

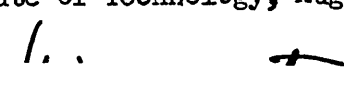
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THE PRODUCTION OF SHELTER
a study in prefabrication

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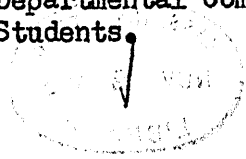
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A B S T R A C T

Title of the thesis :

THE PRODUCTION OF SHELTER : a study in prefabrication

Name of the Author :

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Summary of Contents :

This thesis attempts to derive some of the concepts which are believed to be important in an industrialised architecture from a survey of past and present social and technical trends.

The first and major section of the thesis is a review of the philosophies which at different periods made particular buildings important, and of the techniques which were available at each stage. This is followed by a discussion of present social needs and technical possibilities, both of which, it is believed, require the use of a fully industrialised architecture to meet the demand for shelter adequately in terms of quantity and quality. In addition, it is suggested that only through the use of such prefabricated components can the variable space made necessary by rapid social and personal changes be created. In the concluding chapter of this section, the relationship between such an architecture and the probable form of the city is investigated.

The second part of the thesis consists of diagrams illustrating certain concepts on which the detailed design of prefabricated elements might be based if the conclusions of the first part are accepted. The diagrams shown do not refer to any particular material or situation but are intended to demonstrate principles of design only.

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Professor of Architecture

Table of Contents :

PART I

Chapter 1	The Prime Building Need	page 4
Chapter 2	The Structure of Buildings	page 15
Chapter 3	The Present Social and Technical Demands	page 25
Chapter 4	The Emerging Form of the City	page 31
Bibliography		page 46

PART II

Diagrams of the design concepts for a system of prefabrication

Chapter I

The Prime Building Need

It has recently come to be realised that the history of architecture is not the story of steady progress towards a single goal, but rather a series of differing experiments each intent on satisfying contemporary needs; varying thus, for example, from the history of medical science and being more like that of political economy. Due largely to the fusion of the work done in the 19th century by Viollet-Le-Duc, Ruskin and others it became possible at the same time to acknowledge that each of these experiments was conditioned by a number of factors whose combination tended to influence the shape and purpose of the buildings we now see.

Architecture at any given time may thus be likened to a living organism whose function is dependent on the interaction of a multitude of related parts. As in the organism, so in architecture, however, there is one factor which, though related to and affected by the remainder, yet significantly guides the resultant whole. In the case of architecture that factor may best be defined as the dominant philosophy of the age; namely that body of knowledge which an age formulates or accepts to explain the phenomena surrounding it and which at the same time characterises it most. Architecture, being its corollary, inevitably finds its fullest expression in the building type to whose purpose this philosophy is most closely related. It is this building type, catering for the needs which its contemporaries consider most important and expressing its time clearest, which, by analogy, might be termed the dominant building of the age. Temple and theatre, baths and forum, basilica, cathedral, palace, mansion - may thus be said to describe the locus of architectural importance in the history

of European architecture up to the 19th century.

Whether the dominant philosophy controls architecture, as has just been postulated, or whether as Sir Herbert Read has suggested in the Norton lectures for 1953-54, the dominant philosophy is itself created or at least influenced by art, is for the moment unimportant. The essential point is that a relationship exists and can be demonstrated. History provides innumerable examples and three have been chosen here almost at random to illustrate this particular interaction.

The history of Ancient Egypt furnishes the first. The monotony of its architecture has long been a by-word to historians; for three thousand years an unbroken tradition governed by the inundations of the Nile and a simple belief in a complexity of all-powerful gods ensuring immortality to the favoured, expressed itself in temple and funereal architecture. During the whole of this time history can discover only one rebel, the Pharaoh Ikhnaton. In the fourteenth century he made an attempt to introduce a monotheistic form of worship and to create a new way of life which, by contrast, should value individualism and the joy of living. Almost at once the house becomes an important feature of Egyptian architecture. The chief examples are at Tel-El-Amarna which Ikhnaton founded as an expression of the new thought. Ikhnaton's revolution was however a failure. The old order was restored under Tut-ank-Amun and with it temple and tomb architecture. It is interesting to note here, almost as an epilogue to Egyptian history, that when the Nile valley was conquered in 650 A.D. by religious fanatics again preoccupied with the notion of death, the temple, now the mosque, became once more the prime building need. It is not surprising therefore to find that the Muslim conquerors when they robbed the

pyramids of Gizeh of their surface coating of polished sand stone used it not for any palaces they might have built on the banks of the Nile but for the mosques of Cairo. On the other hand modern Cairo, until recently - worldly, monarchic, capitalist - builds palace, opera house and flats for the bourgeoisie.

