structures,because of their greater adoptability potential.

With those benefits that High-tech architecture has to offer,it is applied throughout a variety of building types with the same success.The programme constraints put by different building types,such as offices,factories,hospitals,warehouses and others may result in different requirements.However,there are factors applicable to all,as has been discussed above.The fact that High-tech approach brings the potential of solution of those highly important points,indeed reinforces the soundness of its philosophy.So,the design proposal of this study could have been any one of the typologies of contemporary architecture.I propose a cultural activities centre where the culture reflected by this building mechanism is supported by other practices and techniques developed in industry and art as well as in crafts.

6. THE PROGRAMME AND THE PROPOSED PROJECT SITE

This thesis puts forward the argument that architects to be innovative should be stimulated by the new building materials for making architecture which reflects the society of its time more than any other art form.The thesis likewise emphasises the importance of the learning process into the materials and into the techniques a new architecture imposes.A learning process,which would have to include extensive studies on its materials,starting from the manufacturing methods until the assembly of that product. They would also have to be concerned about the properties such as durability,finishing,stability,thermal qualities and so on of the material they are designing in.

In order to support the essentiality of this learning process,a valid argument,both in art and technology;this new building system is integrated into a project which proposes a workshops and studio complex which is organized and managed by a "Foundation of Research and Development of Art and Craft and Industrial Products."

This Institution's main effort is to stimulate design and research to produce new products and methods concerning all sectors of industry and applied arts.The stimulation is not only for the designers and technicians of this team but also for the industrial firms who would like to improve upon their products with the benefit of the extensive research this group has to offer.The institution should also create and encourage the social contact between people which is essential to broaden the area of this learning process by the means of studio works,lectures, exhibitions,meetings which are enclosed in its organization and also by concerts,dramas and other attractions and gatherings.

The idea to create a flow of thought through different forms of cooperation,to involve people in a mutual task in order to exchange knowledge and skill is the basic idea behind this project.

The complex will also feature outdoor facilities for stage performances,shows and market days where the products of the studios and workshops might be sold thus attracting a larger publicity to the place.

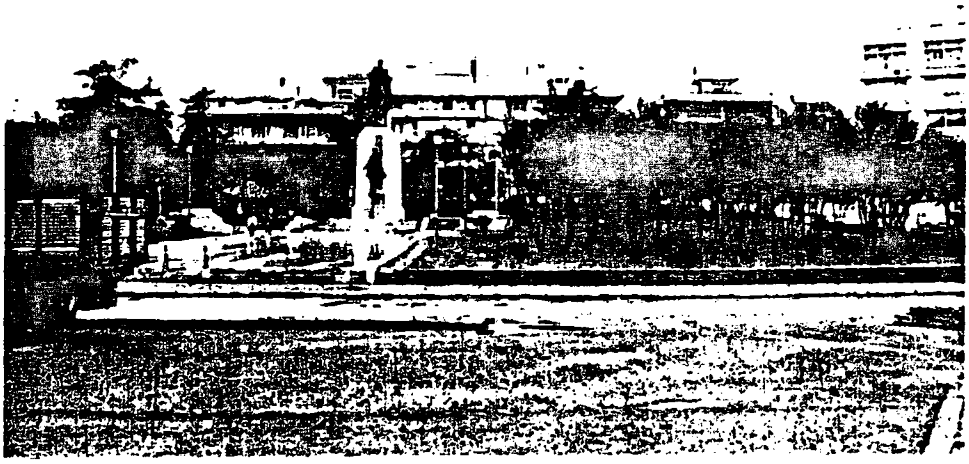
The project site chosen is located in Istanbul:in a part where the social,cultural,historical and recreational values and activities are concentrated.This part is surrounded by Dolmabahçe, Beşiktaş,Maçka,Taksim,Harbiye,Nişantaşı which represents several of the city's main districts also known for highly concentrated activities of commerce and tourism.

Zoning the activities:

- In Taksim,the Atatürk Cultural Centre is of importance for the operas,theatres and concerts it holds.In Harbiye and in Taksim the accumulation of many hotels which includes the Hilton,Sheraton, Divan,Etap enlivens the environment with their social activity potential as well as touristic.

- Also in Taksim,in Maçka and in Gümüşsuyu the faculties of engineering,architecture and social sciences of the Istanbul Technical University and in Fındıklı the Mimar Sinan Faculty of Fine Arts and in Beşiktaş Applied Fine Arts University is located.
- In Harbiye,the Sport and Exhibition Palace provides activities of sports,exhibitions and concerts.The Military Museum in its old and new buildings provides traditional concerts and restoration works of antiquities are undertaken.
- In Nişantaşı where there are numerous small galleries of art the district also includes many shops selling architectural and industrial products.
- Elmadağ is a commercial and recreational centre where a number of banks,offices,shops and discos and nightclubs are situated.

Each of these districts are formed by buildings that display a high level of architectural quality.An outstanding historical building is the Dolmabahçe palace.The site for the proposed project is in the part of the lands that belongs to this palace.The site on the hill which forms the background to the palace from the Bosphorus,presents a topographically interesting piece of land as it includes great variations in altitudes.The richness of greenery inherent in this site's quality,dating back to the times before the palace was built,conditions any building



Picture (32) :MaÇka Park,looking towards the apartment

Picture (33) : Maçka Park looking towards the apartments.

proposed to employ the most elegant and light materials.Another important design criteria that the site dictates is the silhouette it will present from the Bosphorus,a unique phenomena with its water-front houses and palaces reflecting a rich culture.

The proposed project programme will include:

Workshops and Studios for;

- Painting
- Pottery
- Visual graphics
- Sculpture
- Architectural works
- Photographic works
- Furniture design
- Glass
- Theatre props
- Wooden products
- Metal products
- Plastic products
- Machinery and equipment etc,etc,.

Exhibition areas for;

- Art and Craft
- Industrial products

Outdoor facilities to held;

- Concerts
- Dramas
- Exhibitions
- Meetings

The programme also features management offices,a reference and periodicals library and a snack restaurant and a bar.In its use the complex will be integrated to the Taslik Coffee House and to the existing sporting club containing activities for swimming, tennis,basketball and etc,.

The project will call for maximum flexibility in its planning and the usage of the materials it is constructed in due to its varying and different tasks:

In the studios and workshops:

- Facilitating the possibility to modify the localities according to the actual needs,such as turning a studio into a store,showroom etc,.
- In accommodating the different forms of work through out the studios and the workshops.
- In joining several spaces to form a larger unit of working space or vice versa in dividing a space to form smaller units.
- In enabling appropriate responses to the jobs undertaken from other firms,in research,design and in the production of the prototypes.

In the exhibition areas:

- To form larger and varying places for short term exhibitions stage performances,seminars etc,.
- To create varying accommodation for long term installations as libraries,offices and stores etc,.

Outdoor facilities;

- In accommodating the crowds of people on special event days such as for concerts,fairs,shows,market days and so on.
- In providing performance stages,seating areas,food and drink facilities,transient market stalls.
- In installing the necessary equipment for lighting,sound and decors.

The complex will also require advanced engineering systems integrated to its constitution:in heating,in ventilation,in lighting and in other fields according to the needs required by the complex especially the workshops.

7. MATERIALS EMPLOYED

In order to justify our argument of learning into the materials one is designing with,this part of the study will concentrate on some of the products of the building science which are proposed to be used in this project.

7.1. PROFILED METAL SHEET

The term profiled metal sheet cladding describes a group of steel or aluminium products for forming economic weather skins. Profiling imparts stiffness and hence strength to thin and otherwise flexible materials.

These claddings are characterised by low thermal capacity, mass and noise reduction capabilities;an inability to support dead or live loads;and a lack of resistance to impact damage.In addition they are not fire resistant unless formed into composite systems incorporating fire-resistant materials.

However,their low-mass can lead to economies in the building structure and foundations.They can be rapidly erected,or dismantled and re-erected and they can be renewed easily.Their durability depends on the quality of the external protective and decorative coatings applied to them.

There are three basic profiles:sinusoidal,symmetrical trapezoidal and asymmetrical trapezoidal.These profiles were developed for structural reasons;generally,the deeper the profile the more robust the sheet.However,appearance often dictates the choice of profile and because robust sheets tend to have more visually pleasing profiling than weaker ones the profile is often overspecified for its purely structural function.

The sheeting is attached to a substructure of rails and purlins bolted to the building's main frame.It may be lined with thermal insulation and faced internally with liner boards.It may have insulation bonded to it or it may be installed over insulated metal liner trays.

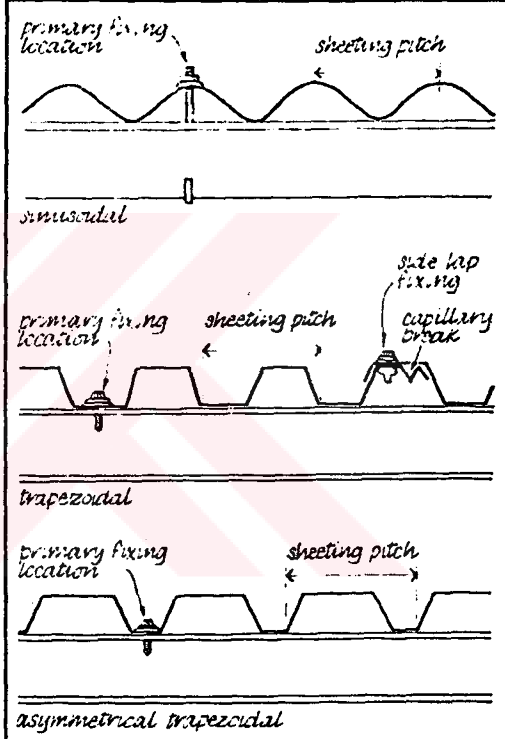


Figure (16) :Basic sheet profiles

7.1.1. STRUCTURE AND STABILITY

The design of the structural frame,including calculation of support centres and member sizes,should be done by structural engineers,the profiler supplying the necessary load/span information.Support centres depend on the particular profile specified,its strength being derived from its shape, metal thickness,metal grade and length.

7.1.1.1. GRADES OF METAL

Generally,steel sheet for profiling is obtainable in thicknesses ranging between 0.4 mm and 0.7 mm.Aluminium sheet is available in thicknesses ranging between 0.5 mm and 1.6 mm. Support rail centres vary according to the sheet profile,between 2 mt and 3.3 mt.The maximum deflection for insulated walls should be span divided by 150.

7.1.2. FIXINGS AND MOVEMENT

7.1.2.1. MATERIALS' QUALITY

Primary fixings are fasteners which attach cladding to structure and must withstand all loads applied to the sheeting. Secondary fixings attach sheets together at side and end laps and assist in transferring loads between sheets and improve weather seating of lap joints.

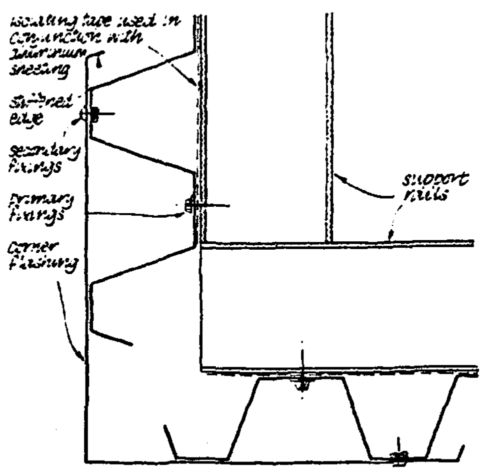


Figure (17) :Typical external corner detail showing primary and secondary fixings.

Care should be taken to protect against bimetallic corrosion both in respect of fixings to sheeting and fixings to structure. Water resistance is provided by synthetic rubber washers fitted beneath the heads of fixing screws and their load-spreading metal washers,and under the heads of the blind rivets.

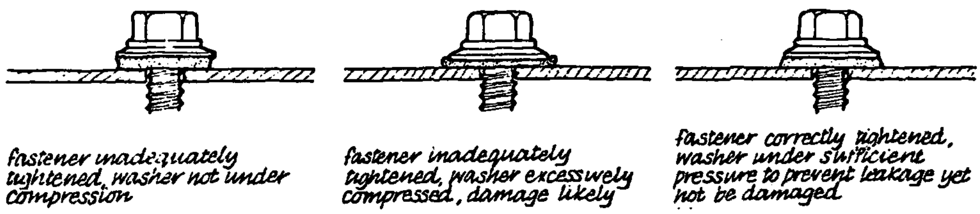


Figure (18) :Visual check of adequate tightness of fixing

7.1.2.2. FIXING METHODS

Primary fixings should be through the crown of sinusoidal sheets and the troughs of trapezoidal ones.Though it has become common practice for secondary fasteners to be made through the crown,maximum shear strength is provided in end and side laps by fastening through the side walls of profiles.While side wall fixings on roofs is recommended,on walling it is not as important.

Maximum centres for primary fastenings through steel sheeting are 450 mm and through aluminium sheeting are 400 mm.In an In any event a primary fastener should be located in every third corrugation.Secondary fixings should be at a maximum of 500 mm centres (90).

7.1.3. WEATHER RESISTANCE

7.1.3.1. WATER PROOFING

Profiled metal sheet is intrinsically weather-tight,but careful detailing is required to ensure that leakage does not occur at lap joints,flashings or fixings.

Generally,vertical sheeting joints do not need to be sealed to prevent leakage,but the sheets should be secondary fixed together at about 400 mm centres.End laps should be avoided;full height sheets should be used whereever practicable.If end laps have to be formed they should be located as far to the top of the wall as possible.

7.1.3.2. SEALANTS

Sealants are rarely needed on a vertical sheeting although they may be used in exposed positions.

7.1.3.2.1. SEALANT MATERIALS

Grease based sealants can be used in thin joints because they allow proper nesting of one sheet into the profiles of

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(90) BS 4868:1972 Profiled aluminium sheet for building.

another. Preformed mastic ribbon sealants can be used, but only the soft varieties. At least 20 percent compression is required for effective seals. The ribbons should be laid in an even width and be worked well into the corners of the profiles (91).

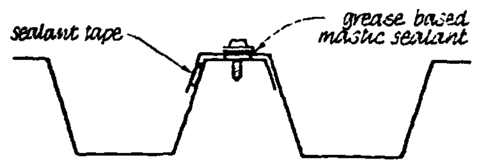

Figure (19) :Side lap seal

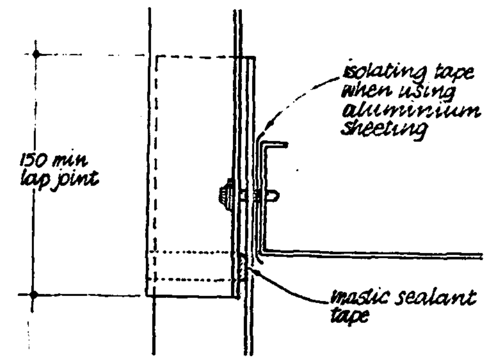

Figure (20) :End lap seal

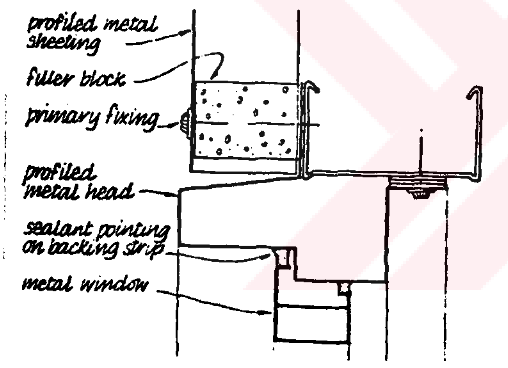

Figure (21) :Filler block at lintel.

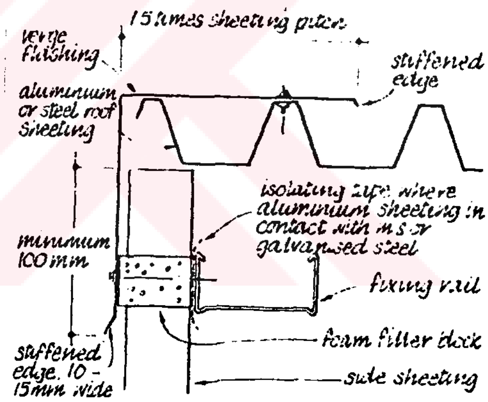

Figure (22) :Filler block at verge.

7.1.3.2.1. FILLER BLOCKS

Filler blocks are used to seal cavities formed between the profiled sheeting and its supports or flashings. They help to exclude draughts and moisture and in maintaining continuity of thermal insulation.

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(91) BS 1494:Fixing accessories for building purposes
Part 1: 1964 Fixings for sheet, roof and wall coverings.

Filler blocks must be reasonably compressible to compensate for differences in the depth and width of individual profiles.They should be made from non-porous materials,preferably closed-cell structures,and should be capable of withstanding long temperatures of about 80 centigrade.Rubbers and rigid foam plastics are unsuitable,but expanded polyethylene,expanded polyvinyl chloride and expanded polyurethane are suitable.

Filler blocks should always be secured to prevent displacement.

7.1.4. THERMAL QUALITIES

Profiled metal sheeting can be obtained in pre-insulated lengths or factory made insulating components can be combined during construction or linings can be designed according to individual preference.When dealing with thermal insulation, consideration should also be given to fire resistance,noise reduction and the type and style of wall lining required.All four factors can be resolved at the same time by using the appropriate form of composite construction.

7.1.4.1. MATERIALS

Quilts and rigid boards can be used as insulation either over or under the sheeting supports.Mineral wool is widely used in sandwich construction,supported between the supports by linings of plasterboard, insulation board or metal trays or sheets. It is available in various thicknesses up to 100 mm. Spacers should be used on the main fasteners to maintain the thickness of insulation over structural supports.

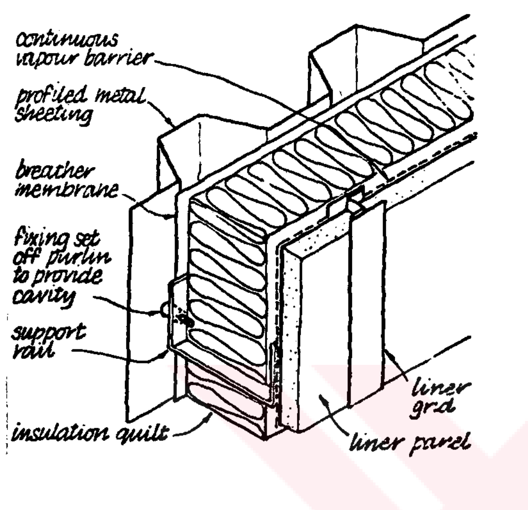


Figure (23) :Typical insulated construction with insution quilt.

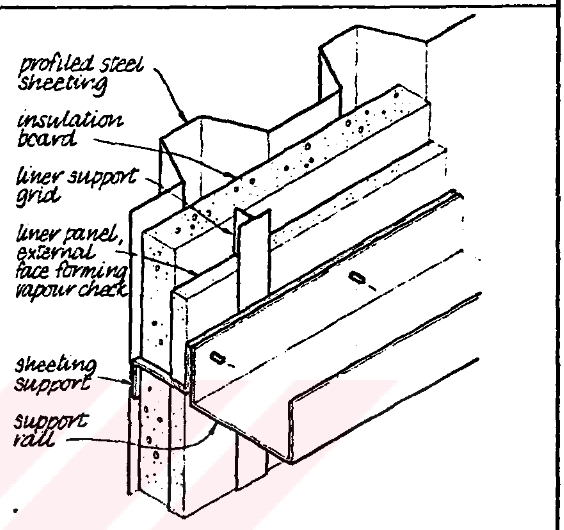


Figure (24) :Typical insulated construction with insulation board.

7.1.5. DURABILITY AND MAINTANENCE

7.1.5.1. STEEL

The durability of steel sheet depends on the quality and character of the decorative finish. Available finishes include hot dip galvanising, aluminium coating, aluminium/zinc coating, PVC, silicone polyester, acrylic and PVF_2, with life expectancies of 20 yearsand in excess of 25 years respectively.

Paint systems have been developed for repainting profiled steel, increasing the sheeting's life by up to eight to ten years.

The aluminium/zinc coating is between 15 and 25 microns thick and has a tenacious bond to the steel sheet.It has as estimated life expectancy based on measurements of coating loss,in excess of 40 years in a normal industrial environment.Like other such coatings it forms a protective oxide patina when exposed to air which dulls the surface.

7.1.5.2. ALUMINIUM

Aluminium sheeting does not require protective painting.Mill finished aluminium develops an aluminium oxide coating on exposure to the air which acts as a protection against further corrosion. However,the oxide causes dulling of the surface and industrial grime can attack the surface affecting the sheeting's appearance, although not its performance.

Aluminium sheeting can also be stove-enamelled in a variety of colours and these coatings are particularly durable.Unlike colour-coated steel,if the coating becomes damaged there is little or no long term effect on the underlying material.

7.2. METAL PANELS

The advantage of metal composite panels over more traditional profiled sheeting is that insulation cores can be incorporated between the metal skins,resulting in better spanning characteritics and speed of assembly.

Costs for a metal system vary considerably according to its complexity and required performance.Non-standard items,such as curved panels,sloping panels and staggered glazing will all increase base price costs.

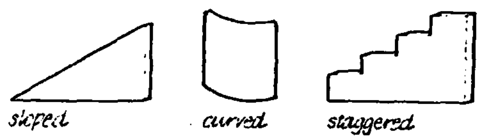


Figure (25) :Panel shapes to avoid in limiting costs.

7.2.1. MANUFACTURING METHODS

7.2.1.1. FORMING METAL SHEETS

Sizes of the panels are constrained by methods of forming and pressing the metal,ways of incorporating their insulation cores and sometimes methods of finishing.

The choice of steel or aluminium largely depends upon the type of finish to be used.Aluminium is also marginally more expensive than steel and its spanning characteristics are lower but it offers better corrosion resistance,particularly at the cut edges.

Sheets of steel or aluminium-normally 0.5-0.9 mm thick-can be formed either by press braking (bending) simple sections in one direction only,by rolling more complicated sections,also in one direction only,or by pressing or stamping,making use of more sophisticated deep drawing methods.

The width of the panel is influenced by the size of metal coil widths,normally available up to a maximum of 1250 mm.

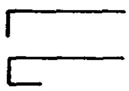
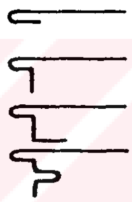
Method	*Profile*		
Press braking Press brakes commonly available with V-shaped stamp, max 4 m long.	Will press simple L- and U-shaped profiles		Simple bend Double bend
Rolling Continuous rolling or rolling separate sheets. No limit on length other than that of handling and transport	Simple profiles possible on small interchangeable rollers. More complex profiles need large and expensive fixed stand machines		Crimped Return end Double return end Complex profile
Stamping Steel sheets normally limited to 2 × 1 m	All four edges or face profile can be stamped in one operation. With large panels it is normal to stamp profiles and form edges by press braking		Stamped panel edge
Pressing (using deep drawing techniques) specialised shape forming using Superform aluminium is possible. It is relatively expensive compared to other methods of forming	Three dimensional shapes and tray panels, such as at the Sainsbury Centre produced with Superform aluminium. There may be a limitation in depth of tray possible using superforming techniques. Sainsbury panels, at 100 mm deep, were difficult to form. More normal deep drawn profiles are 20-40 mm deep		Deep section in tray form

Table (1) :Methods of metal panel forming

.2.1.2. INCORPORATING INSULATION CORES

Many composite units are produced incorporating an insulation ore,which may also improve strength characteristics.This either omes as pre-cut sheet,to make laminated panels,or is foamed in place etween the two panel skins.Table (2) illustrates these two methods f incorporating insulation cores.

Method	*Insulating materials*
Laminated panels Produced on a heated platten press or vacuum press . Maximum platten press size 6 × 2·5 m. Maximum vacuum press size 8 m × 3 m	Normally polystyrene board either as extruded polystyrene available in sheets up to 600 mm wide or as expanded bead polystyrene available in sheets up to 900 mm wide
Foamed panels Produced either on horizontal moulds or vertical moulds Materials react, foam and cure between treated metal skins	Normally polyisocyanurate (a modified form of polyurethane). Vertical foaming normally restricted to 600 mm due to possible over foaming above that dimension

Table (2) :Incorporating insulation.

Architects should be concerned with the standardization of oaming and density control of the foam at the panel-core nterface.Similar considerations should be given to the lamination echniques with board insulation,particularly regarding the flatness f the board and the quality of the adhesives used.

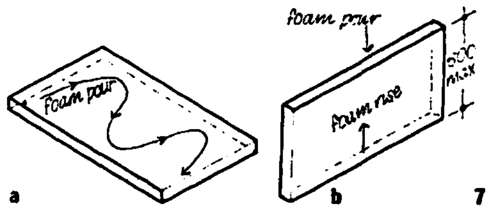


Figure (26) :Horizontal and vertical pouring of foam cores.

7.2.2. DURABILITY

Durability of metal panels,especially steel,depends on life to first maintanence of anodic coatings or paint finishes,which are usually quoted as 15-20 years.Two methods of finishing are commonly available and these may influence the size of the panel achievable.

	Typical finish	*Size constraints*
Pre-finished metal (Metal finished before forming)	Stainless steel	Affected by sizes available. Check with BSC stainless division
	Pre-coated, such as BSC Plastisol, PVF_2	Normally available in 1200 mm width coils
Post-coated metal (Finish applied after forming)	Painting, such as electrostatic painting, PVF_2 with varnish coat	Influenced by size of available automatic spray box or by limits of hand spraying—check with manufacturer
	Anodising	Influenced by depth of anodising bath available. Check with manufacturer
	Vitreous enamelling	Height of curing oven affects one dimension and special steel normally only available in 1150 mm widths (vitreous enamel panels 1·2 × 2·4 m max)

Table (3) :Finishing and panel sizes

7.2.2.1. SURFACE TEMPERATURE

Surface temperature of dark coloured panels using insulation cores can be high.For example,an ambient temperature of approximately 30 centigrade can result in a temperature of approximately 80 centigrade on the outer surface of the panel,depending on its colour (92).