The transition from the late Roman society of the Hellenic world to the Christian societies of the West and East provides the second illustration. If Rome held any beliefs, its principal one was surely that of its own supremacy and certain destiny. Institutions which gave added importance to either the Roman or his society were thus considered vital. The baths catering for the ostentatious physical and social ritual of the patrician, and the law courts, at the edge of the Forum, investing for perhaps the first time in history the functions of government with a certain architectural dignity, were two such institutions. When however belief in government and empire was supplanted by fervent belief in God, the place of worship naturally became the dominant building. In the West the structural form of the basilica was accepted and adapted to the new function; in the East, under Orthodox Christendom, that of the baths was combined with certain developments of the Near East and modulated until it triumphed in the church of the Haghia Sophia. In the West the basilica was further developed, thanks to the impetus which the Church received from the Crusades and the reforms and the reorganisation of the Hildebrandine Papacy, into the cathedrals of France and England which were to be the dominant building of the Middle Ages; so much so that when after the Black Death there was a shortage of masons in England, only cathedrals and colleges could employ them without the King's leave. As in the previous example, the Muslim world again provides a postscript. When the civilisation of the East Roman Empire was absorbed by that of the Ottoman, equally religious and monotheistic, it was possible for the 'Osmanlis not only to convert Haghia Sophia and the other churches of the

empire to their own use but to build the mosques of Constantinople on their model.

The gradual emergence of the Renaissance from the Medieval world has been chosen as the final example. For almost a thousand years the thought of Western Europe had been centred on the belief in the fatherhood of God and by corollary - in theory at any rate - a universal brotherhood of man resulting from a single and special creation of mankind. Coupled with this was the traditional acceptance of the cosmogony defined in Genesis and the clearly ruled out scheme of existence laid down by St. Augustine. This body of dogma was unquestioned throughout almost the whole of the period; neither Church nor State encouraged enquiry. Towards the beginning of the 15th century however the rigidity of the accepted dogma began to be undermined by the gradual accumulation of economic and technical changes and the introduction into Italy of the Byzantine spirit of enquiry, first through Athens, then administered by the Florentines, and later by the events following the capture of Constantinople; the discovery of America dealt it the death blow. In the succeeding hundred and fifty years the Renaissance spread to France, the Low Countries, England, Germany and Scandinavia. Its effects varied from place to place. In Italy where the Church was able to keep a partial grip on men's loyalty, building activity was, as in Florence, for example, divided between palaces and cathedral. Tudor England on the other hand not only ceased to build churches but destroyed existing ones to furnish material for the homes of its aristocracy and rising merchant class and to endow the lay collegiate establishments from which it was to draw its strength. It is interesting to note for example that Bannister Fletcher, the standard authority, does not list a single church built in England between 1558 and 1625. Even where despite a noted neglect of public worship and a marked irreverence on the part of the clergy, churches continue to be built alongside temporal buildings, the new

dominant philosophy has a profound effect on their planning and appearance. The changed relation between the laity and the clergy makes the long Gothic cathedral undesirable. Not until the architecture of the Counter-Reformation, the Baroque, is reached responding as in Central Europe to the nearby challenge of Protestantism, does the church again become a prime building need.

Whatever may have influenced the structure or decoration of the buildings considered, their choice as the principal buildings of their age was, as can be seen from the examples, largely controlled by the beliefs of their contemporaries. What influence these beliefs in turn had on the details of planning and appearance, on style, is for the moment irrelevant, as is the reciprocal effect of style on thought. It is more significant that before the 19th century there was seldom, if ever, a conflict between the building need which arose out of the dominant philosophy and that which might, in retrospect, be considered socially necessary. The results of the Industrial Revolution furnished the first dilemma.

The changed conditions which came about from the effective cooperation of capitalism and mechanisation with their emphasis on concentrated units of production linked to world-wide distribution, necessitated firstly the erection of factories and then that of means of communication - railroad stations, bridges, tunnels, harbours. Simultaneously there arose a new self-confidence and certainty of the future which, somewhat as in the later days of Rome, expressed itself architecturally in England in the building of clubs, first becoming important as institutions after Waterloo, and on the Continent in that of theatres and operas.

Before this time, that is until the end of the 18th century, the home of the labourer and craftsman had been the cottage. Simple, possibly unhygienic but

seldom more so than the house of the merchant or the palace, it had satisfied basic human needs. Even in the walled medieval town the fields and gardens came right up to the buildings and many of the physiological functions were performed out-of-doors. Cleanliness and privacy, two essentials neglected by the builders of the 19th century, were, even if it meant going outside the house, almost always attainable. The urbanisation of the poor during the Industrial Revolution completely destroyed this situation.

The slums of the towns were the new reality. The mill hands and miners lived, surrounded by an oppressive urban desert, in houses where a single room held a family in each of its four corners and the cesspool was below the boarded floor. Cholera broke out in England in 1832 and again in 1848. It was possible for a Poor Law Commissioner to write that "the prisons were formerly distinguished for their filth and bad ventilation; but the description given by Howard of the worst prisons he visited in England (which he states were amongst the worst he had seen in Europe) were exceeded in every wynd in Edinburgh and Glasgow inspected by Dr. Arnott and myself. More filth, worse physical suffering, and more moral disorder than Howard describes are to be found amongst the cellar populations of the working people of Liverpool, Manchester, or Leeds and in large portions of the Metropolis."

The house of workman was not the dominant building of the 19th century; nor has it become that yet. A frightening death rate and an alarmed conscience have sent the worker from the urban slum into the sub-urban housing estate, but they have not yet given him a home - the dominant philosophy has not changed sufficiently for that. Ever since the Renaissance and particularly since the end of the 18th century, the guiding thought of Western Europe has been based largely

upon systems of economics. These have varied from time to time, from the adventurous and possible romantic schemes of the Elizabethans to the pious hopes of the Victorians in eternal prosperity, all of which, until recently at any rate, were designed to perpetuate a capitalist form of society. Today's conception of the everyday world is still governed, with some notable exceptions, by an economic viewpoint.

Orthodox political opinion sees two alternatives only for the social and economic set-up of modern society : capitalism and marxian socialism. Capitalism being conceived as an individualistic form of society fostering private enterprise, guaranteeing certain minimum civil and ideological rights to each person but no specific economic rights. The dominant group, wielding state power and obtaining on a percentage basis a major share of the national income and thus of goods and services, is considered to be composed of the bourgeois class, the manufacturers, landowners, rentiers, etc. Socialism on the other hand being viewed as a classless form of society ensuring an equitable distribution of wealth by not allowing the property rights of any instrument of production to be held by an individual or group. It is also assumed that the whole of this society is composed of the "working class" and that there is thus no dominant section.

To these clear cut alternatives James Burnham has added a third, managerial society. This he defines as a political and economic set-up in which neither the proletariat nor the capitalists nor the bourgeoisie are the dominant group but the managers, this new class consisting of "operating executives, production managers, plant superintendents", the higher grade civil servants of nationalised industries, industrial scientists and so on. Though the instruments of production are state-owned, the managers, being the ruling class within the state, gain preferential distribution of goods and services. Managerial society has thus

certain features found both in capitalism and socialism but is distinct from both. Furthermore Burnham believes that it is towards this form of society that both capitalist nations and the one socialist experiment are tending. It would be comparatively easy to document the progress which the managerial revolution has made in Europe, the Soviet Union, India or the USA if space permitted.

It may yet be too early to say toward which, if any, of these three alternatives our societies are moving. On the evidence available at the moment it is however difficult to deny that the theory of the managerial revolution appears the most likely. Moreover recent changes in architecture seem, if anything, to corroborate the theory.

The effects may be seen in both the manner of building organisation and the choice of building types. Until not so long ago competitive tendering was almost universally adopted; it was a system typical of capitalist organisation and worked successfully within its framework. In some countries however regulation of the cost and supply of materials as well as factory production and the employment of specialist sub-contractors, each so characteristic of managerial society, have tended to make competitive tendering less common. Its place is frequently being taken there by either the cost-plus accounting system or the target contract. Both methods alter the present relation between client, architect and builder and require for their effective working an organisation in which production managers, scientists, key industrial workers and architects are all of particular importance. As regards building types, it is obvious that despite the gradual change over from capitalism, the home, in its widest sense, did not become the dominant building. On the other hand it is not entirely accidental that in the U.S.A. and England a high proportion of contemporary design was before the war associated with organisations typical of managerial society, the Tennessee Valley Authority and the London Passenger Transport Board. Or indeed that where the managerial revolution

has made little progress, as in Denmark for example, the greatest emphasis can be found on the home whatever one's opinion of its architectural merits.