7.2.2.2. PERFORMANCE OF FINISHES

Some finishes are more vulnerable to damage during assembly and handling on site.In general,the thicker the subcoat the better the chance of durable paint application.

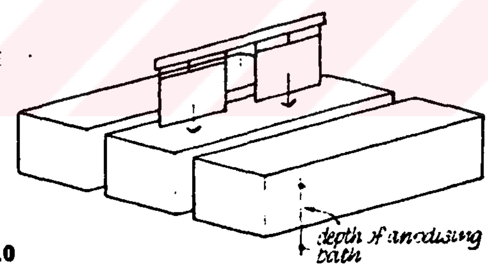


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Figure (27) :Anodising bath size limits panel size.

Table (4) illustrates the performance of finishes.

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(92) BSC roofing and cladding in steel-a guide to architectural practice,Nov 1985.Page 26,table 6.

Finish	Nature of finish	Performance
BSC Plastisol	Thick coating (200 microns)	Good resistance to impact but has some loss of colour in time
PVF_2	Thin coating (25 microns)	Good resistance to ultra-violet light but needs protecting during installation
Silicone polyester	Thin coating (25 microns)	Not as good as PVF_2 for colour fastness nor as good as Plastisol for abrasion
H. H. Robertsons' Versicore	Thin top coating for appearance on thick epoxy primer applied to both sides of steel	Good corrosion resistance
Polyester powder coating	Only available on aluminium (60-80 microns)	Good colour retention and available in wide colour range
Vitreous enamelling	Only available on steel	Good weather resistance but some colours (such as chromes) may not be available
Anodising	Only available with aluminium as silver or anodic colours	Good weather resistance but difficult to control colour match on large panels
Duranar PVF_2 with varnish	Available as relatively expensive post-coat system 50-70 microns thick	Good weather resistance but need to control the thickness of the varnish coat

Table (4) :Comparative performance of finishes

7.2.3. STRUCTURE AND STABILITY

The permissible limit of the panel's deflection under the wind load is 1 in 150.

There are essentially two types of panel:

- Framed panels:Relatively thick gauges of steel or aluminium 2-3 mm thick are stiffened either by forming into trays or by using an additional edge member welded to the back of the metal skin.

Insulation,usually in the sheet form,is then applied to the back of the panel,on site or in the factory.

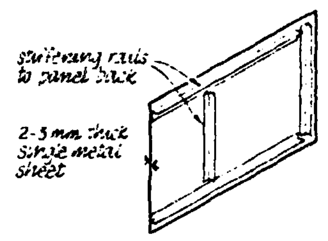

Figure (28) :Back of framed panel showing stiffening rails. But insulation has not been inserted between them.

- Sandwich panels:This is the most common type where thinner gauges of steel or aluminium 0.5-0.9 mm thick are seperated by means of an insulated core material which can either be laminated or foamed during production.In this case the core material acts in a similar way to the web of an I-beam and its thickness will therefore affect the spanning performance of the panel.These are often given additional structural performance by profiling the outer skins,although flat panels are also available.

7.2.4. WEATHER RESISTANCE

7.2.4.1. WATER PROOFING

Most metal panel systems use preformed neoprene,silicone or EPDM gaskets as a jointing material as opposed to sealants,although occasionally a mixture of techniques is used.

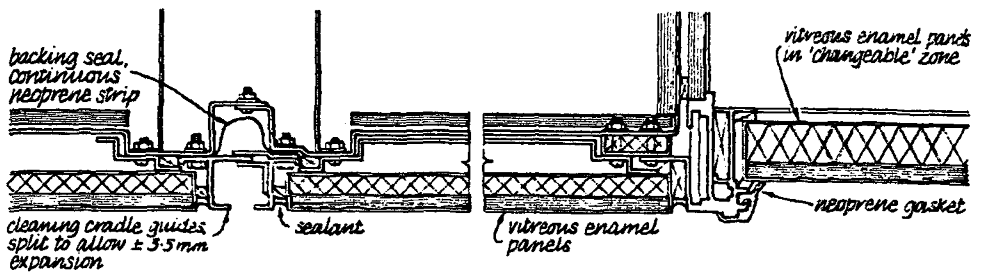

Figure (29) :Metal panels using both sealants and gaskets

How a joint is formed will vary with the method of panel assembly.There are essentially two methods :panel to subframe and panel to panel assemblies.

-panel to subframe assemblies:panels are mounted onto a subframe assembly (normally aluminium) using structural gaskets.

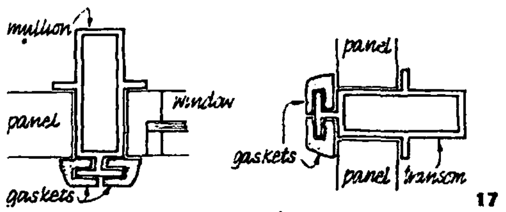

Figure (30) :Panel on subframe: Horizontal same as vertical joint.

-panel to panel assemblies:Here the panels are linked together,often incorporating a secret fixing within the joint.Common types include tongue and groove joints or locking capping pieces mounted over top hat sections.

The major difference between the two is that with panel to subframe assembly direct window junctions are possible on all four sides using the same gasket joint,thus allowing complete interchangeability of solid and glazing.Window to panel solutions are possible with panel to panel assemblies,but by means of a third member jointing piece.The horizontal and vertical joints will be different,thus offering less interchangeability.

Panel to panel assemblies,particularly those using tongue and groove joints,normally rely on sequential assembly and stacking.

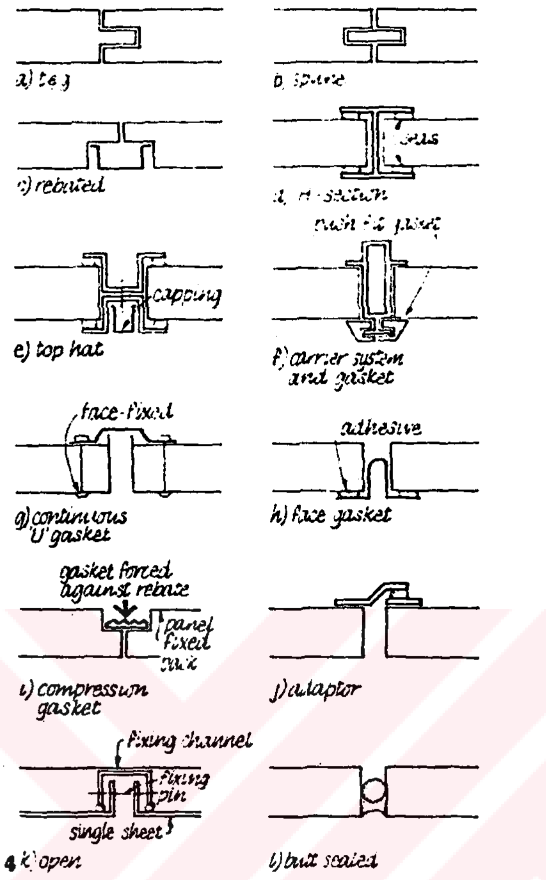

Figure (31):Generic joint types

7.2.5. THERMAL QUALITIES

Various types of core materials can be used, including: honeycomb cores (in paper and aluminium); mineral wool; end grain balsa; polyurethane(normally foamed); polyisocyanurate(modified form of polyurethane); styrofoam; PVC (93).

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(93) A.J.BROOKES, <u>Cladding of buildings</u>, Construction Press, 1983, Chapter 5, 'Sheet metal cladding panels'.

Polyurethane foam(and its modified form of polyurethane polyisocyanurate) and polystyrene board are the two most common types.Polyurethane foam offers better thermal performance in relation to its thicknesses than polystyrene board.

7.2.6. FIXINGS

Composite panels with self-finished inner skin are often bolted directly on to the structural framework,fixed from inside.Where panels are mounted on to a block wall they can only be fixed from outside.

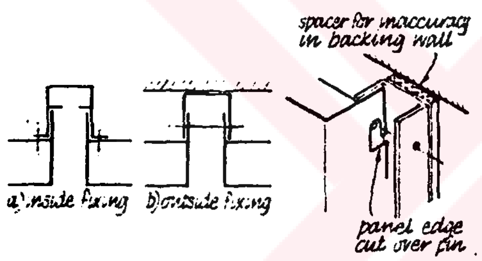

Figure (32) :a)panels mounted on frame and fixed from inside b)panels mounted on block wall and fixed from outside.

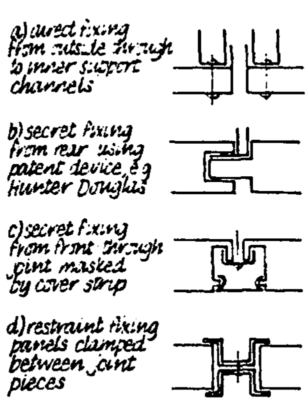

Figure (33) :a-d Types of fixing.

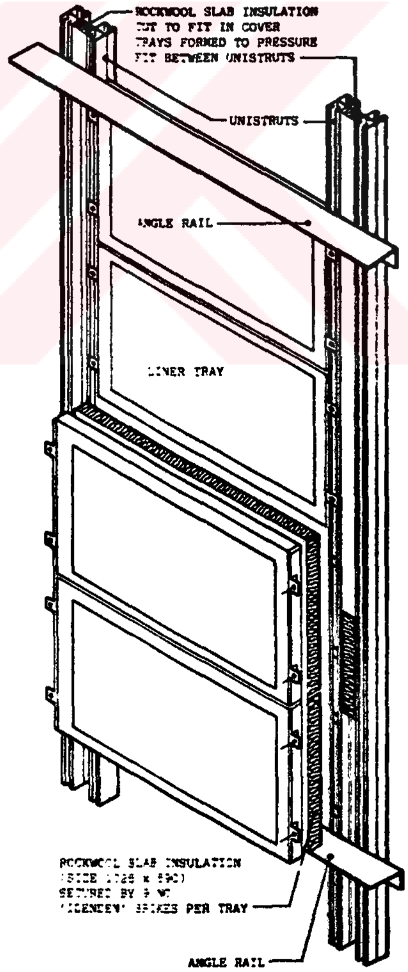

Figure (34) :Fixing of liner trays containing insulation.

7.3. G.R.P. (GLASS REINFORCED POLYESTER)

G.R.P. is a light,strong material that commonly provides cladding in sheet forms,sometimes as sandwich panels.

The main advantages of G.R.P. are its light weight and mouldability.Other advantages include:

-Lightweight products of low density yet high strength,
-Thermosetting,so it can be moulded without added heat or pressure.Thus moulding of relatively short runs of large complex shapes is possible,although longer runs will be cheaper,
-Large numbers of possible surface textures and integral colours,
-Can be used in composite panels with insulant cores,
-Impermeability of 'gel coat' surface.

Its limitations include:
-Combustibility.All synthetic resins,being organic,are combustible to some degree.
-High flexibility;(low modulus of elasticity can entail large deflections;)
-Relatively high cost of materials and need for skilled production with tight quality control procedures,
-Limited sound insulation.

7.3.1. MANUFACTURE

Polyester resin in a semi-fluid state is applied in layers with glass reinforcement (E glass) on a mould.The gel coat,the first layer of resin which forms the outer surface of the G.R.P., provides protection to the laminate.Coloured pigments can be added either to the resin or to the gel coat.Chemicals and fillers can be added to improve the fire retardancy of the composite.

Moulding can be hand lay up (contact moulding),vacuum moulding or press moulding.Contact moulding either by hand rollers or spray gun is the most common technique but press moulding has the advantage that a finish can be obtained on both external and internal surfaces.Vacuum moulding offers faster curing but in practice is seldom used.

7.3.1.1. THE NEED FOR STANDARDISATION

G.R.P.,like all components produced in an industrialised process,can only achieve economy of production if a high degree of standardisation is obtained.Too great a variety of panel sizes and shapes requires individual moulds which are costly.

Standardisation can also minimise the need for management control in identifying panels and simplify stacking arrangements and their fixing during the building process.

Moulds can be in steel,g.r. G.R.P.,or timber.Steel moulds are more expensive but are more accurate and can make a larger number of castings at least 150.

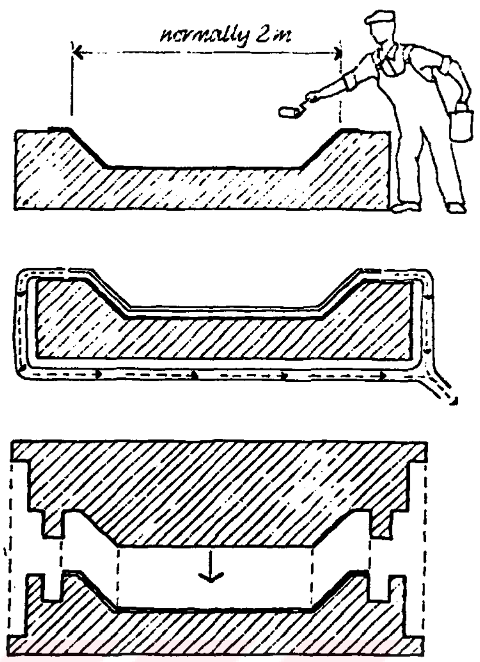

Figure (35) :Alternative methods of moulding GRP. Hand lay up,Vacuum moulding,Press moulding.

7.3.1.2. QUALITY CONTROL IN THE FACTORY

The quality of the product is therefore dependent upon the quality of labour force and the condition of curing.Ideally,the G.R.P. panels should be left in a curing box for at least 16 hours.The size of the curing box available may limit panel size.

Time of curing and thickness of gel coat are important considerations which affect the durability of the finished panel.Quality of gel coat is affected by the temperature and amount of catalyst used.

Excessive catalyst can cause cracking or crazing on the surface.Inadequate catalyst can produce inadequate curing resulting in defects and blistering below the gel coat.

To prevent accidental damage during installation it is important to protect the panels during manufacture,transport and assembly.

7.3.2. DURABILITY

Durability of G.R.P. depends mainly on the quality of the gel coat.If this breaks down and the glass fibres are exposed then moisture will soak up by capillary action between the fibres and the resin,causing deterioration of the composite. Thus it is essential to seal all exposed cut edges.In addition, panels should not be exposed to the weather without a gel coat.

7.3.2.1. COLOUR

It is normal practice to incorporate a colour into the gel coat.Colour fastness and consistency of colour can be affected by a number of factors during production,primarily:

- contamination of the resin
- curing times
- thickness of gel coat
- rubbing down with abrasive compounds
- polishing with wax which may go white when exposed
- storage of panels in polythene when humidity changes affect surface coating (94).

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(94) Guidance notes for the construction of GRP cladding panels, October 1981,British Plastics Federation.

7.3.2.2. SURFACE FINISH

- Shiny surface:The most common finish for panels up to 1 m. wide but over that,surface ripple may become apparent.
- Matt texture:Produced by laying a textured surface in the mould.The coarser the texture the more the surface deflection can be accommodated.But if texture is too coarse it slows down the rate of lamination.
- Riven slate:Produced by laying riven slate in the mould.But slate size is limited and joints between slates may show.
- Ribbed:Mini rib cast in the mould can reduce apparent surface deflection and improve weathering.

7.3.3. STRUCTURE AND STABILITY

G.R.P. has high tensile strength but a low modulus of elasticity.So although it can carry quite high loads this causes great deformation or deflection.Obtaining stiffness by increasing thickness is prohibitively expensive.Instead,shaping is used to stiffen single skins of G.R.P.,either the whole profile,by adding ribs or using sandwich construction.

7.3.3.1. SHAPED PROFILES

The cost of G.R.P. is directly related to surface area.Deep profiles can increase costs disproportionately unless they reduce the cost of the framing structure.

7.3.3.2. RIBBED CONSTRUCTION

This is the most common way of stiffening G.R.P. panels. Edge and intermediate ribs on the backs of panels can easily be formed by overlaminating top hat sections.Usually these are G.R.P.,sometimes cardboard or metal(commonly aluminium).

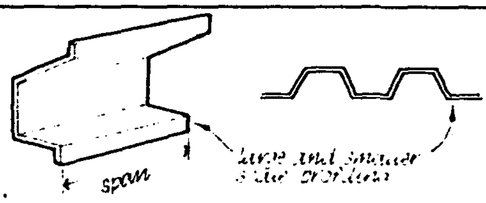

Figure (36) :Profiling of panels to increase stiffness.

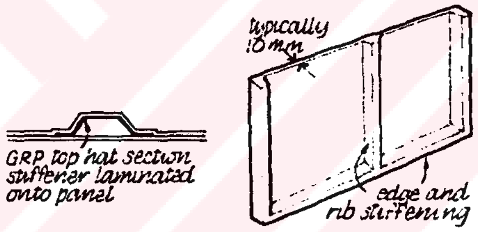

Figure (37) :Forming ribs for panel stiffness.

7.3.3.3. SANDWICH CONSTRUCTION

Two types available:

- Foamed core:Usually polyurethane is used.Internal G.R.P. connectors are desirable to prevent shear failure between core and skins,but may cause pattern staining.
- Sheet insulation core:Stiffening provided by integral G.R.P.

between sheets of insulation.It may also cause pattern staining.

Pattern staining may be disguised by incorporating woven glass in the face laminate or be disguised with a surface texture.

Sandwich panels can be subject to areas of air entrapment during production resulting in large blisters when the panels are exposed to the sun's heat.Delamination of the outer skin from foamed cores can also result from thermal stress (95).To reduce these risks it is advisable to design with single sheet folded or ribbed material for stiffening,applying insulation on site.

Sandwich panels weigh around 10 kg/m^2 and must be stiff enough to support this self weight without significant deformation.

7.3.3.4. TOLERANCES

It may be possible to take advantage of the inevitable flexibility of large panels to take up out-of-plane inaccuracies in the adjacent structure.Up to ±15 mm is possible,depending on the panel size.Manufacturing tolerances for twist in the panel are less critical than for inflexible materials like precast concrete.

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(95) A.J.BROOKES,<u>Cladding of buildings</u>,Construction Press,Chapter 2,1983.

7.3.4. FIXINGS AND MOVEMENT

Allowances must be made in the fixing system for thermal and moisture differential movement between the G.R.P. and the supporting structure.The fixing may also have to take up any inaccuracies of the adjacent structure.

7.3.4.1. METHODS OF FIXING

- Direct fixing:Panels are bolted direct to the structure and fixings are exposed.
- Clamped fixing:Panels can be mounted back on to a supporting framework with back fixings,using a clamping device.
- Concealed fixing:Fixing plates laminated within the skin of the panel.Back fixings are possible.

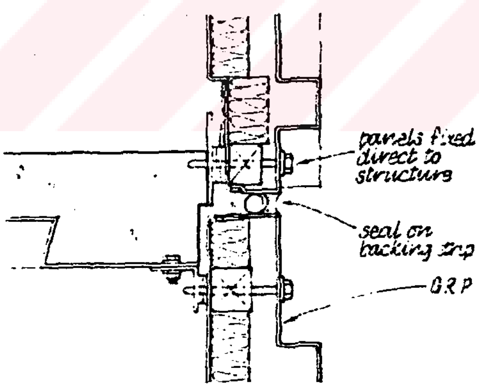


Figure (38) :Example of direct fixing of panel to structure.

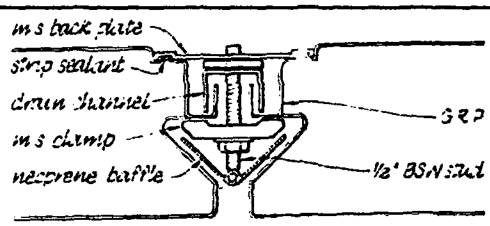


Figure (39) :Example of clamped fixing,the mild steel back plate being attached to the building structure.

In some cases it may be necessary to stiffen the edge of the G.R.P. laminate with mild steel section to act as mounting for the fixing.In this case any holes formed for fixing on the site should be treated or filled.

7.3.4.2. FIXINC PERFORMANCE

Fixings should be able to:

- Accommodate deviations in position and dimension arising from manufacturing and erection tolerances.
- Allow for alignment during installation.
- Withstand the loads imposed.
- Last the life of the panel.

Panels are therefore often fixed rigidly at one point only:all other fixings should be able to accommodate movement.

7.3.5. THERMAL QUALITIES

Single skin G.R.P. offers little thermal performance.An insulant will need to be included within the assembly to give the required U-value.Polystyrene,polyurethane and mineral wool are all commonly used.

8. MATERIALS AND DESIGN CONSIDERATIONS

8.1. ART AND CRAFT EXHIBITION BUILDING

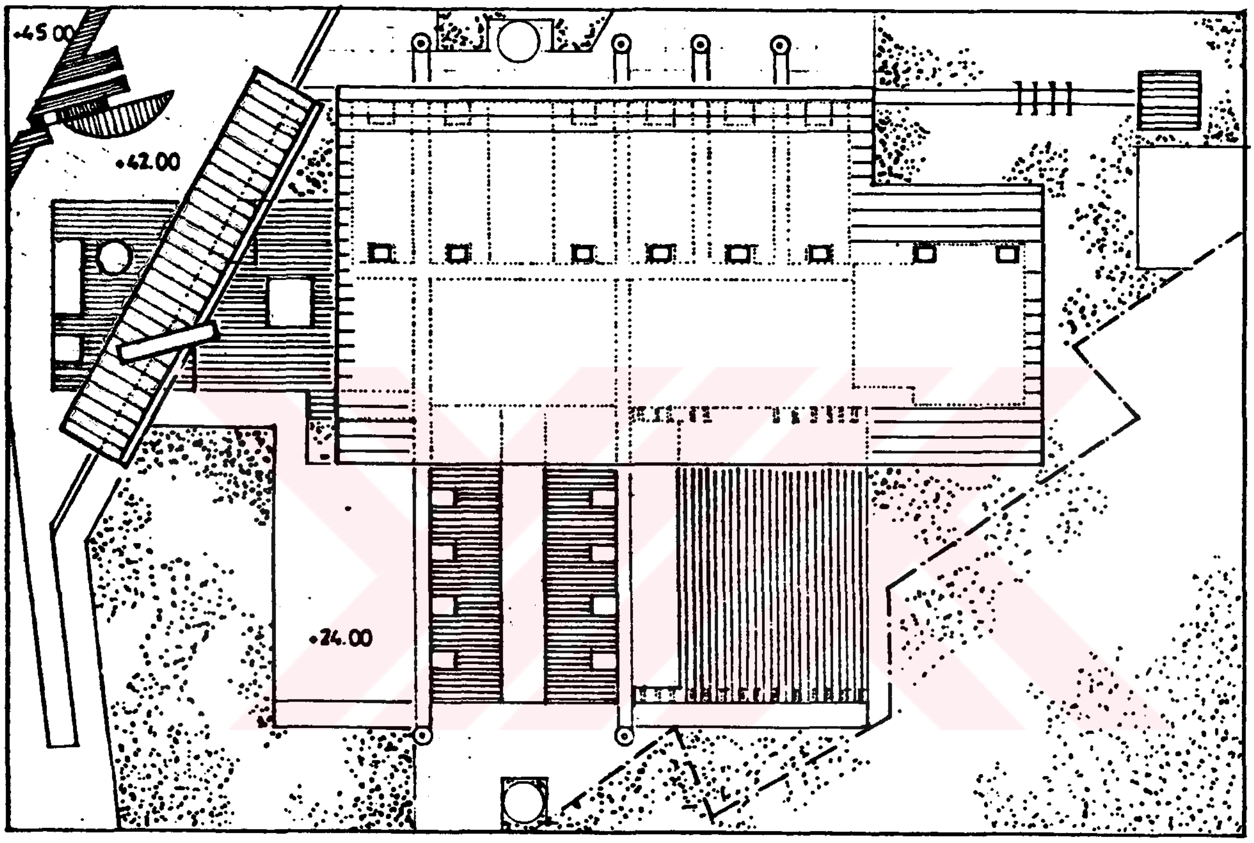


Figure (40) : Plan showing the art and craft exhibition building

8.1.1. ESCALATOR SHAFTS' GLASS FIXING SYSTEM

The art and craft exhibition building is entered through a hall seperating the exhibition area from that of the management office's which further on also provides a space for escalators down to the mezzanine floors.The main connection from these floors to the industrial exhibition area and the rest of the complex is also via a set of escalators positioned next along to the existing stone wall,integrating the vertical transition with vistas varying according to the level of each floor to the Bosphorus,Taslik Coffee House and the complex.

These two escalator shafts,the first being exaggerated in height to denote the entry are constructed in the same material and same system symbolising the vertical transition.In their enveloping skins they employ extended areas of glass which differs in material,for being flexible and in colour from the rest of the glass used on the building.

The cladding system also differs;the subdivisions and frames are eliminated to give way to a flush but flexible skin of glass fitted on the stainless steel structure which forms the shaft boxes,supports the glazing of 2.4m×2.4m glass sheets.

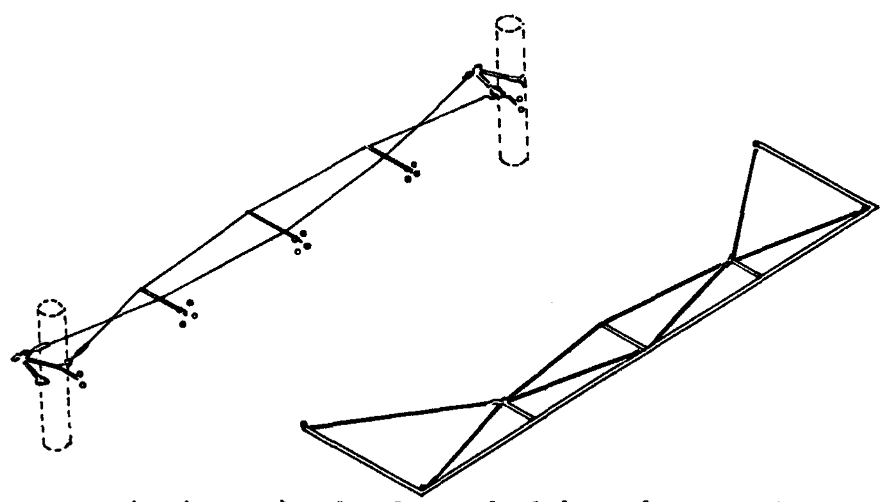


Figure (41) : a) glazing wind bracing system,
b) main horizontal structural frame wind bracing assembly.

Each vertical row of glass sheets is top hung from a central spring.The panes are sealed on all four edges with silicone and jointed at each corner by means of moulded steel fixings with socket joints,to allow movement in any direction.These fixings are linked horizontally with a system of fine cables,providing restraint against wind pressure:144 m^2 of 2.4m×2.4m glass sheets are thus held in place without intermediate framing of any kind,the edges of the glass being simply abutted one to the next.

With this system,the juxtaposition of the shiny and and hard surface of the stainless steel on the structure and the escalators,the smooth and flimsy effect of the glass curtain and the crumbled and rough texture of the stone wall is clearly expressed.

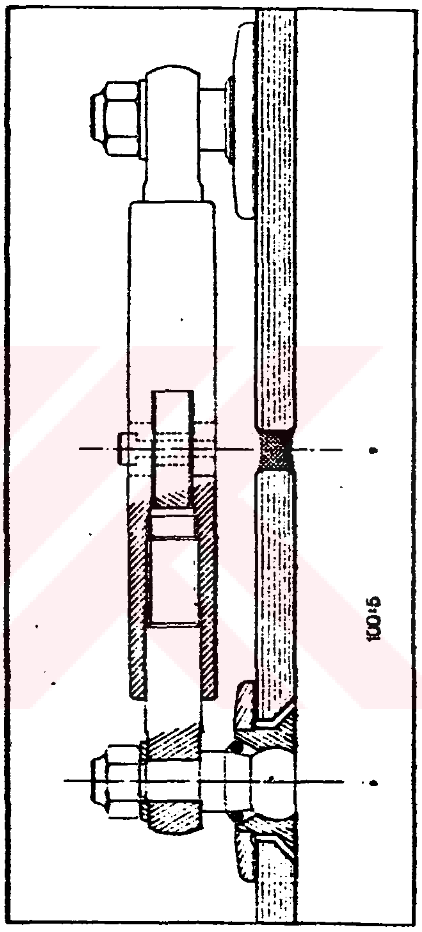


Figure (42) :Section through 'H' assembly which supports glazed elevation.Glass,with silicone joint.

8.1.2. WINDOW FRAMING AND GLAZING

The entire glass facade, as the building employs mechanical systems for ventilation, has no light openings. The toughened plates of tinted glass are supported by employing a 'Trusswall' curtain window cladding system which enables the use of large single panes of glass, 3.6m×3.6m in size. The system uses circular extruded aluminium chords connected by a seperating web that adds stability and strength while also gives a sculptured aesthetic.

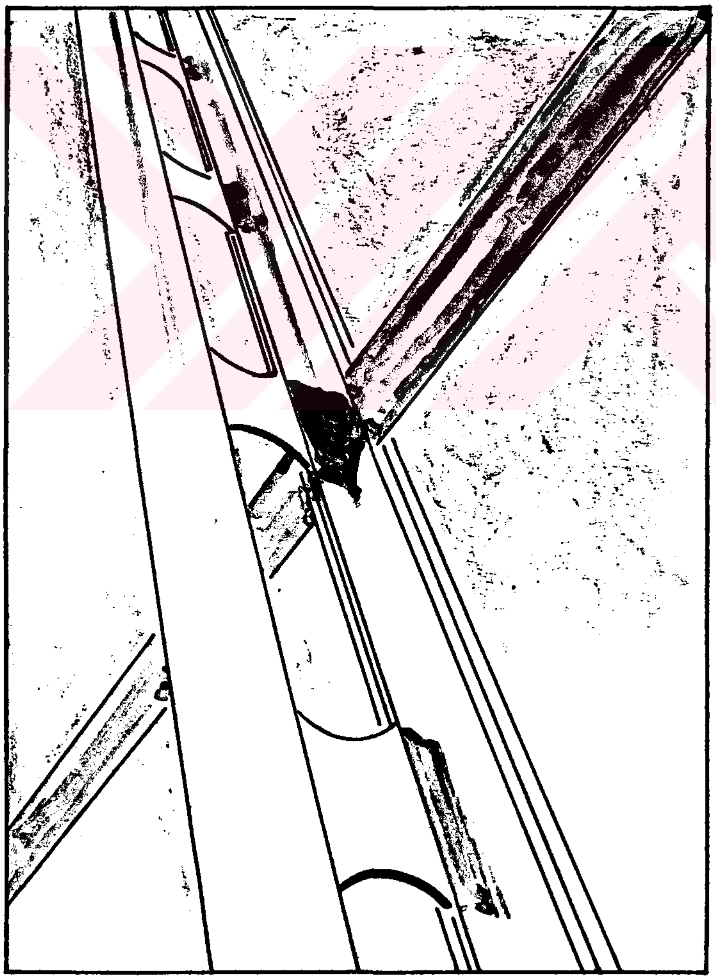


Figure (43) : The 'Trusswall' system.

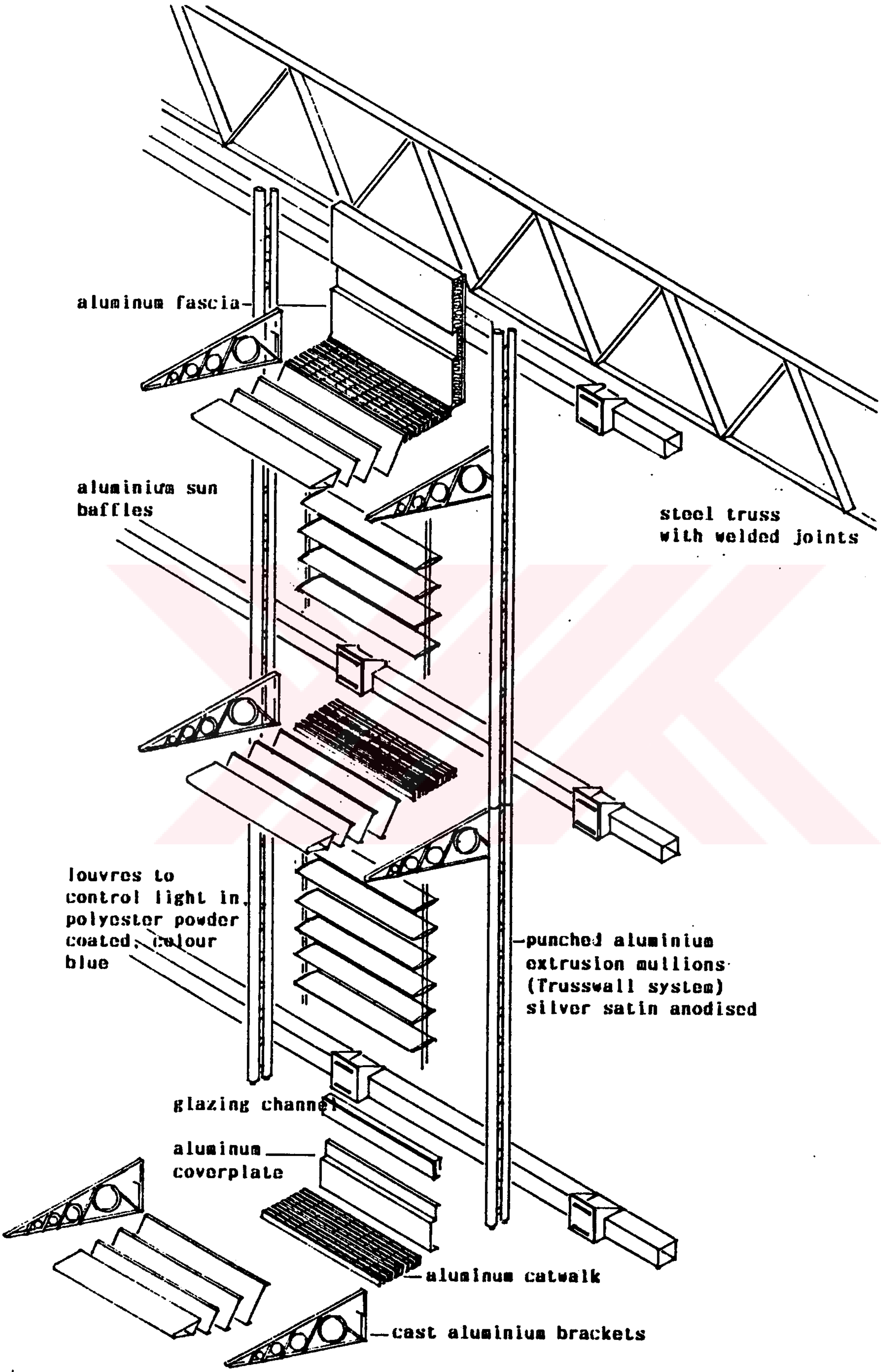


Figure (44) : Exploded isometric of window framing system.

This system is integrated to an automatically operated louvre system which allows views out and controlled light in, varying according to the nature of exhibition.

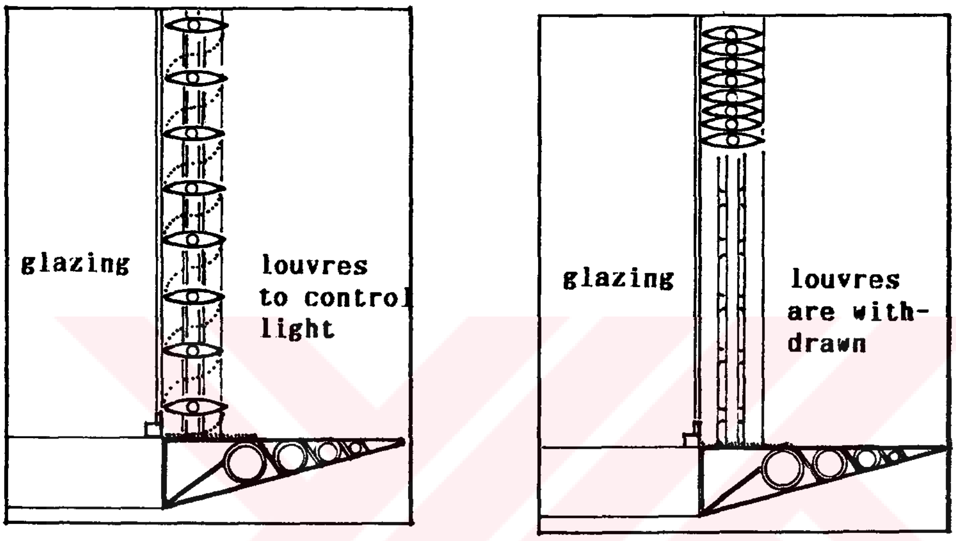


Figure (45) : The louvre system fitted to the mullions.

The system also supports an aluminium catwalk for cleaning and maintanence connected by cast aluminium brackets.Where the mullions,the catwalk,the sun baffles and the brackets are silver satin anodised ,the louvres are polyester powder coated colour blue.

8.1.3. DISPLAYING SYSTEMS

In the exhibition of the art and craft products a system where the displaying panels are supported on steel cables are used.The steel cables with plastic cover are wrapped around a pulley system-on tracks -contained in the structural depth of the roof truss.To support the panels ,theTcables may be pulled down to form a loop around another pulley system included in the raised floor.

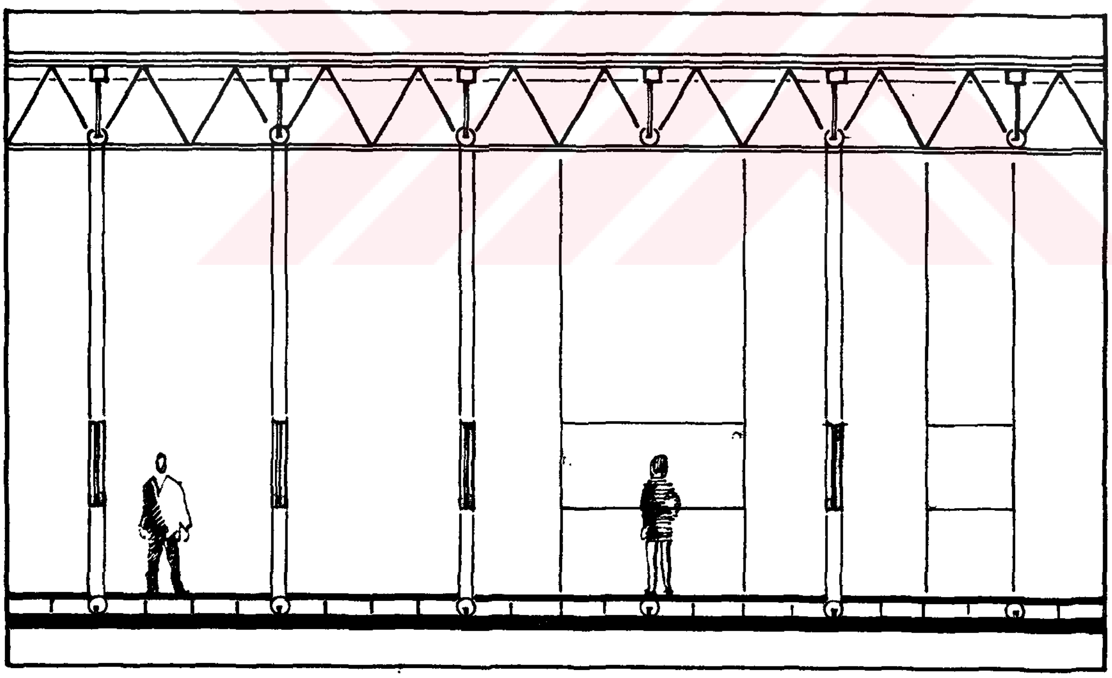
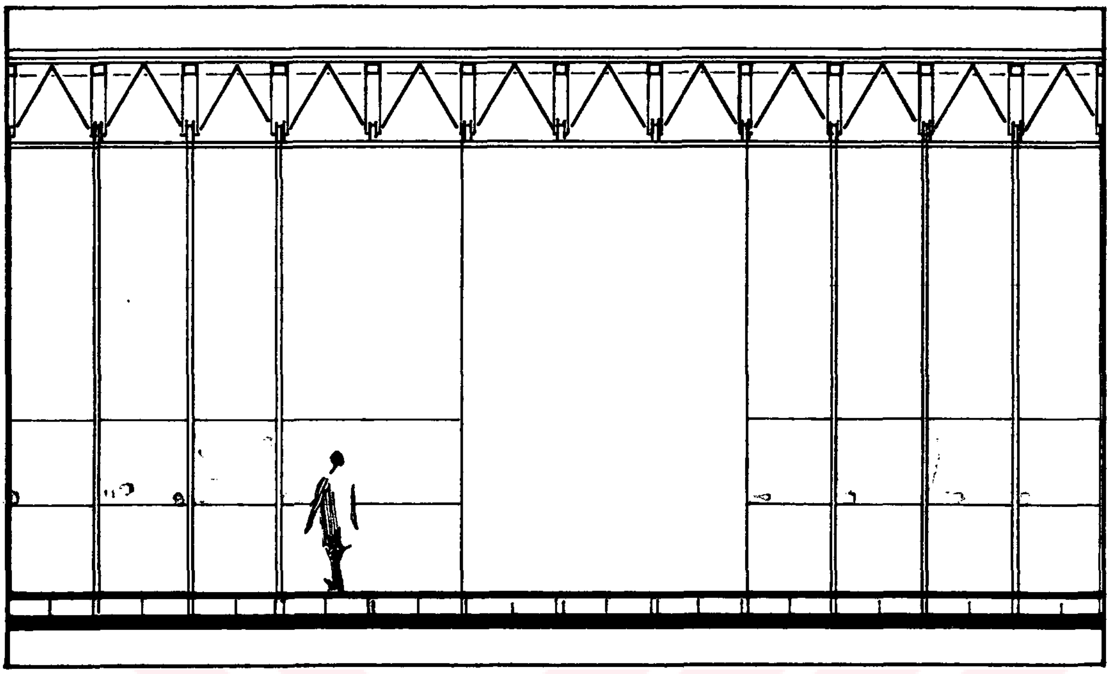


Figure (46) :Displaying panels supported on steel cables.



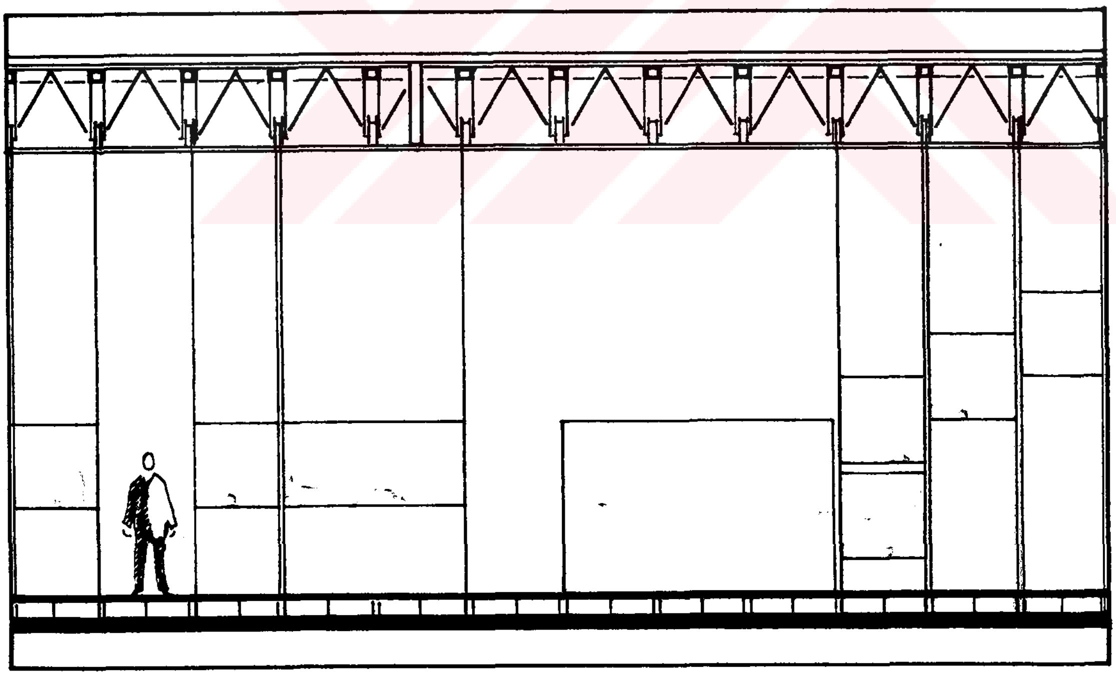


Figure (47) and (48): Alterations on the displaying.

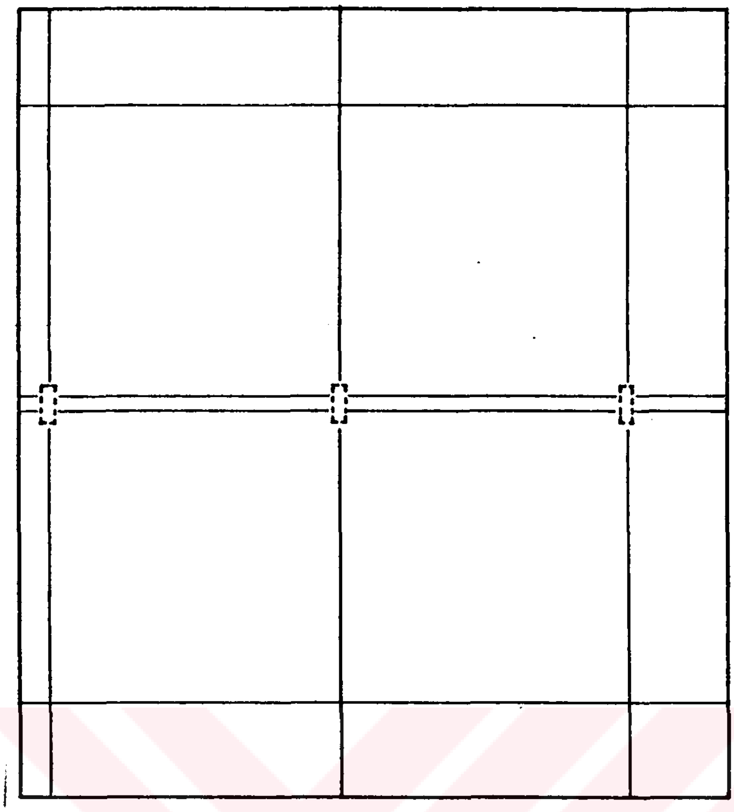


Figure (49) : The track running between the aluminium laminated flooring panels closed off with hard plastic cap.

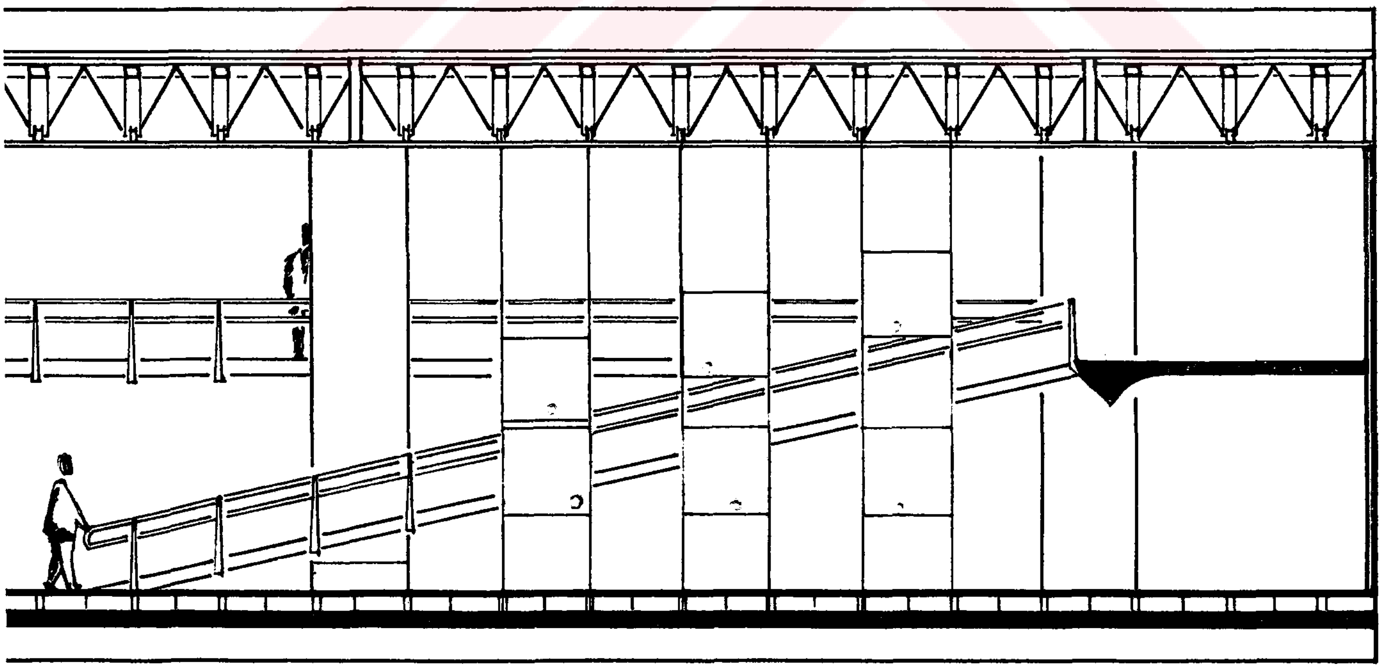
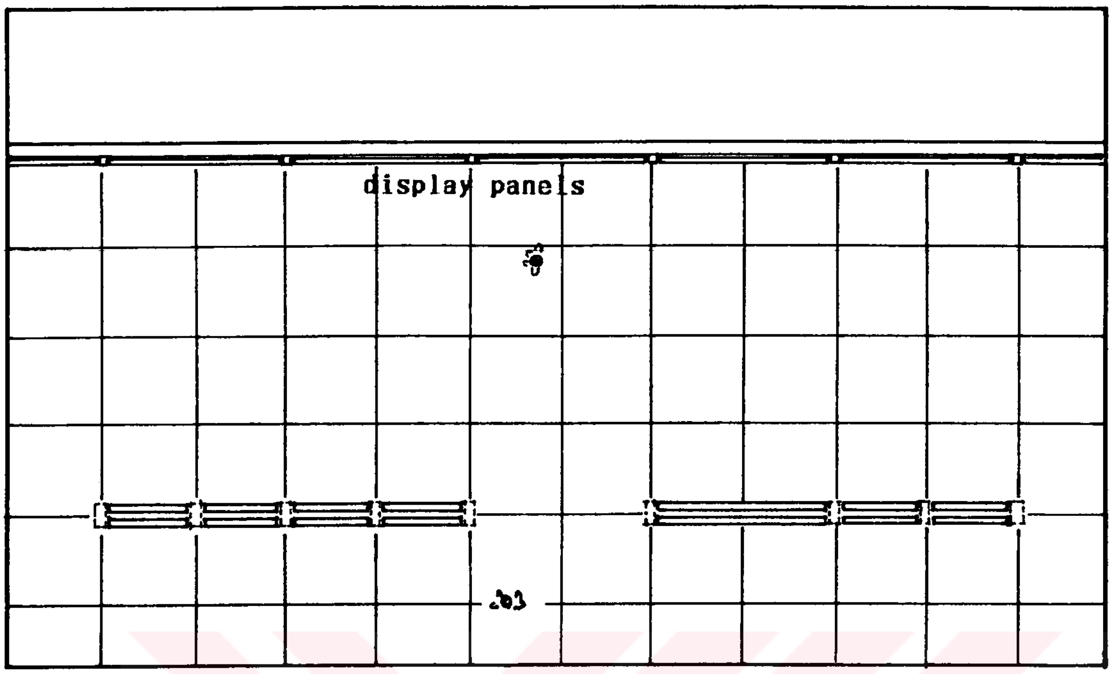


Figure (50) : The ramp and the mezzanine floor may be entirely closed with displaying panels to change the identity of the space.



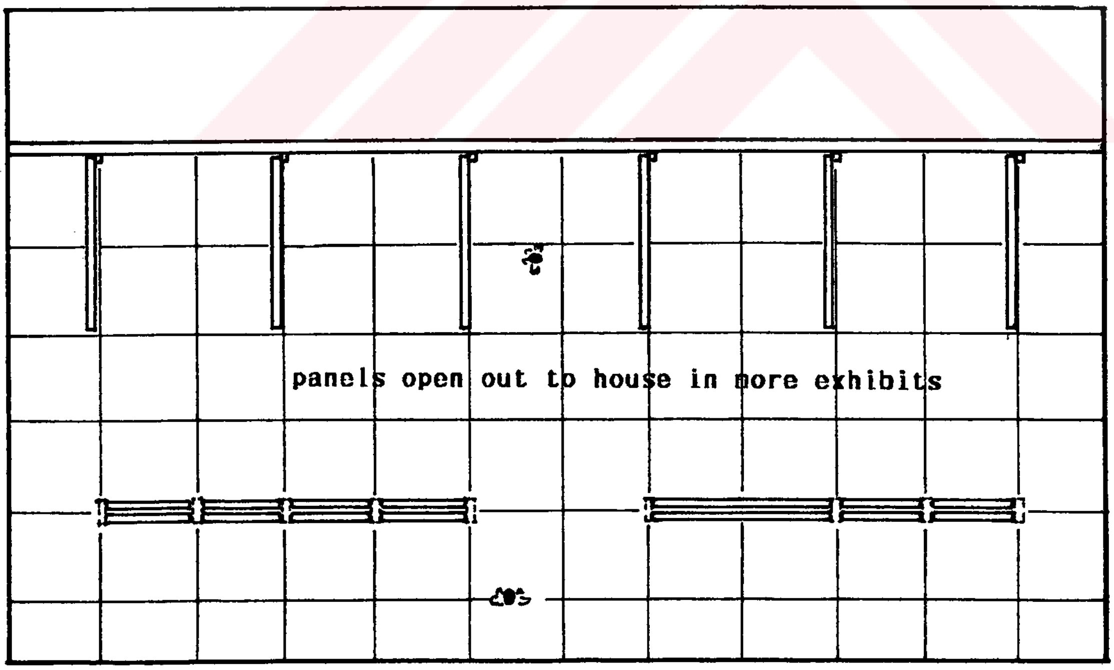


Figure (51) and (52): The display panels on the walls open out to increase the exhibition area.

This system gives an appropriate response to inhabit the flexibility desired in the exhibition process by enabling; fixation for numerous module of display panels;instant change of levels; stacking arrangement of panels up to the ceiling level therefore increasing the capacity;enclosing arrangements of panels to form niches,alleys and other identified space,therefore changing the character of the exhibitions;also when not in use by giving way to an open space to house in other activities.

8.2. THE WORKSHOPS BLOCK

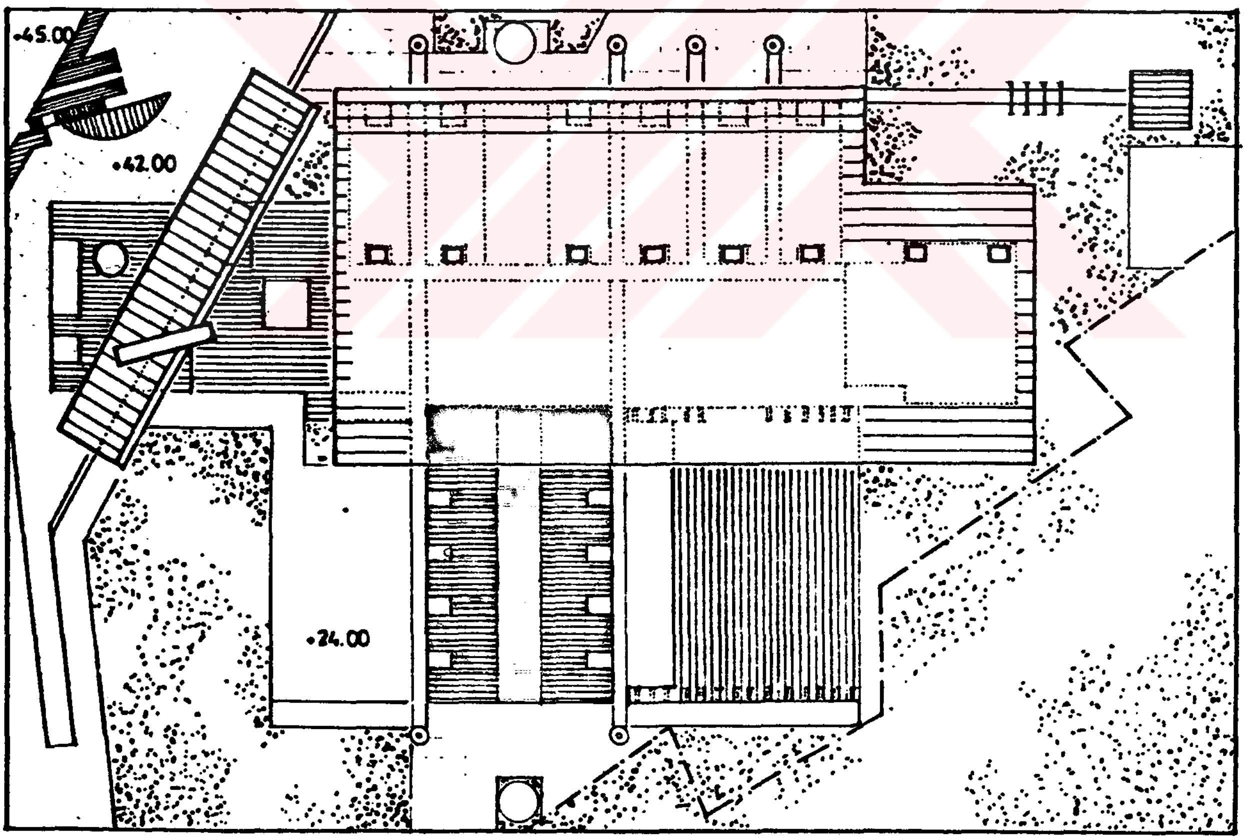


Figure (53) : Plan showing the location of the workshops block.

8.2.1. SERVICES AND STRUCTURE INTEGRATED

The workshops block is designed with a structural system where the structure itself is composed of 19 welded tubular prismatic steel trusses that span 25.2 mt.These are supported on similar lattice towers creating a column-free tube 44.2 mt long,with a ground-to-ceiling clear height of 5.2 mt to permit the installations of greater height and insertion of mezzanines.

This structural system forming two ceiling levels on the top enclosure,and two wall levels on the side enclosure allows its structural depth to become the main 'service zone'.

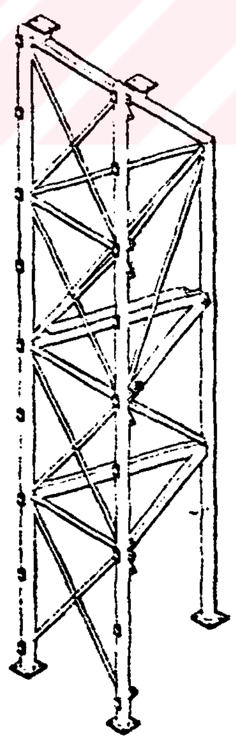
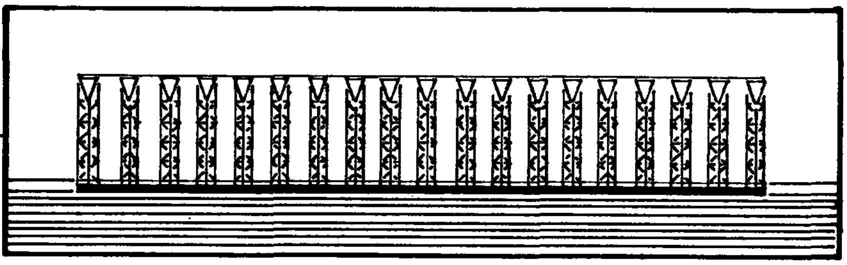
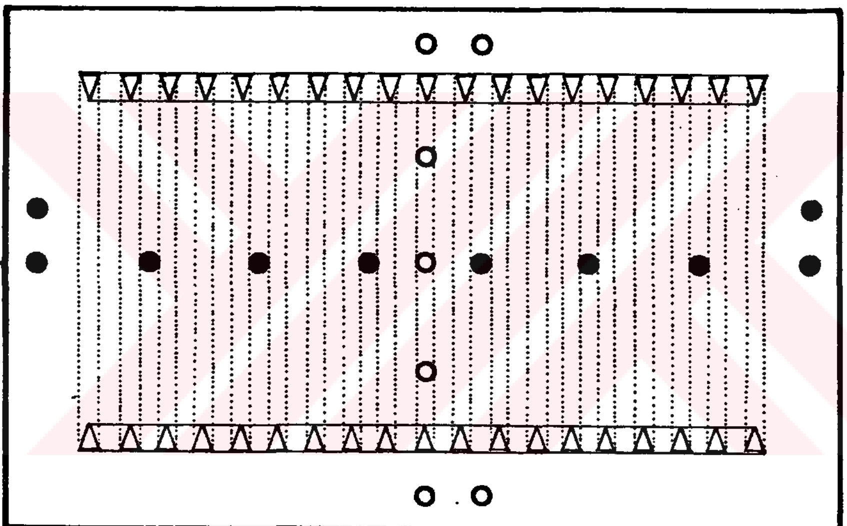


Figure (54) : Structural systems

The roof structure admits light through windows in the top surface,and filters it through louvres below to give a glare free light.
Lights,ventilation,trunking and maintanenence walk-ways occupy the space of this zone.





Service zone integrated into double skin of the vertical enclosure-containing,on ground floor:WC and wet area,storage,mechanical systems shaft and a back exit or entry,on mezzanine floor;mechanical plant space,mechanical systems shaft,storage and a back exit or entry to the walkway bridge as well as work area.

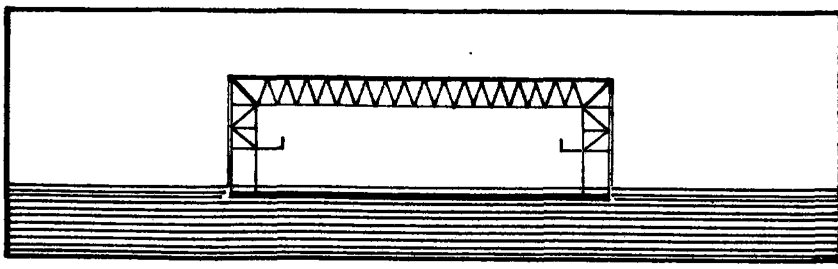


Figure (55) : The workshops block.

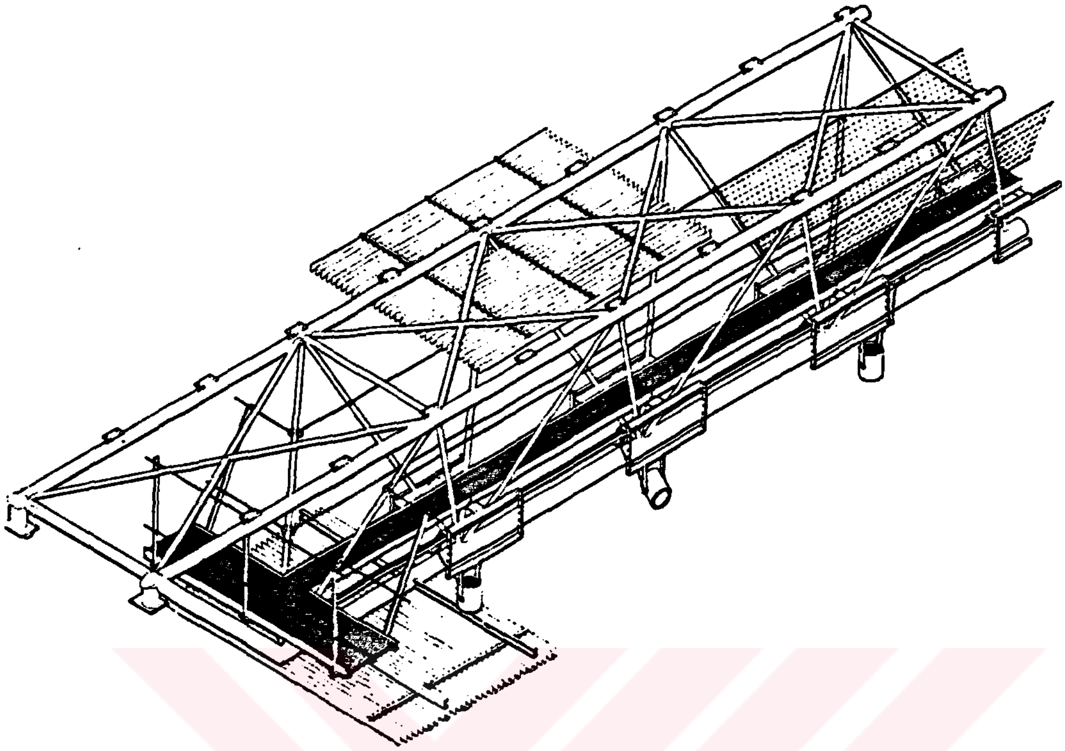


Figure (56) :The roof structure.

8.2.2. CLADDING SYSTEM

Exterior cladding is formed of 600 mm by 1200 mm, aluminum,glass and grill panels.The aluminium panels of sandwich construction,have a poured foam filling and a highly reflective anodised aluminium surface to provide maximum insulation value and cut heat gain.The same type of panels are used for roofing as well.Each panel is fitted into a continuous net of neoprene gaskets that double as rainwater channels.All panels are interchangeable by unfastening six bolts.So according to needs a solid may change to an opening.End walls are clear glass 21.2 mt in length and 5.2 mt in height,expressing the prismatic structure.Each sheet of glass 1.8 mt by 5.2 mt and its supporting fin are held by steel channels anchored into the floor slab and joined with a silicone sealant.

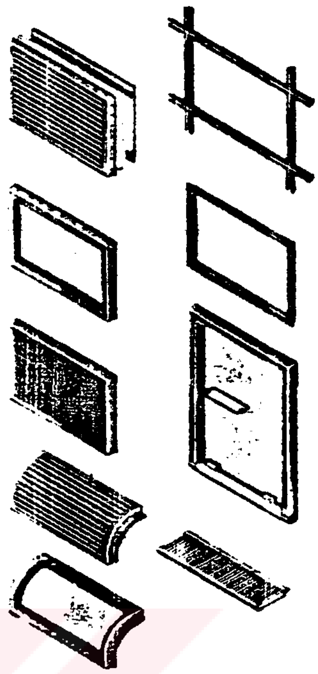
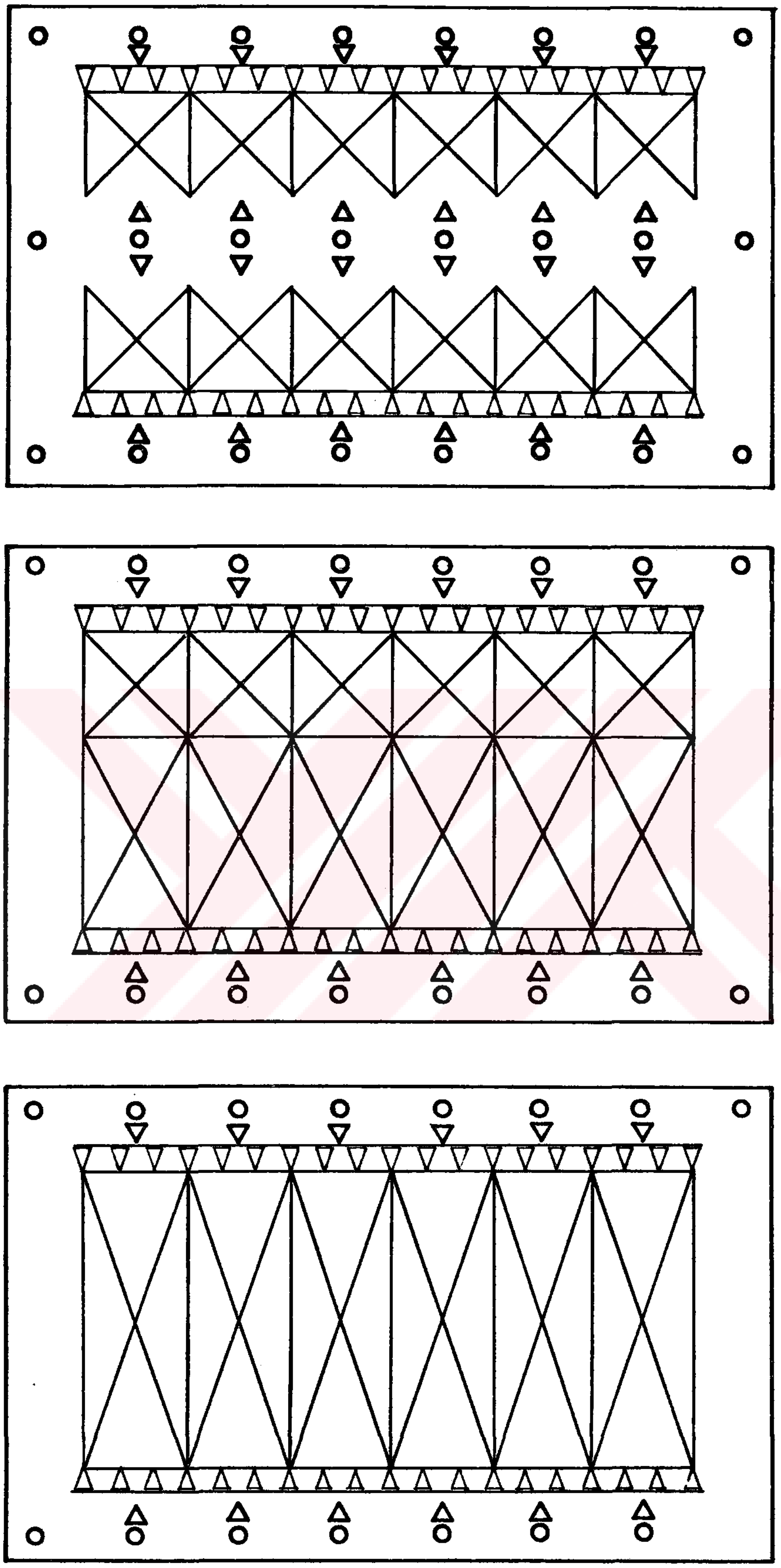


Figure (57) : Cladding systems.

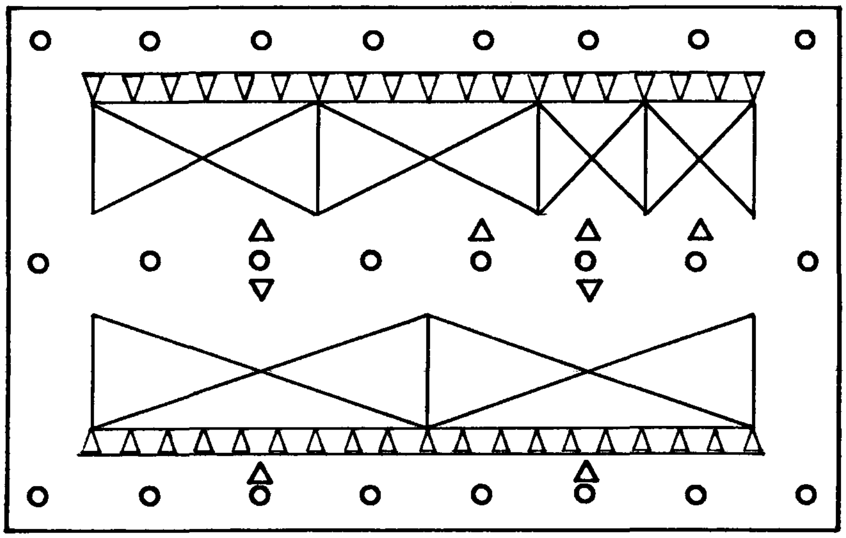
The interior lining system is composed of perforated aluminium strips enclosing the storage,toilets, mechanical shafts and plant space.On ceiling plane these are electrically adjusted.

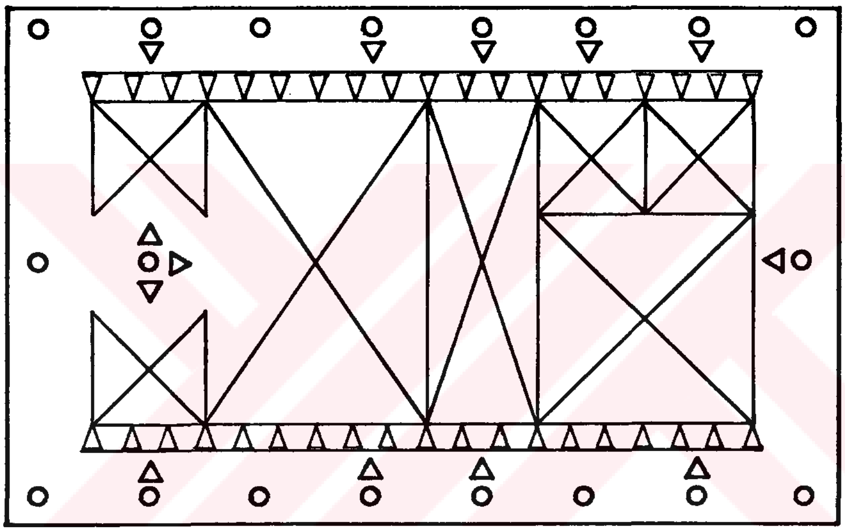
8.2.3. ALTERNATING USE OF INTERIORS

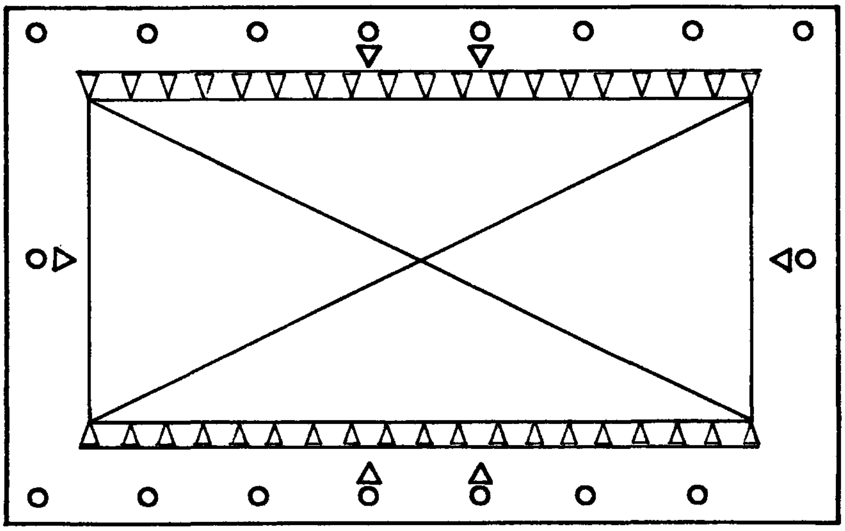
The workshops block due to the different programmes it constitutes has to create the response to result in efficient organizing and workplan.Therefore the system has to enable alterations of spaces to house in the different forms of work and their different flow charts.This is achieved by a system of seperating panels of sandwich construction which are electrical maneuvered to give way different sizes and numbers of work spaces.The flexibility that these panels which slides back and folds to fit into the depth of the lattice towers and examples of its space organization is shown in figures (58) to (63).



Figures (58),(59) and (60) : Alternating arrangements of the workshops block.







Figures (61),(62) and (63): Alternating arrangements of the workshops block.

8.3. THE STUDIOS

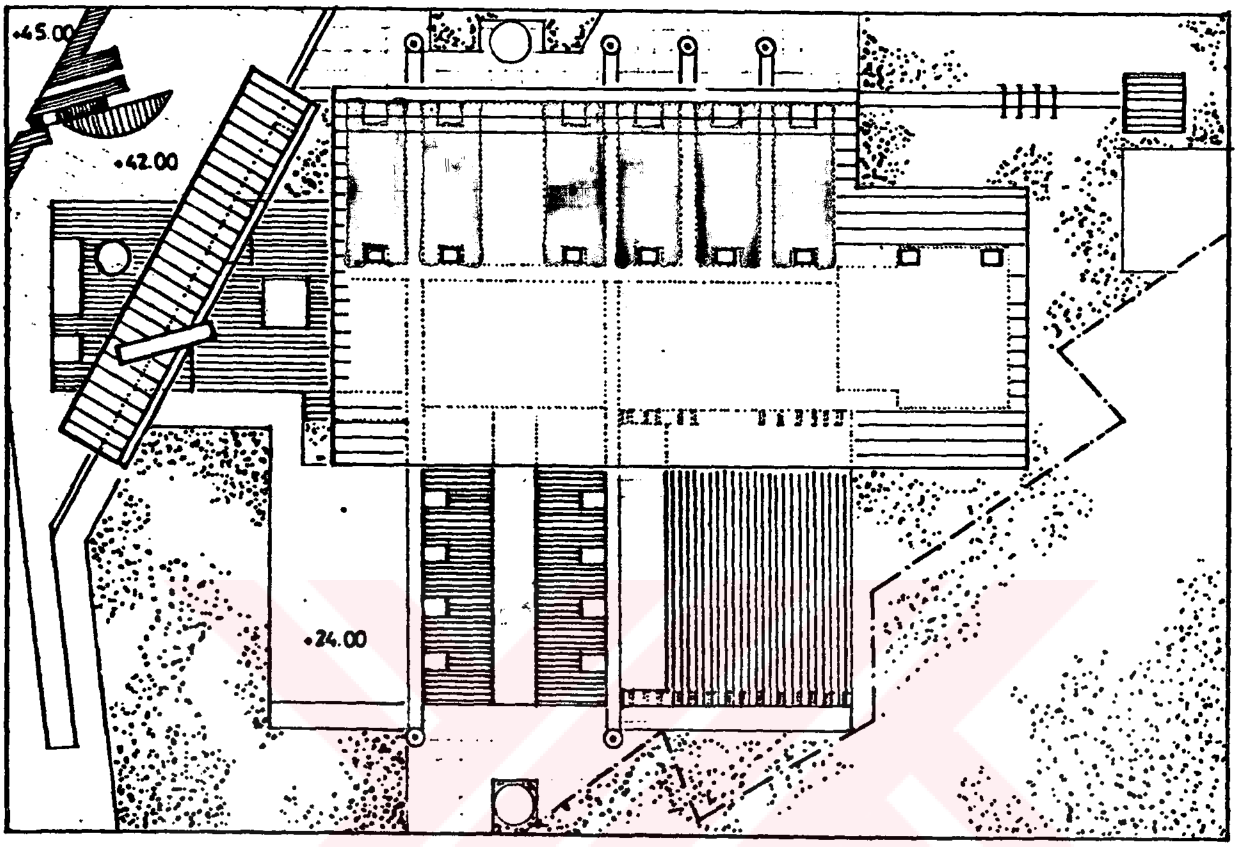


Figure (64) : Plan showing the location of the studios.

8.3.1. ALTERNATING USE OF INTERIORS

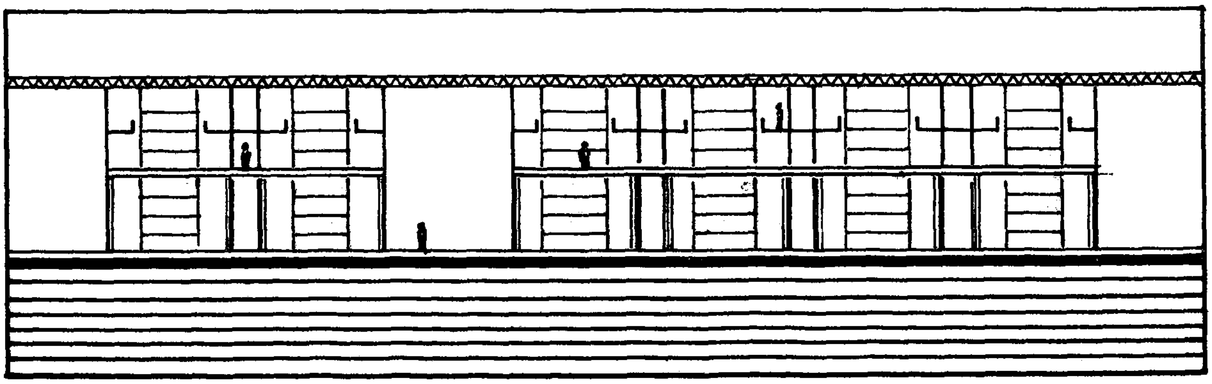
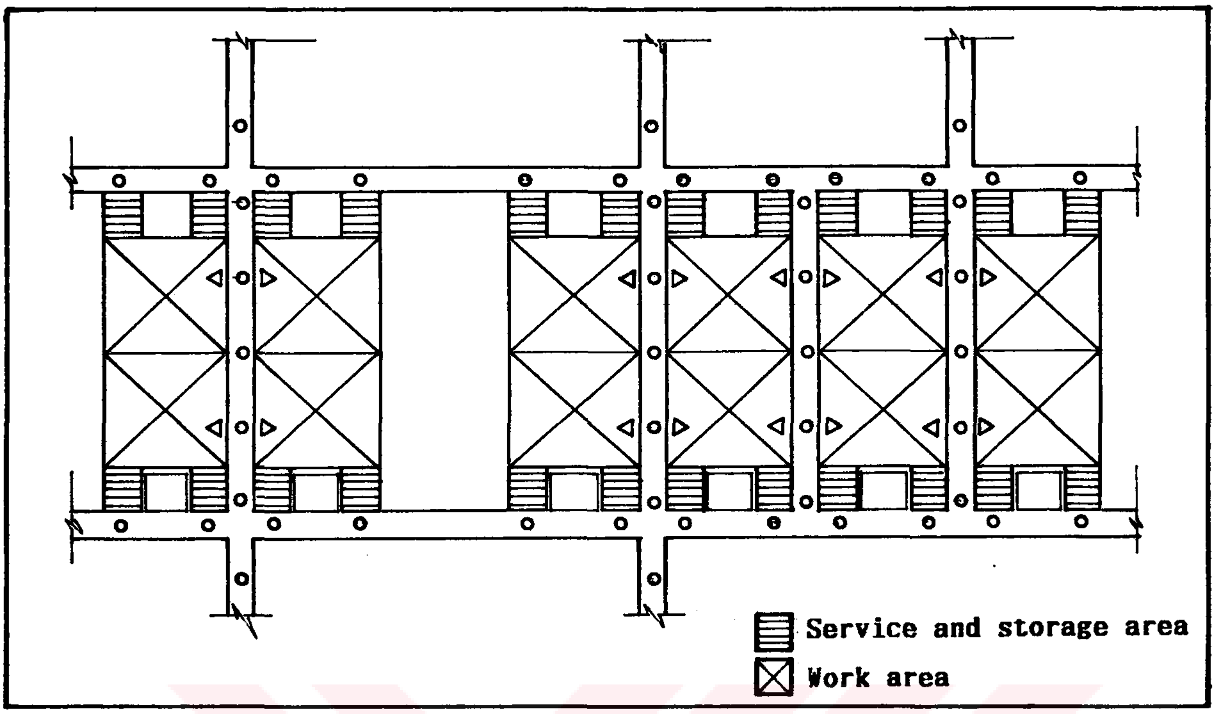
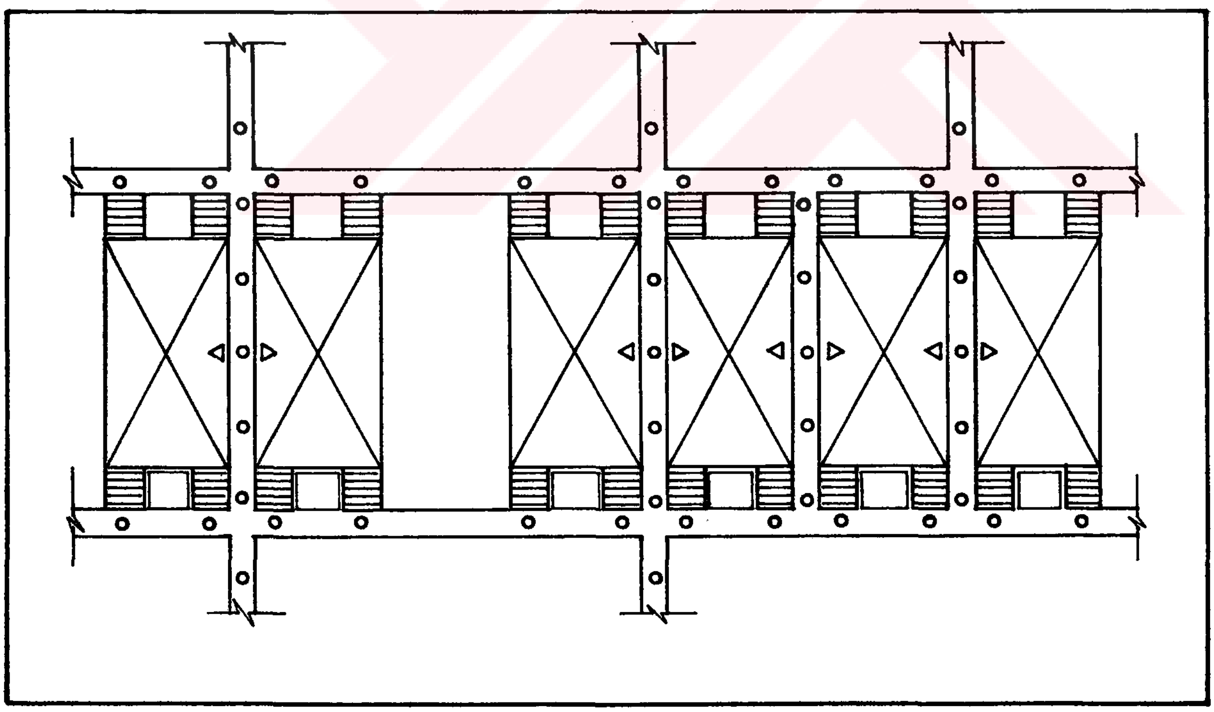
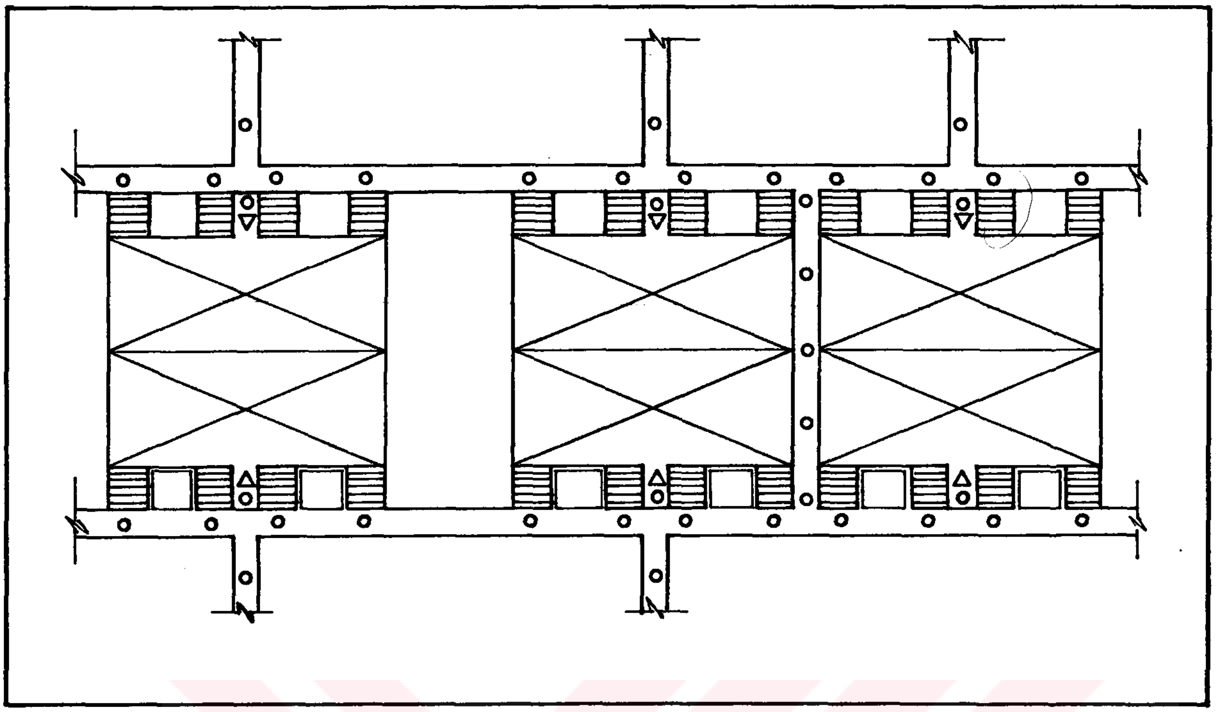


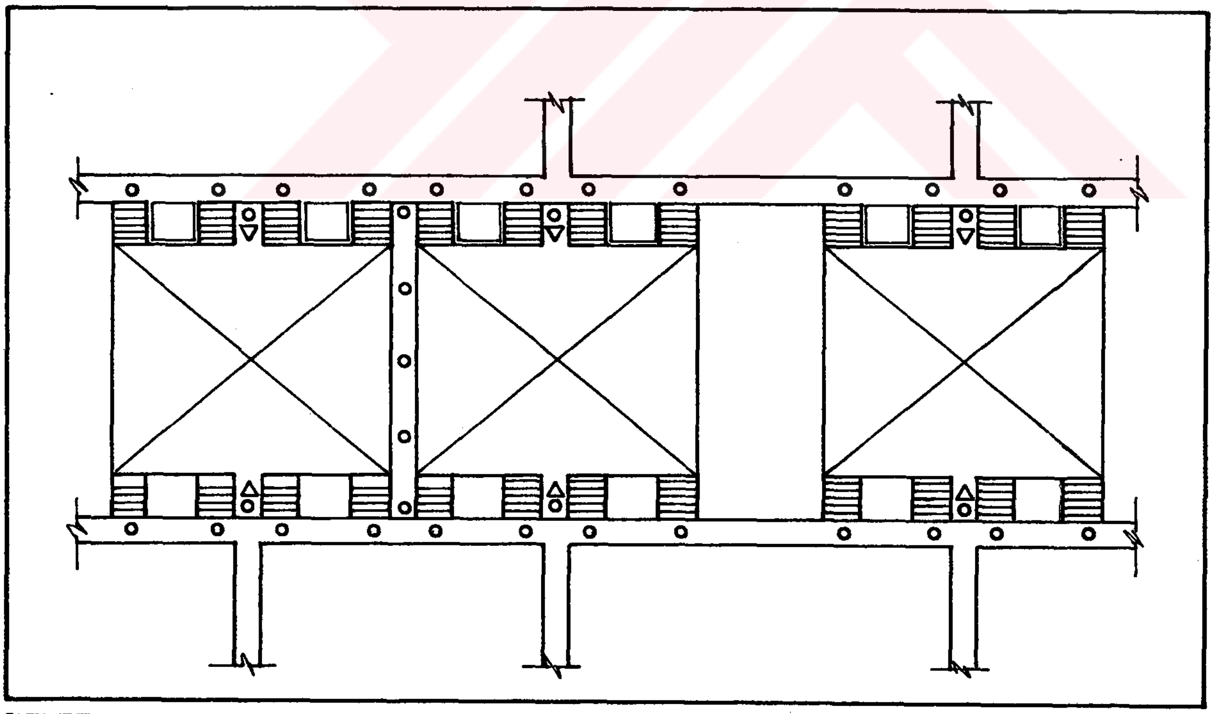
Figure (65) : Studios supported on steel tapered beams, also achieves the same flexibility as of the workshops.





Figures (66) and (67) : Alternating arrangements of studios.





Figures (68) and (69) : Alternating arrangements of studios.

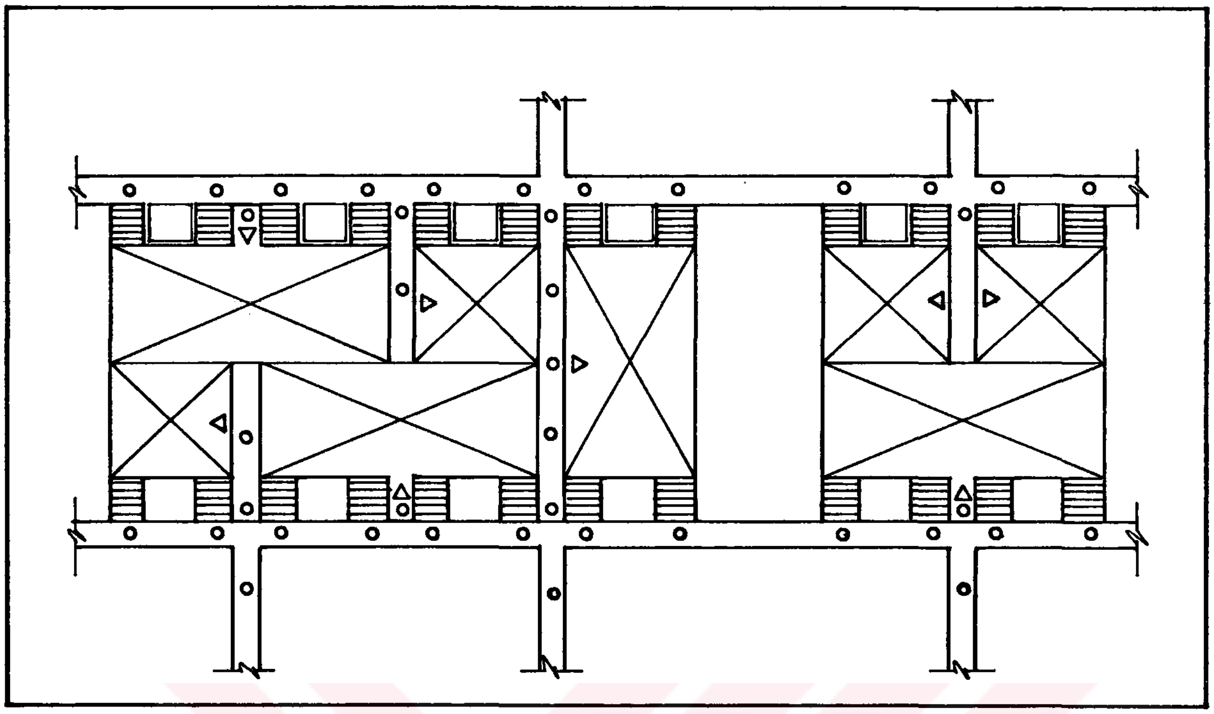


Figure (70) : Alternating arrangements of studios.

8.4. THE MULTI PURPOSE HALL

8.4.1. THE SEATING SYSTEM

Multi purpose hall as the name implies may be used for concerts,dramas,seminars,speeches and other activities where a larger amount of people participating would be of concern.But also it may used for temporary exhibitions where a larger space is required to introduce industrial products.

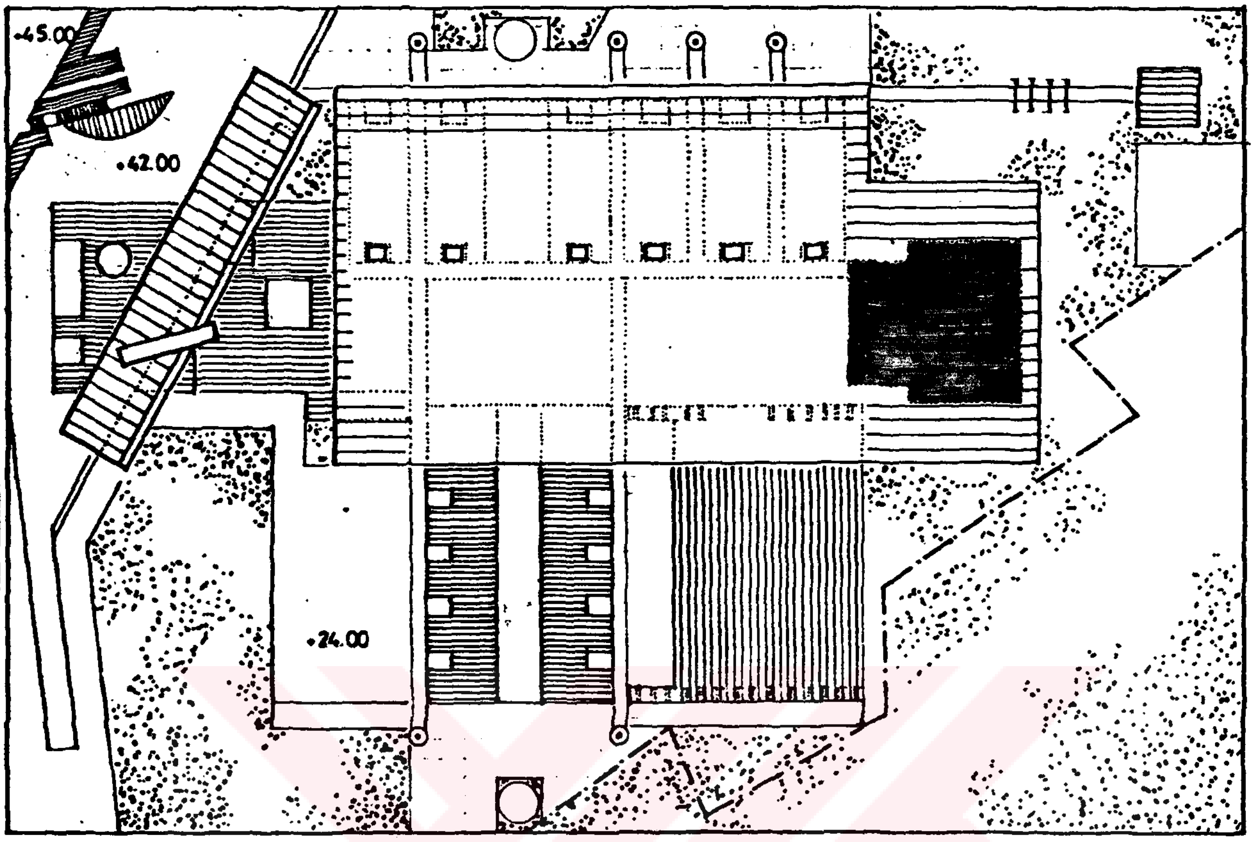


Figure (71) : Plan showing the Multi Purpose Hall.

Therefore the seating system has to be adoptable not only for acccommodating the public interaction,sociality and gregariousness but also for reflecting the sharp edge technology matching to that of the products' it exhibits.Using the same pulley system as in the displaying panels,the seats-plastic composite panels with aluminium honeycomb core-are fixed at the end of steel cables.The seats may be electrically maneouvred to be lowered,tilted sideways to form the seating benches,stages,platforms,etc..

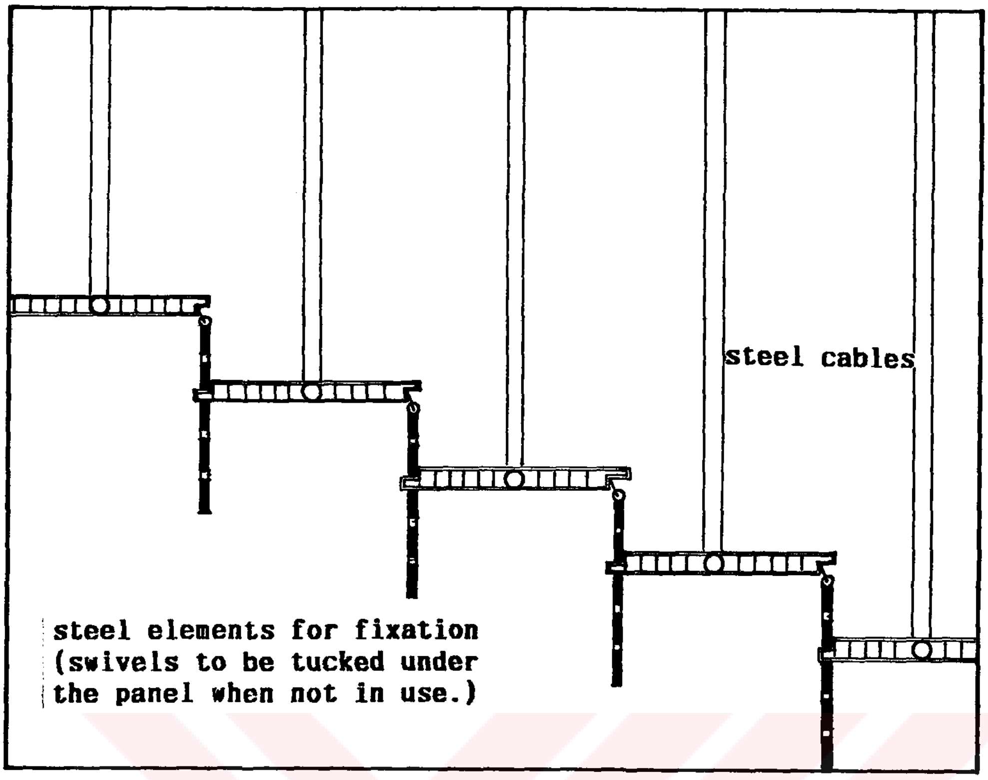


Figure (72) : The plastic panels forming seating

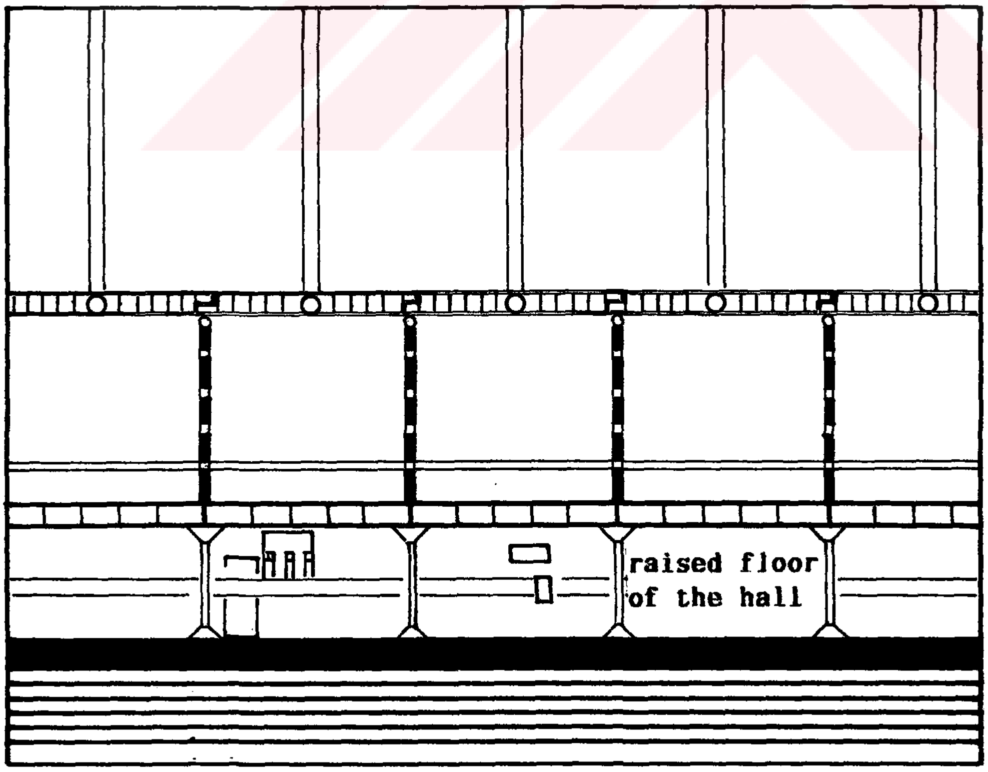


Figure (73) : The plastic panels forming platforms

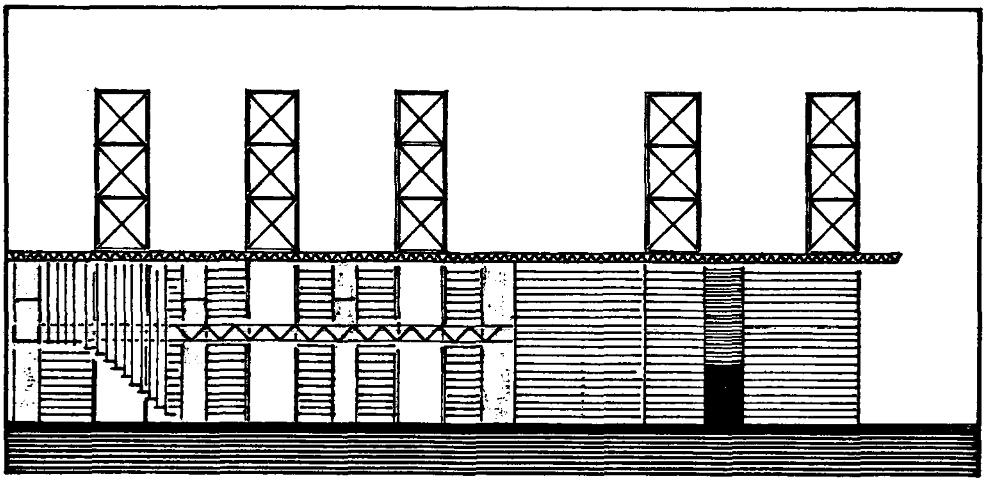


Figure (74) : Forming an amphie facing the hall.

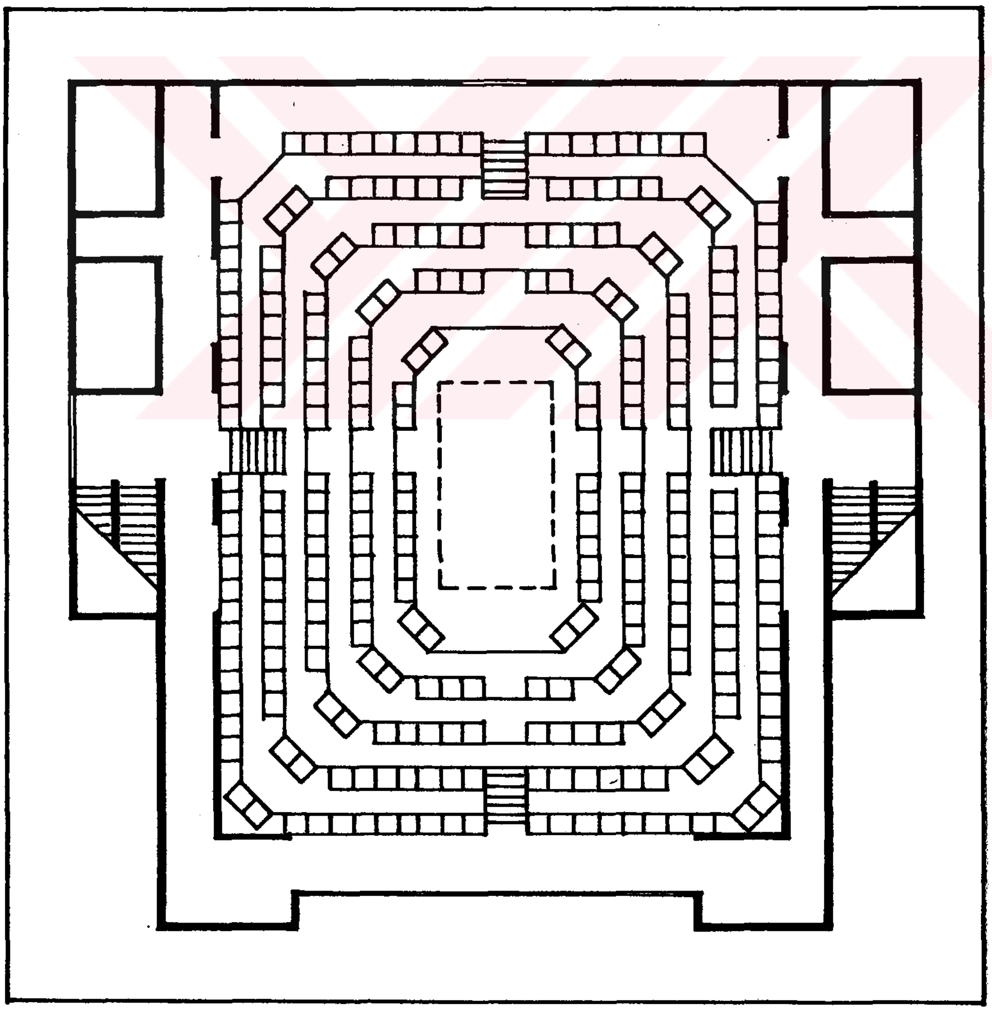
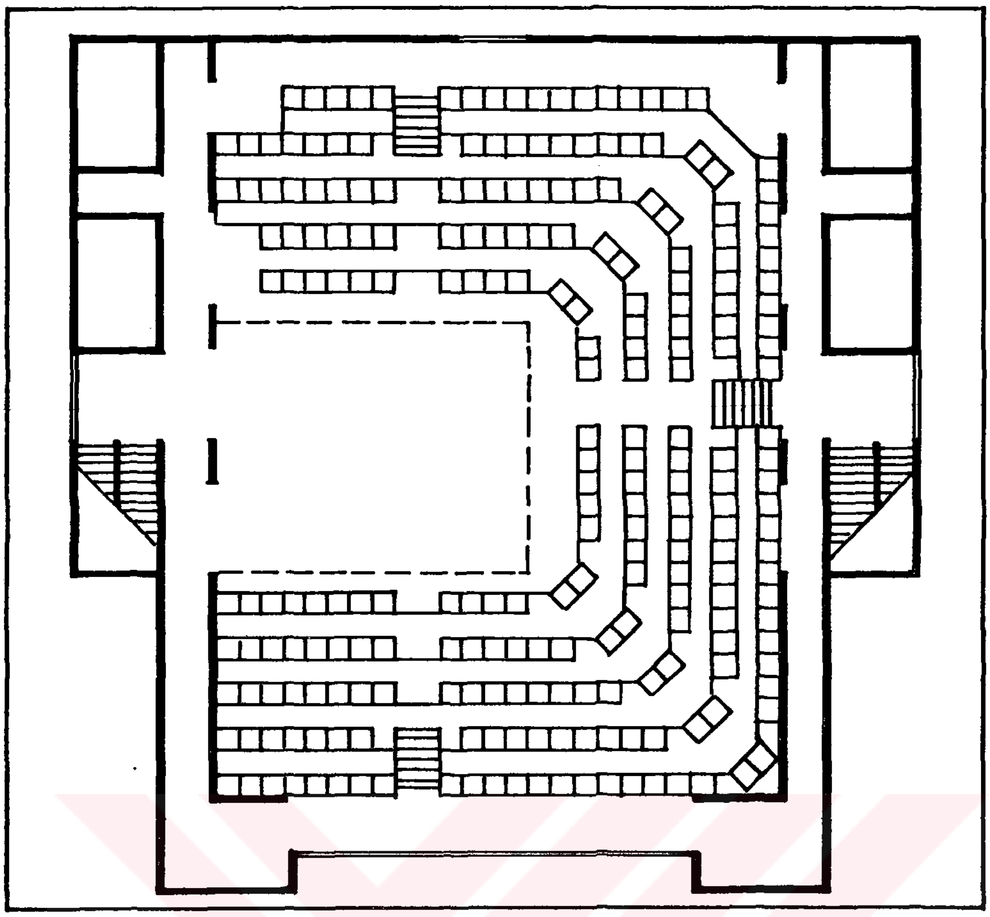
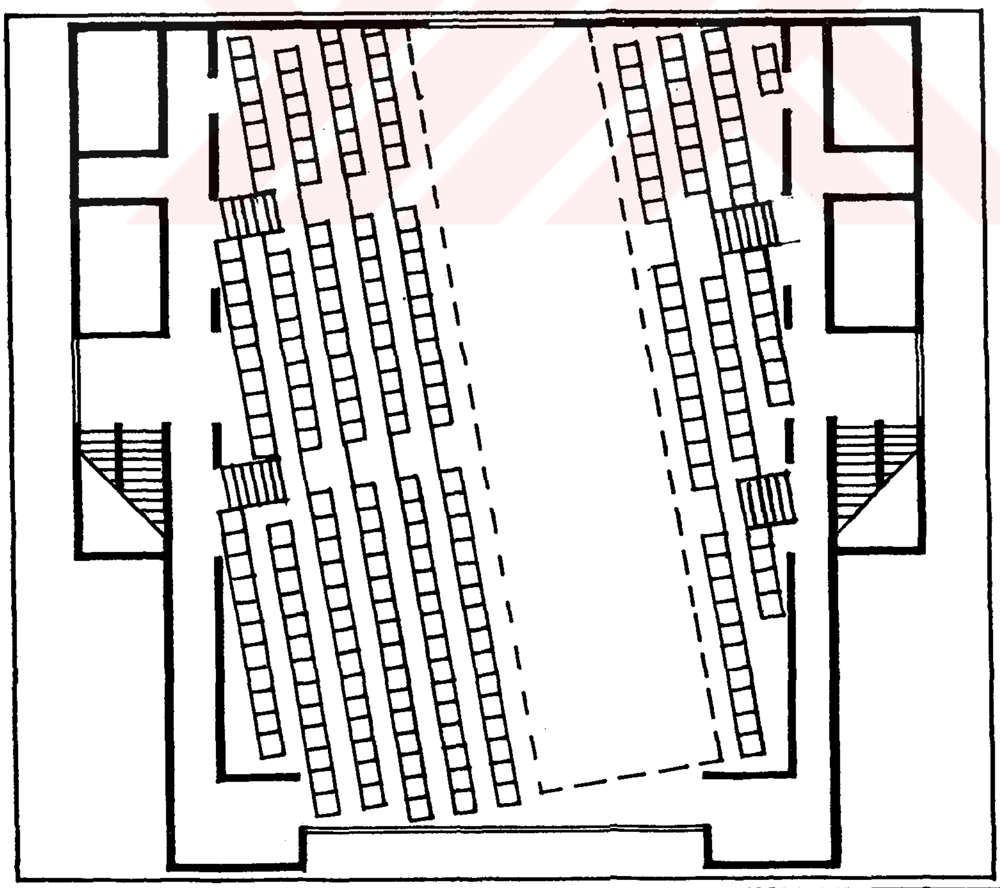


Figure (75) : Alterations on stage and seating.





Figures (76) and (77) : Alterations on stage and seating.

8.4.2. RAISED FLOOR

The multi purpose hall as well as the rest of the complex are designed with raised floor system which in its depth integrates the electrical systems and cabling to enable ease of access to ductwork for maintanence and change.The idea is that there is less disruption to the work force.

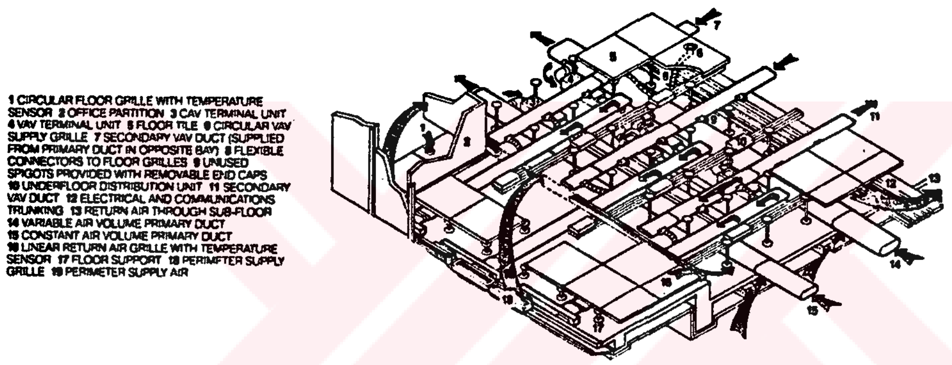


Figure (78) : Modular sub-floor services

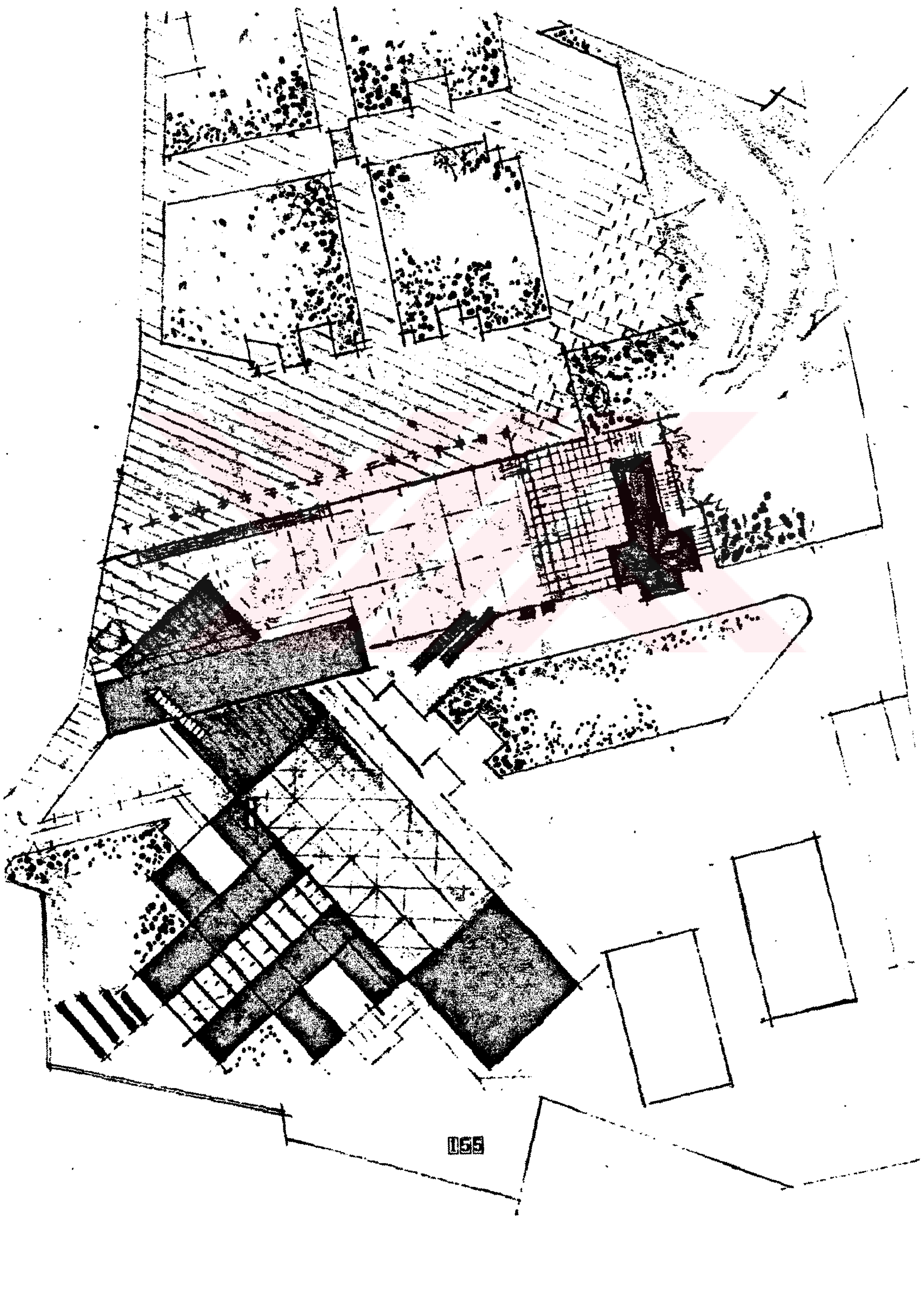
Considerations have to be given for: the achievement of desirable criteria,without discomfort at the outlets:the distribution within the floor cavity and suitably of supports of the floor panelling;the flexibility of the ducting,as the work spaces are intended to be totaly flexible and the partitions changeable;and the flexibility,appearance and structure of the floor panel system,including the air-conditioning and electrical outlets in them as well as the special cases such as pulley system tracks, sliding partitions tracks and others. The workshops would also require servicing such as gas, oxgyen, pressed air piping installed with adequate outlets.

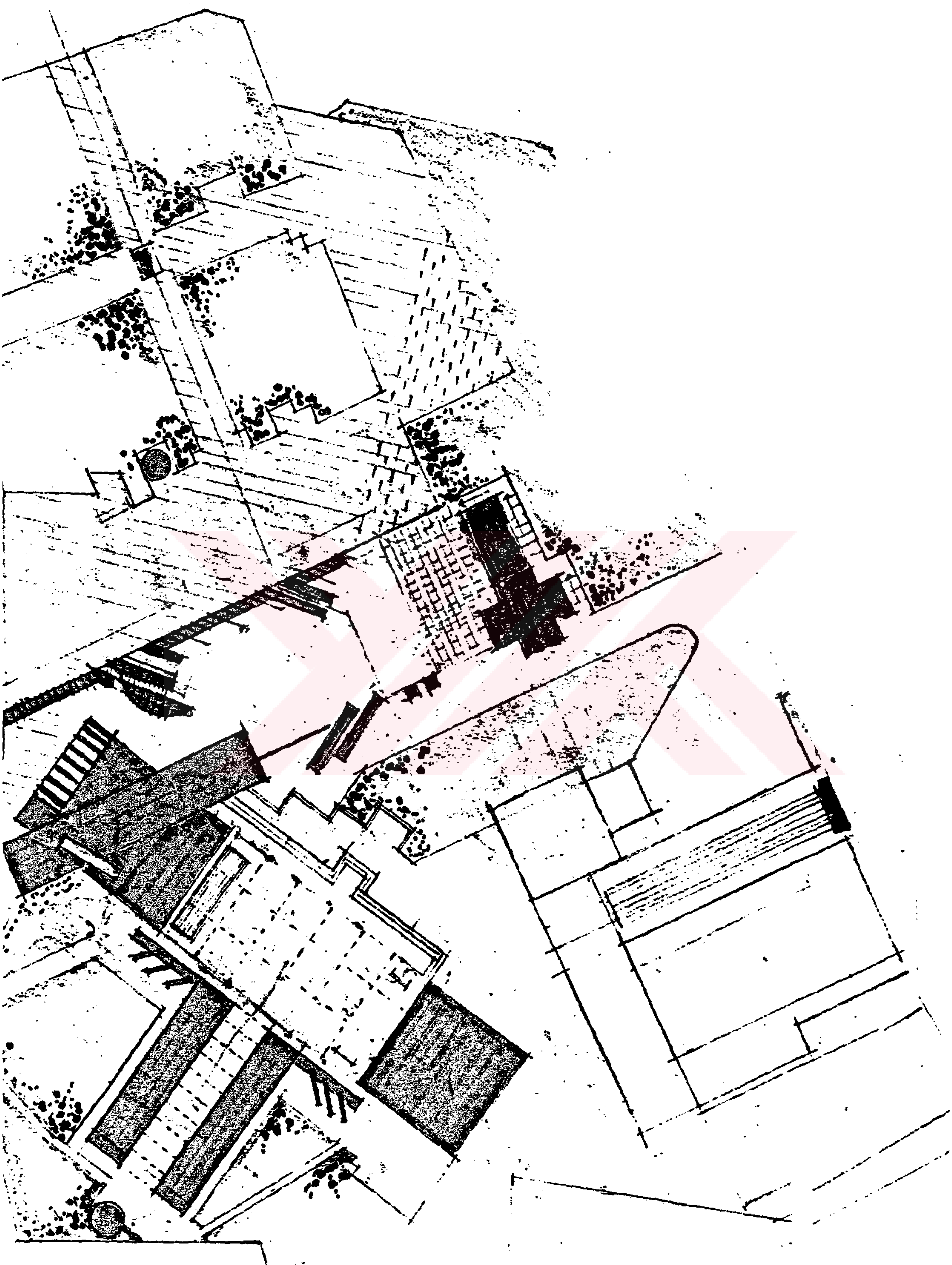
Figure (79) : Section and the detail of the raised floor system.

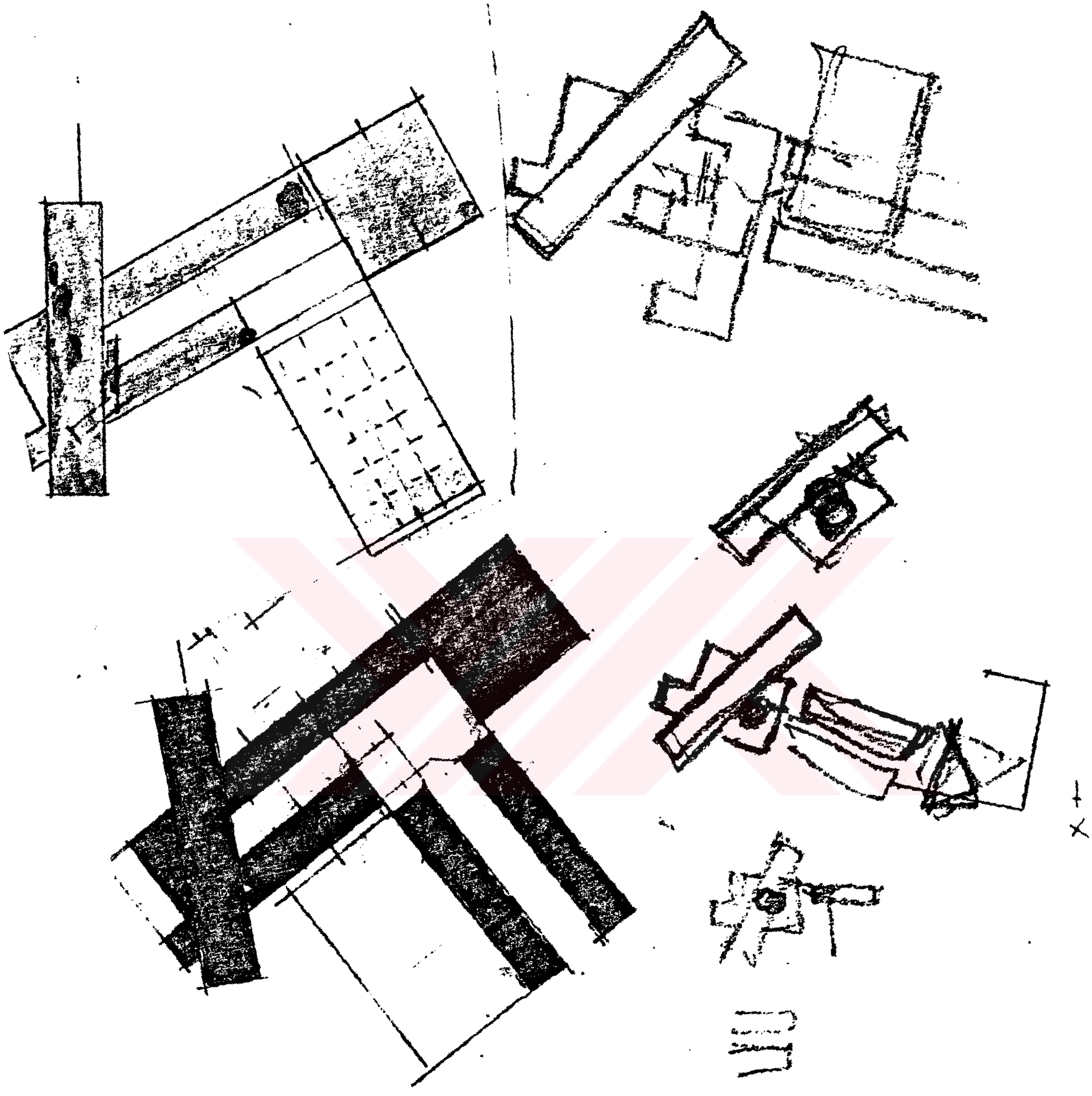
The floor finishing is composed of laminated panels with an aluminium honeycomb core and an edge stop of aluminium for the necessary strength and lightness,and with a plastic wiper in the edge stop to achieve the tolerances required acoustically.The panel sizes are 1200 square;a larger one would require intermediate stringers:a smaller one would have meant too many joints,which would be visually disruptive and uncomfortable.Only in the workshops,multi purpose hall and industrial exhibition area where the weights and access needs are greater and deflection criteria more cririical 600 mm square sized panels are used.

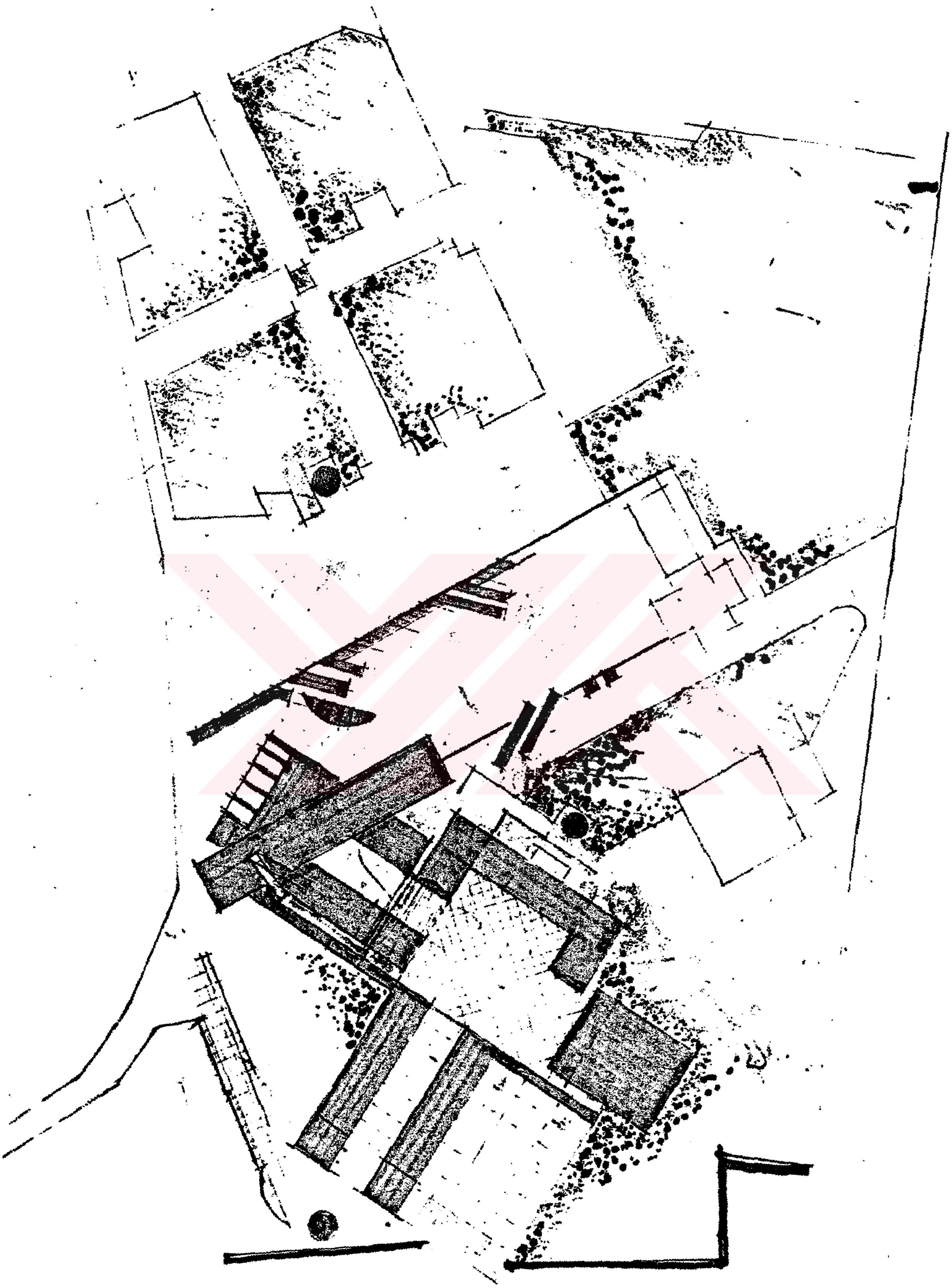
The pedestals supporting the panels are spaced at 1200 mm centres,each are carrying a corner of four panels.They are screwed into cast aluminiumbase plates fixed to the concrete with epoxy adhesive,and they have their own built-in leveling devices.

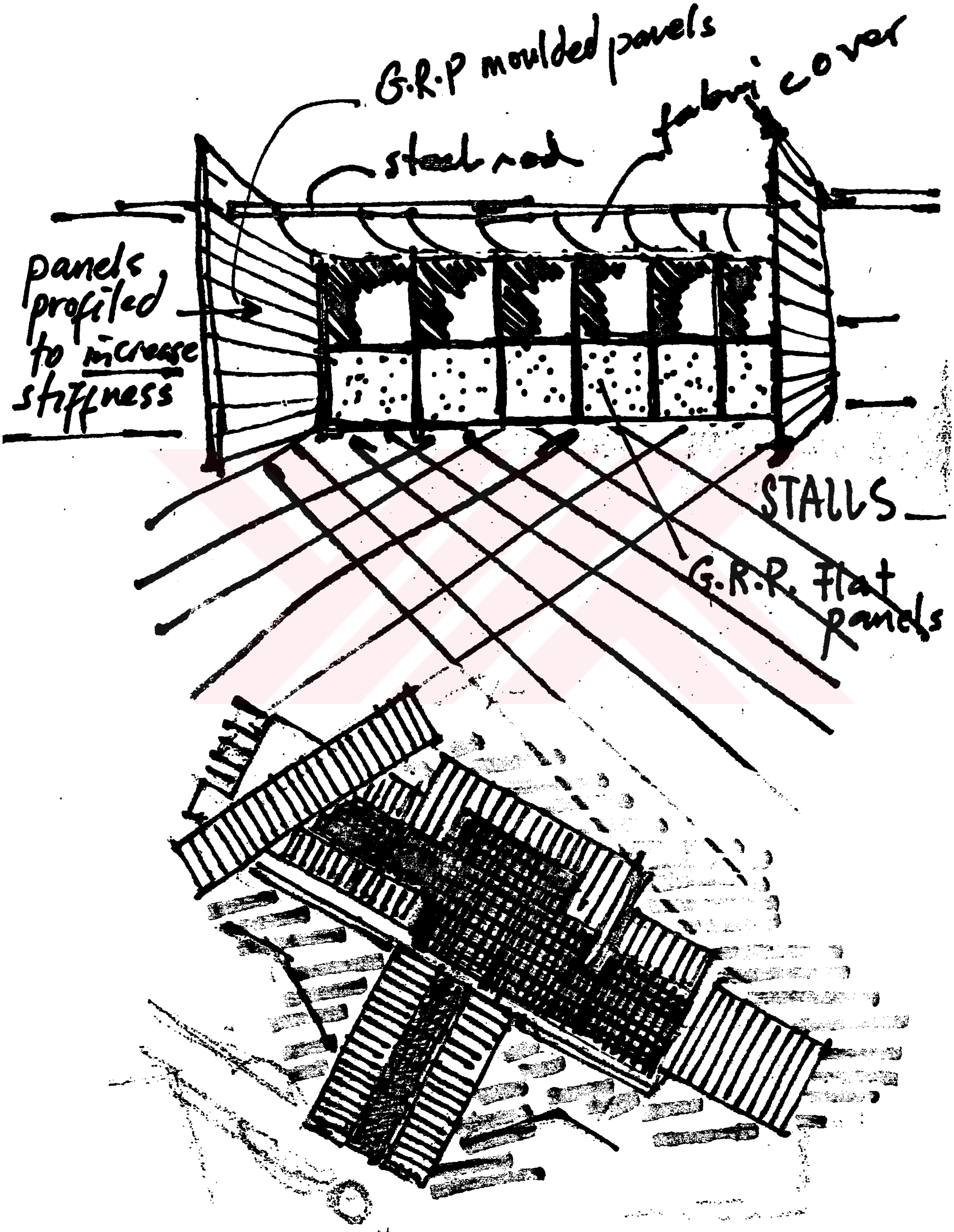
9. SKETCHES AND DESIGN EVOLUTION

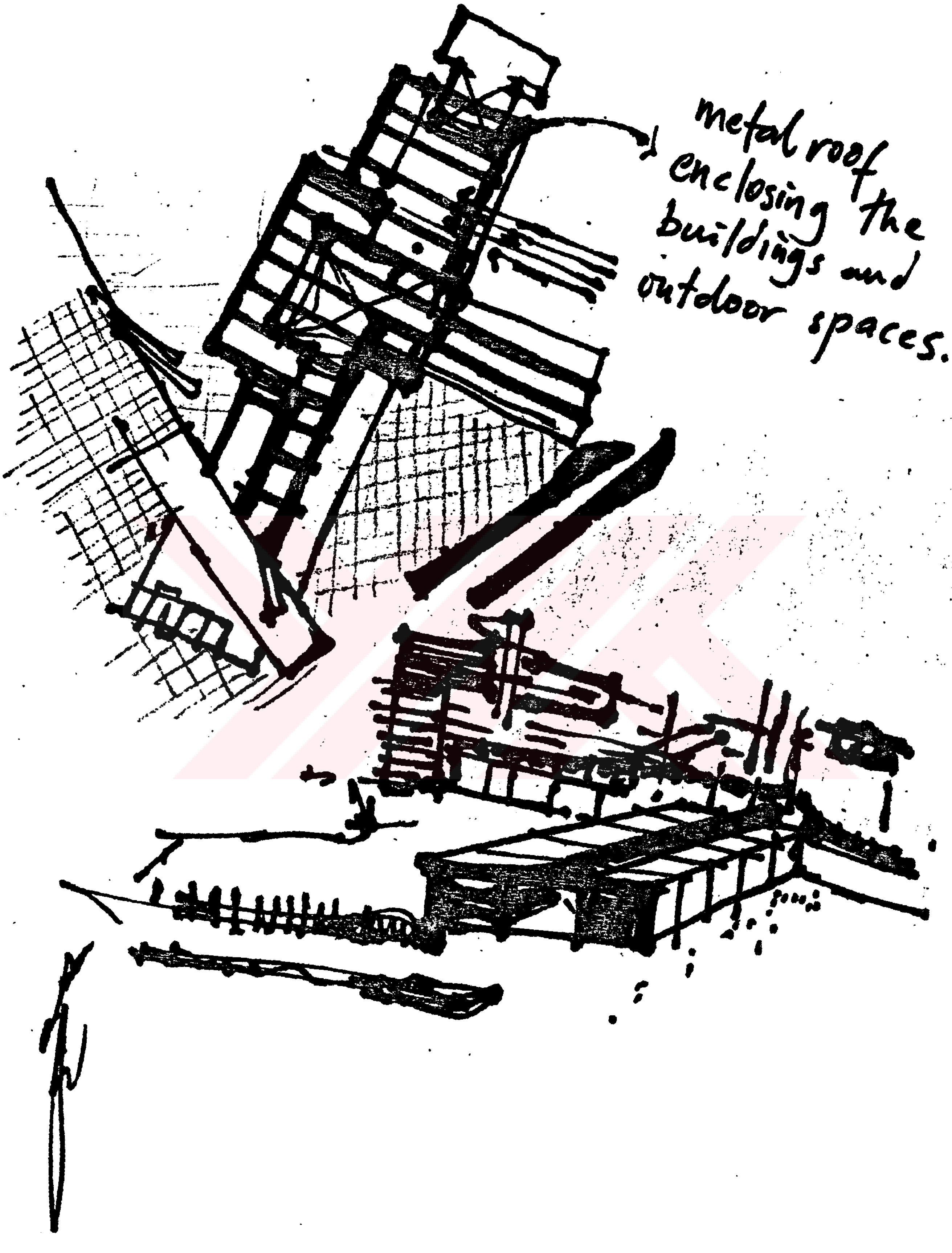


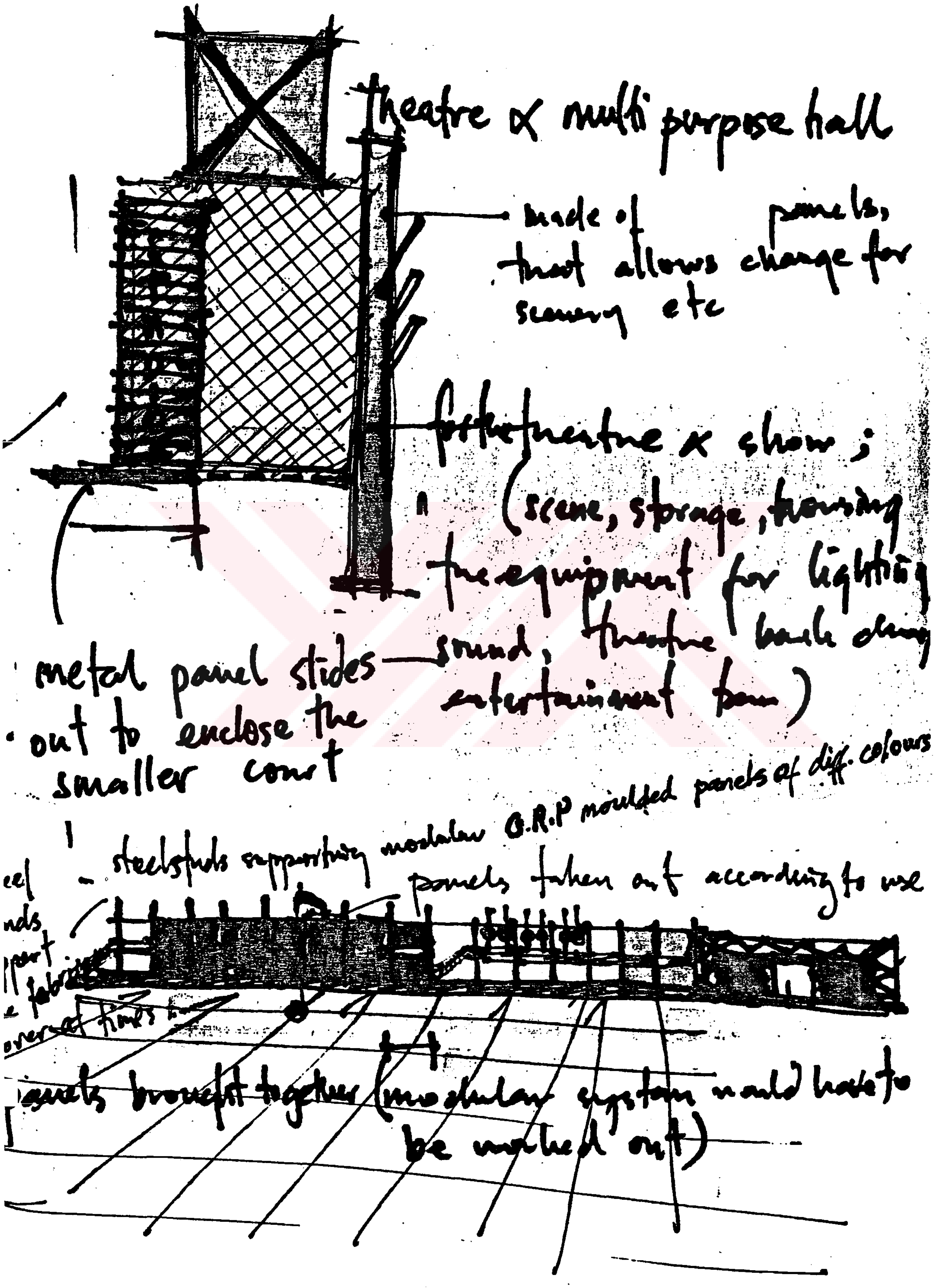


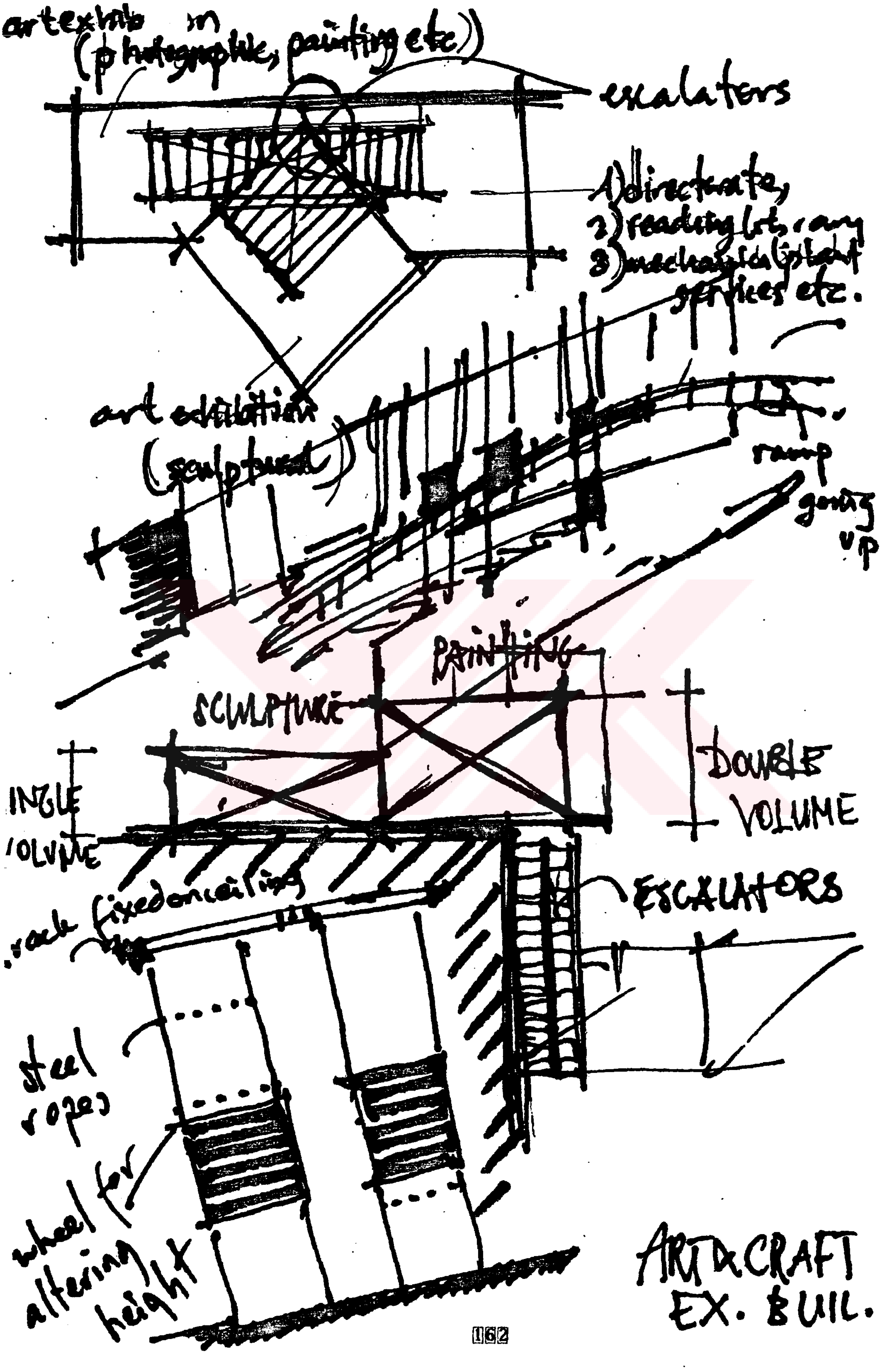


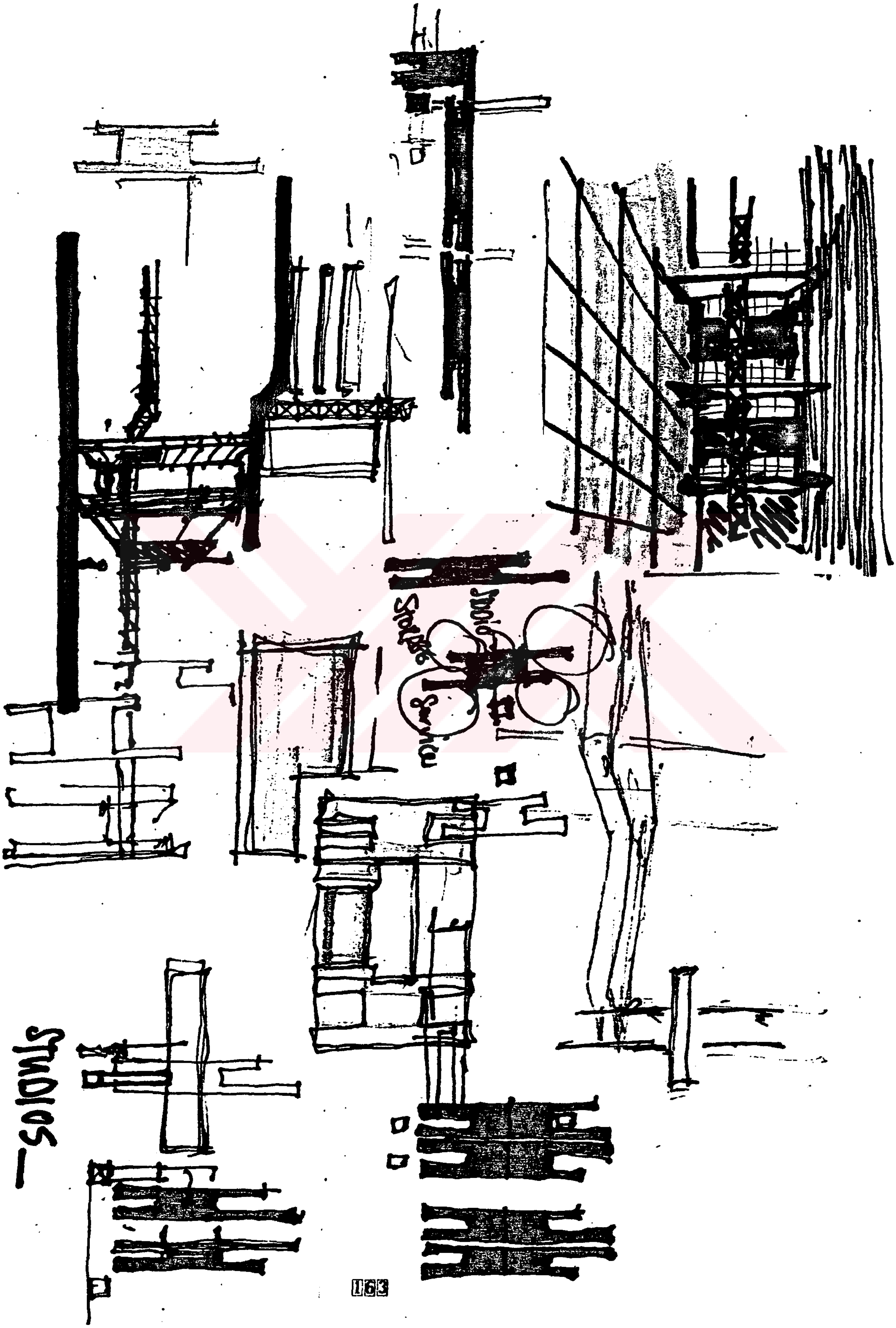


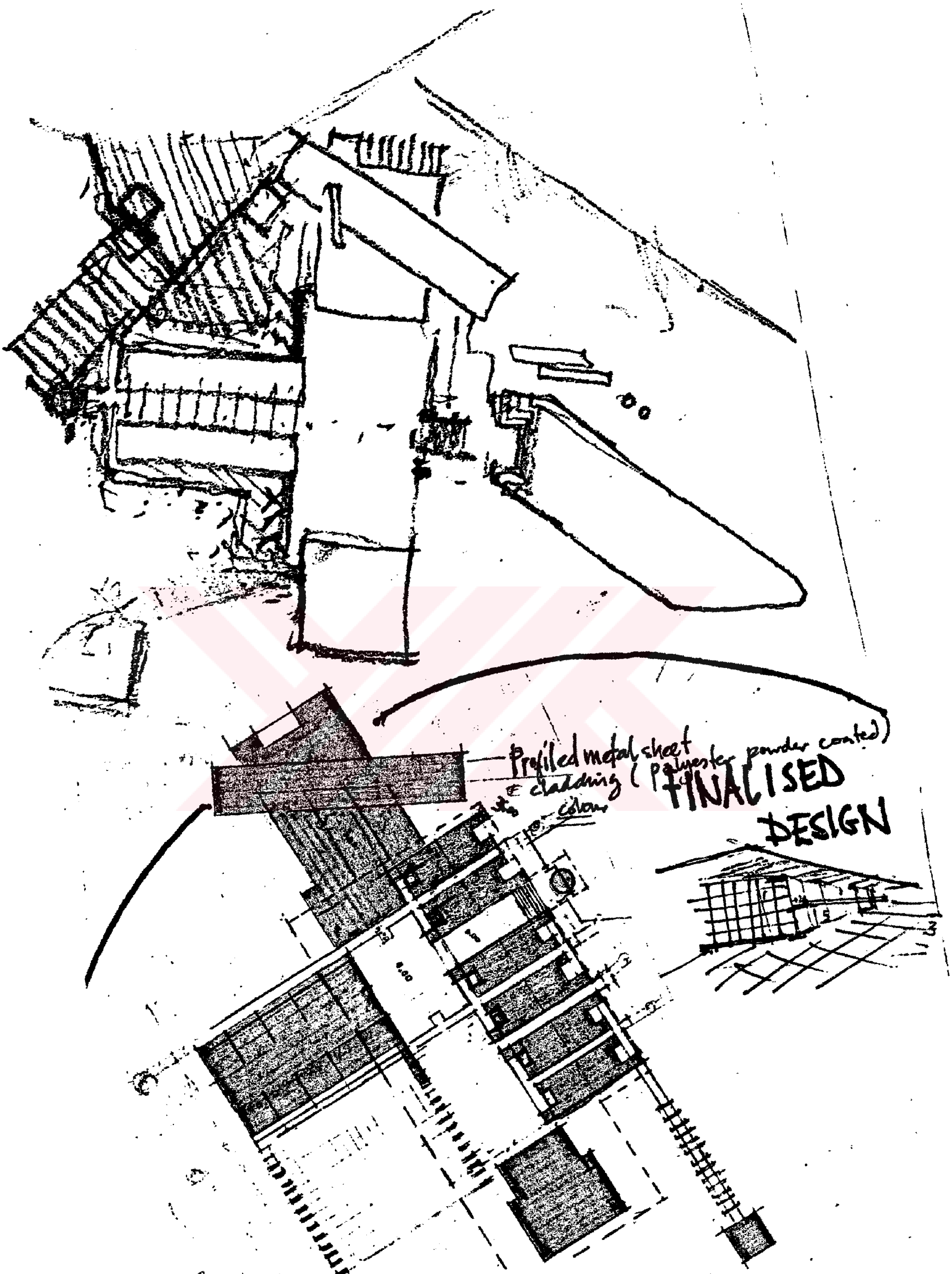

G.R.P moulded panels
fabric cover
steel rod
panels profiled to increase stiffness
STALLS
G.R.P. Flat panels

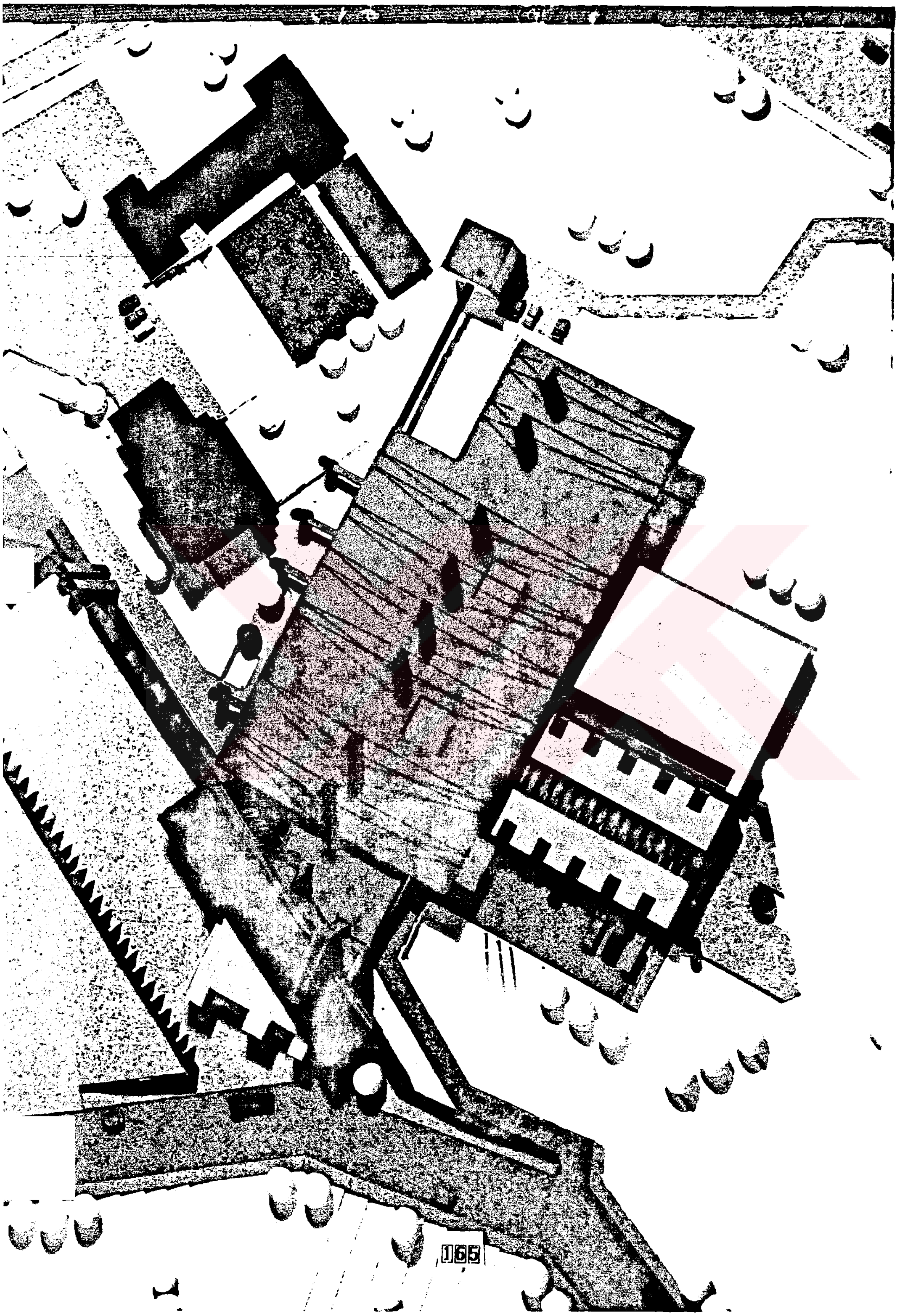

metal roof enclosing the buildings and outdoor spaces.

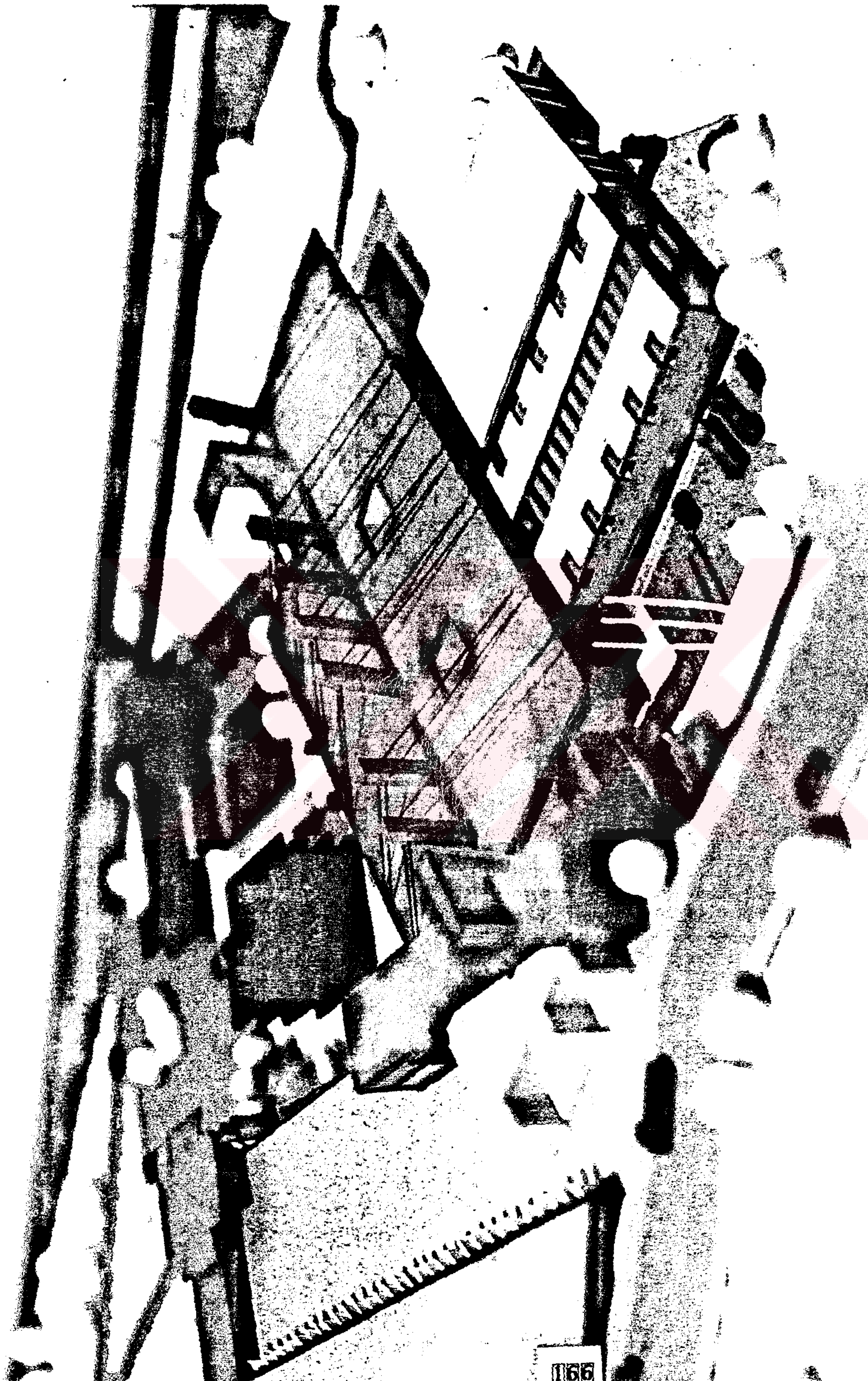

theatre & multi purpose hall
made of panels, that allows change for scenery etc
for the theatre & show; (scene, storage, housing the equipment for lighting, sound, theatre back drop entertainment)
metal panel slides out to enclose the smaller court
steel studs supporting modular G.R.P moulded panels of diff. colours
panels taken out according to use
panels brought together (modular system would have to be worked out)

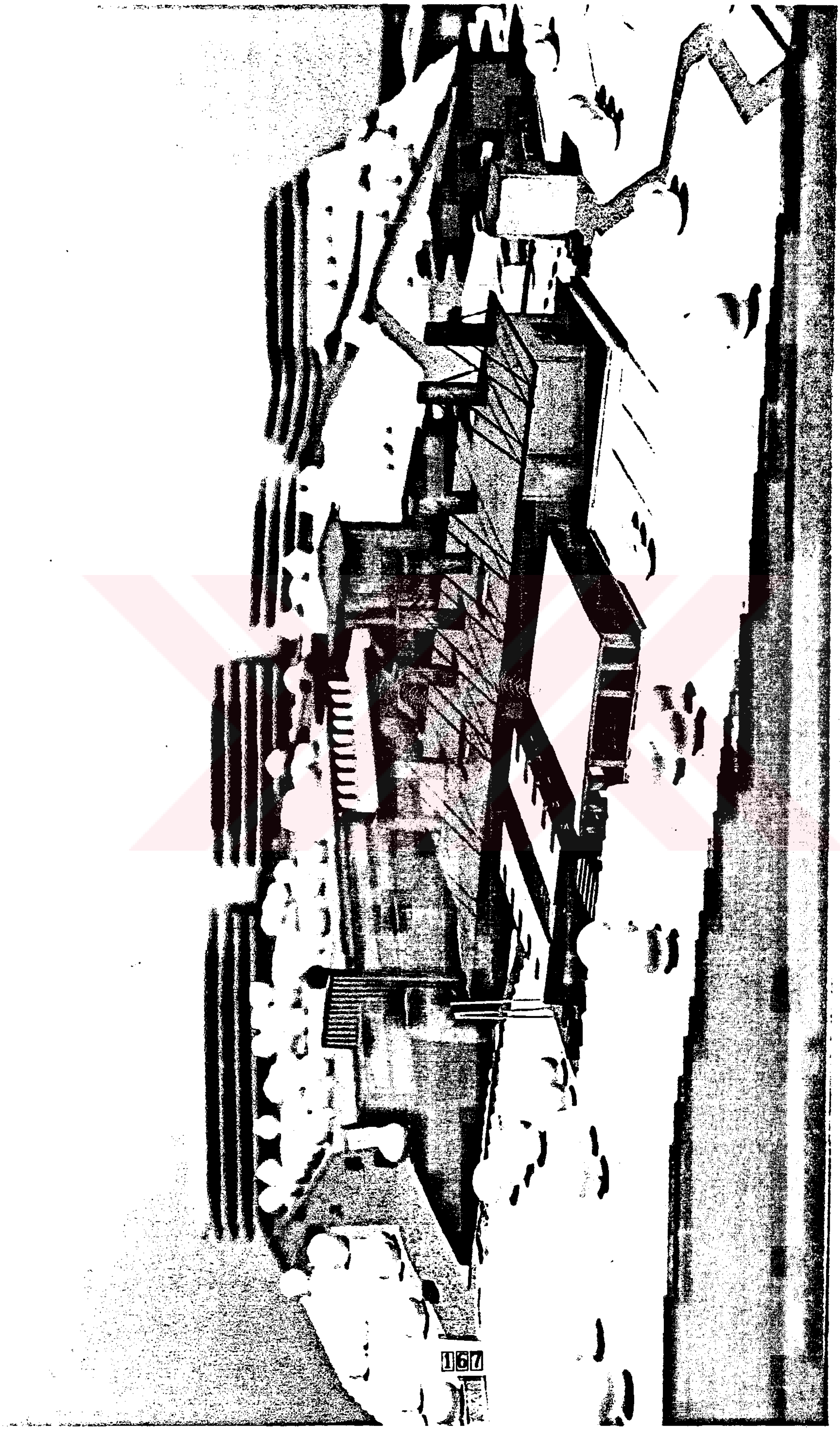

escalaters
art exhibition
(sculptured)
ramp
going
up
PAINTING
SCULPTURE
DOUBLE
VOLUME
INGLE
/OLUME
ESCALATORS
steel
ropes
wheel for
altering
height
ART & CRAFT
EX. BUIL.

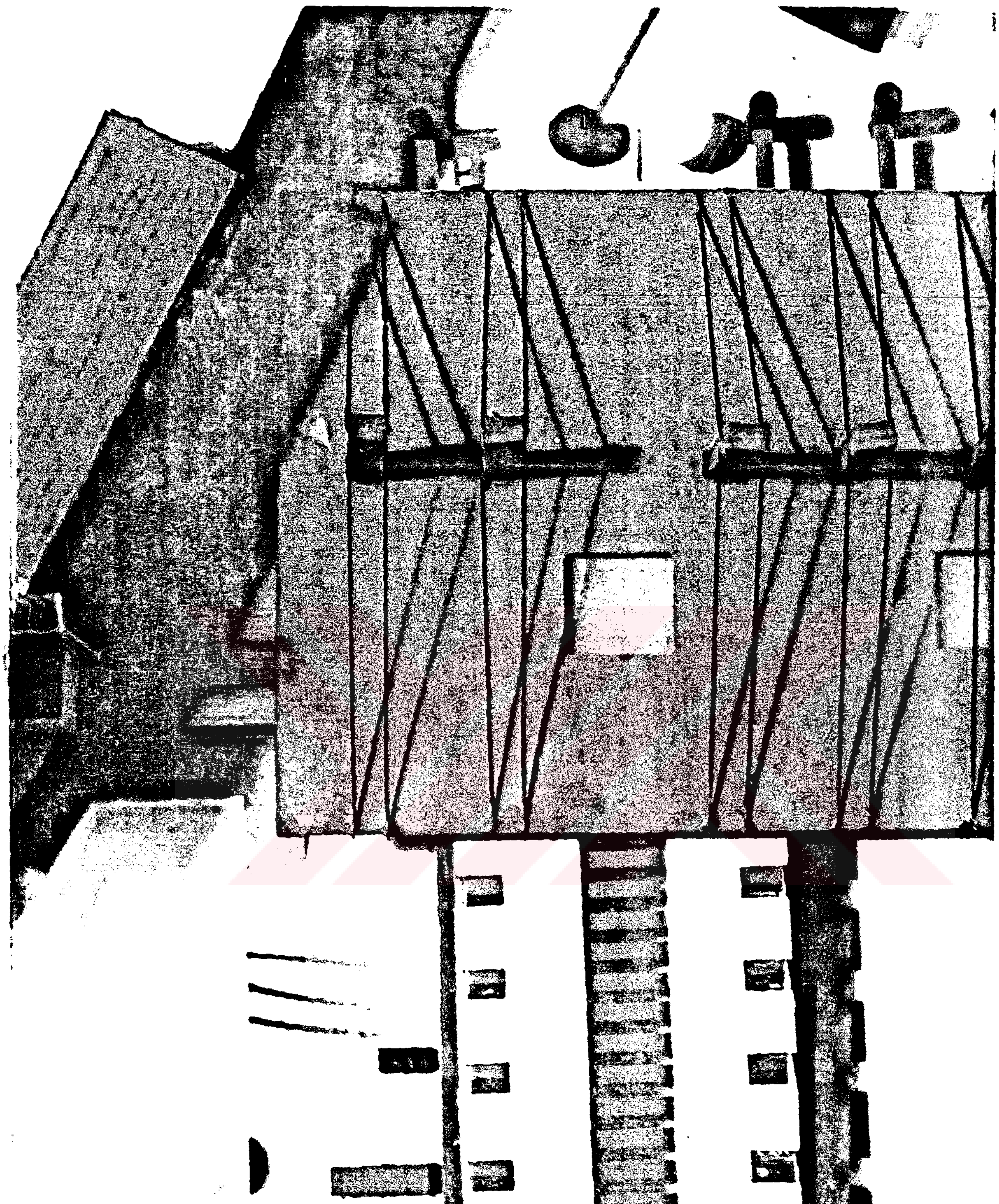

Studios
Storage
Service

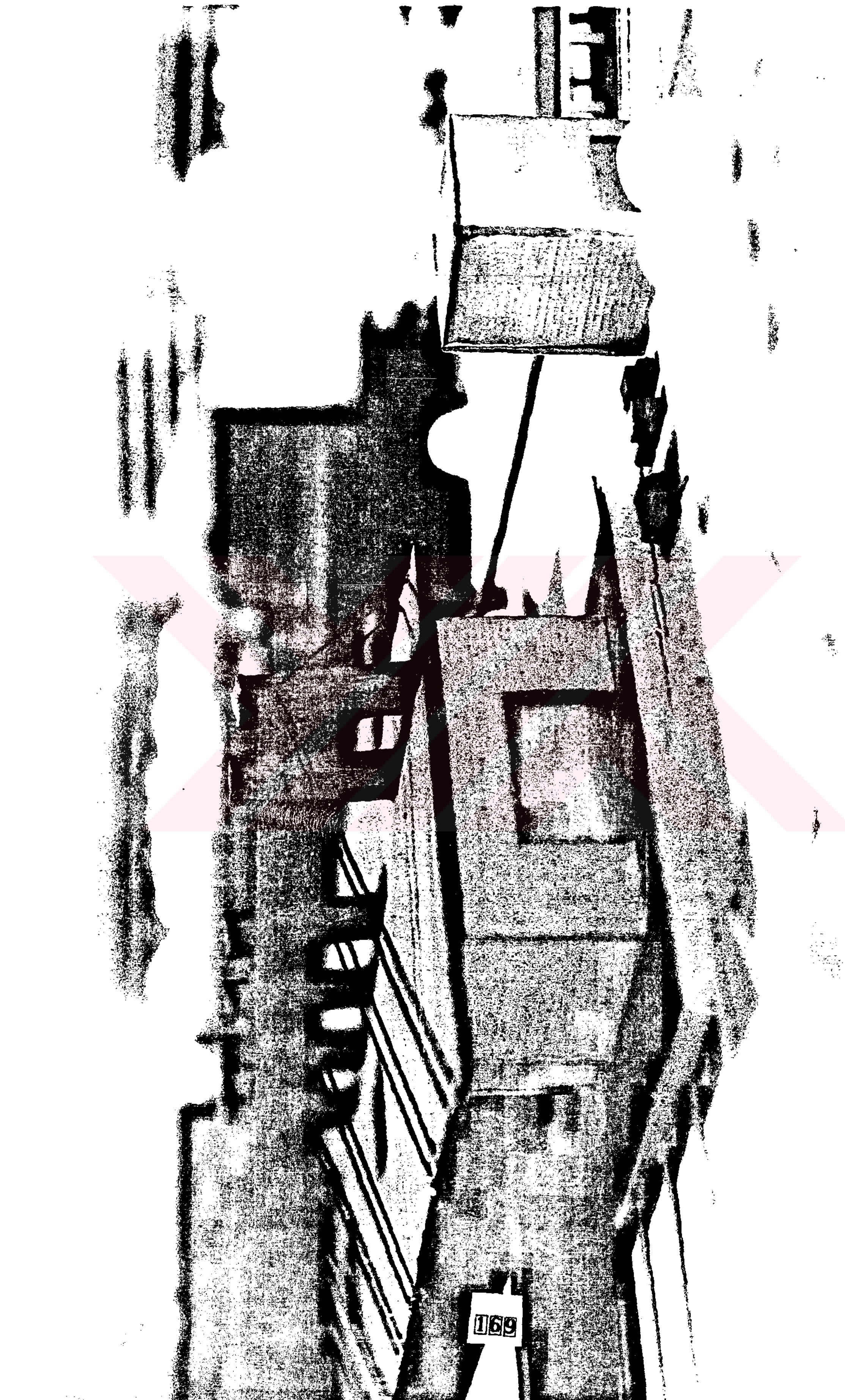

Profiled metal sheet cladding (Polyester powder coated) colour
FINALISED DESIGN

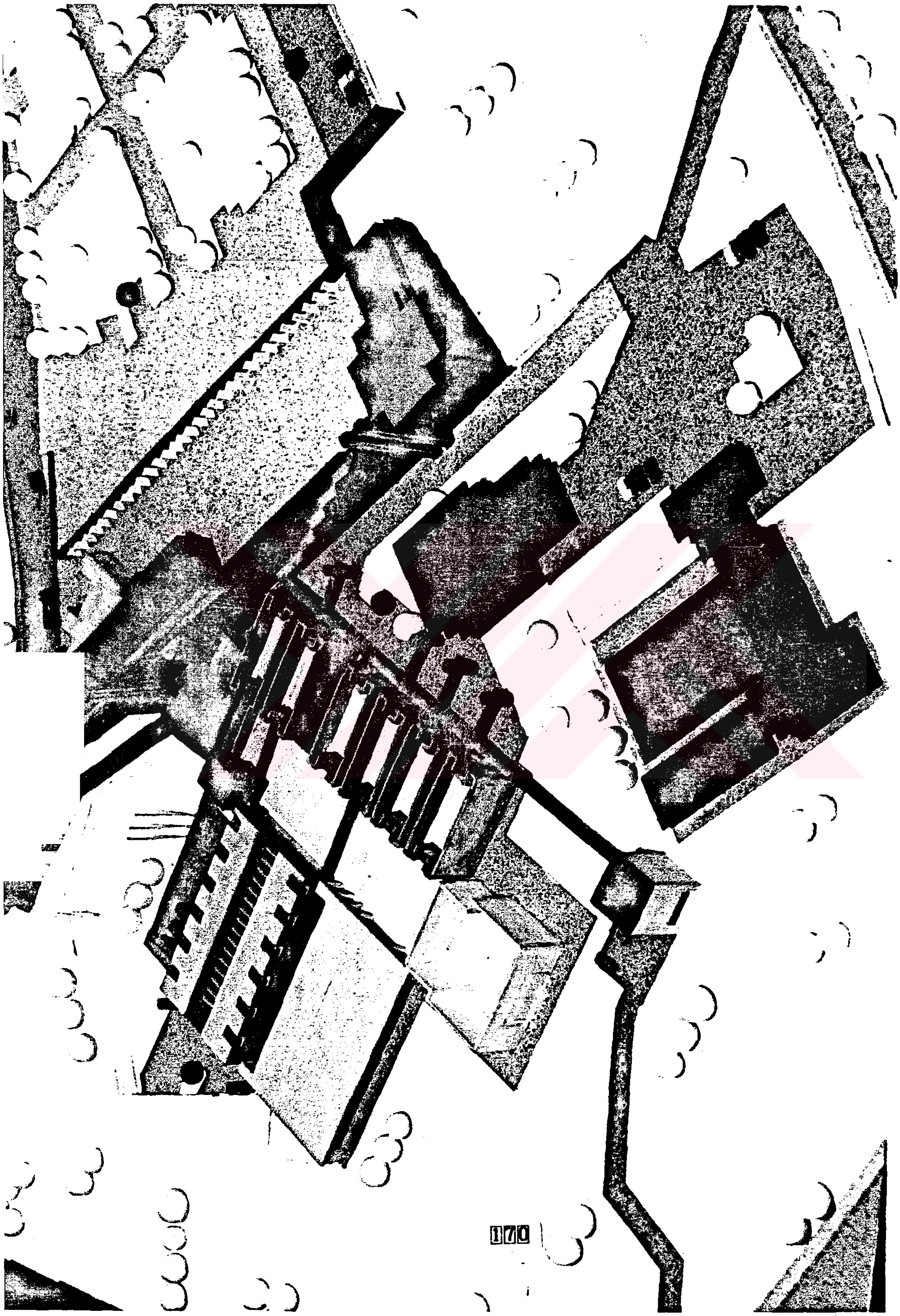


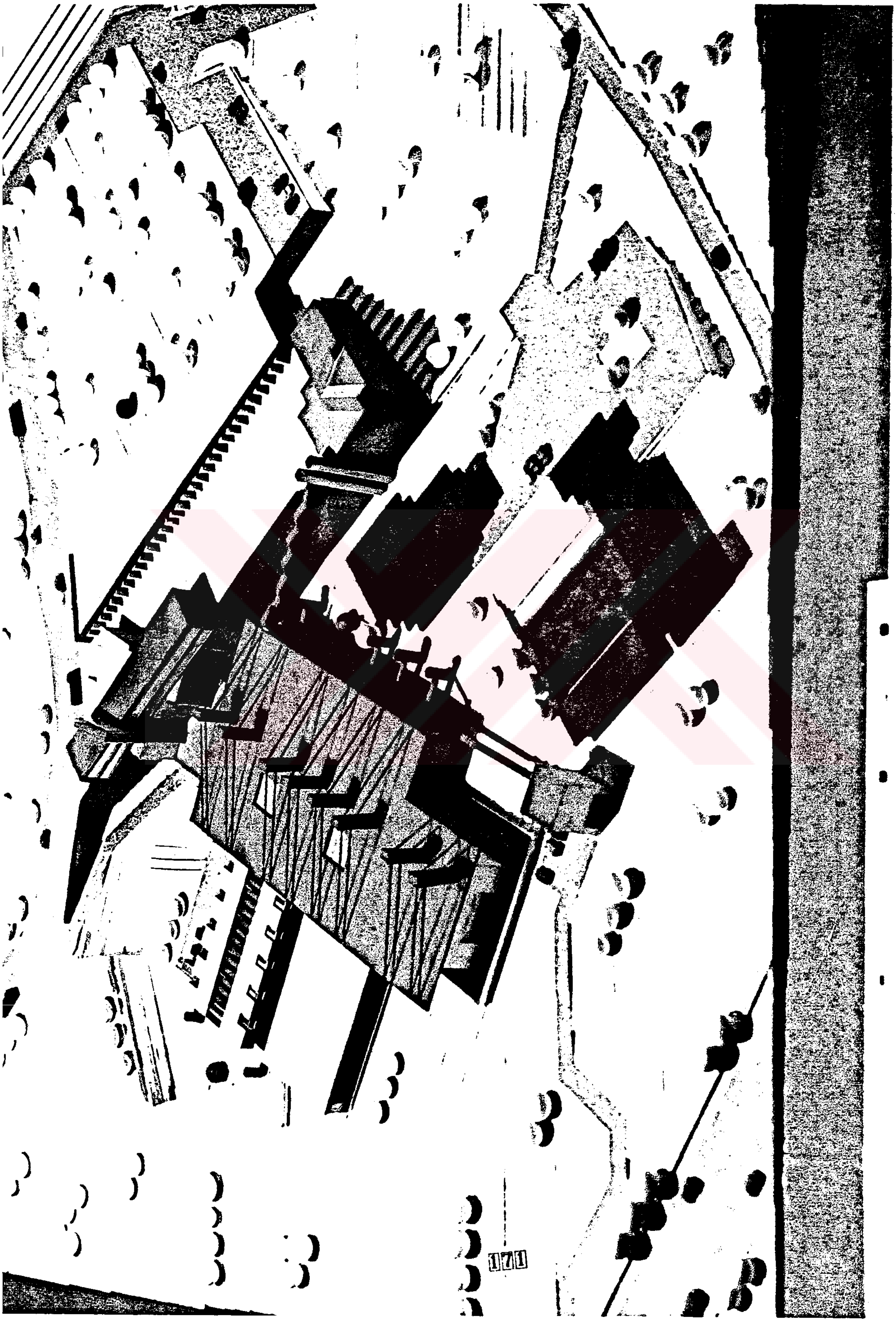





168


169





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