It is in the field of biology that the most significant opposition to this line of thought can be found and from which a new outlook no longer centred on economics is most likely to arise. The most notable facts established by the recent study of human biology are the significance of the relation between man and his environment and the conception of the family, rather than the individual, as the fundamental unit of life. Both demand a new sense of responsibility and a considerable change of outlook; both have the widest implication on planning from economic priorities to the disposition of bedrooms.

It is largely due to the work of two groups that this life-centred philosophy has made any headway - Patrick Geddes and Lewis Mumford, and the Medical Directors of the Peckham Experiment, Innes Pearse and Scott Williamson. In his "Culture of Cities" Mumford made an eloquent appeal for a life economy, a biotechnic order, laying particular emphasis on the new conception of the home as "primarily a biological institution" properly related to school, community centre and workshop. In the later "City Development", discussing his case in terms of post-war housing, he again pleads for a belief in the primary importance of the family, given which "the whole 'problem of housing' would be stated in quite different terms". Seven years before the publication of the "Culture of Cities" Pearse and Williamson wrote their "Case for Action". In it they documented the effect of environment on man from infancy to marriage and emphasised the importance of the home of which they wrote that "it is necessary to define the sphere implied by the word 'home' used in a biological sense. It does not stand for a mere structural unit, the small area enclosed by bricks or concrete

that usually comprises the dwelling-house of the artisan to-day. Home represents the functional field the limits of which are determined by the range of the parents' free activity." It is this conception of home in its widest sense, a free and real association composed of house, workplace, school and community areas which needs translation into the contemporary dominant building.

In our society it is inevitably the town which is the important field of interaction. An industrial community - even assuming the use of automatic factories - demands the grouping of comparatively large numbers of people. How dense this grouping will become depends on modes of transport, social and economic pressures or governmental planning. Whatever its density it does become the area of the "parent's free activity", the most significant unit of social interplay. Thus it is the town as a whole, the town as home, which must become the essential building need. That the "dominant building" of this century should not be a single structure but a large association, is in complete accord with the enlargement of scale created and made possible by post-Industrial Revolution techniques.

Chapter II

The Structure of Buildings

At each stage of history the dominant building has used the current techniques available and in turn modified them through use. Unlike the history of architecture however that of building technology is one of continued progress, of increasing mastery of space, so that each dominant building of the past had a different technology at its disposal. Some of the structural techniques which were available are briefly discussed in the ensuing section.

It can be taken as axiomatic that every structure rising from level ground and under the action of gravity must have one, and at least one, compressive member : any remaining members necessary for stability may be either in tension or compression. For a given force within the elastic limit the size of tensile members is determined by their modulus of elasticity, the size of compressive members by crushing strength and radius of gyration resisting buckling. As a result of these considerations, the characteristics of members in tension are, in terms of appearance, slenderness and a certain degree of movement, of those in compression, mass and maximum rigidity.

The two most primitive structural forms common in architecture which illustrate this contrast are the tent and the igloo. They also show that the particular characteristics of compression and tension were known and employed from the earliest times. However, of the structural materials available up to the time of the Industrial Revolution only timber was stronger in tension than compression. It was though found quite impossible to exploit fully the tensile possibilities of wood as the methods of jointing invariably depended on putting timber in shear and the size of members was therefore determined not by their

working strength in tension but their ability to resist shear at the point of connection. It was this factor which necessitated the bulky members usual in traditional timber trusses rather than lack of experience, for it must be remembered that during the great building periods of pre-renaissance history, both Roman and Gothic, complicated and ingenious timber scaffolding was in use. Permanent timber structures which have survived show that these limitations were well remembered and the fact that the compressive value of timber even perpendicular to the grain is higher than that in shear, exploited. The roof of Westminster Hall in London, with a clear span of 68 feet, one of the largest timber spans of the Middle Ages, was, for example, designed to have all its joints in compression.

Two other materials which however were used structurally less frequently in architecture, rope and wrought iron, were also stronger in tension than compression. Where rope was used extensively, as in shipbuilding, structures having few compressive members were continually developed until in a fully rigged ship naval architects may be said to have created a tensile scaffolding in the sky. Similarly in the Far East where architecture was allowed to be more flexible and ephemeral, rope, mainly bamboo fibre with its high tensile strength was used to build the typical Chinese catenary suspension bridges. An arrow with a string attached to it was shot across the gorge and the rope taken over afterwards. The most famous of these suspension bridges was on the Min River and was part of an irrigation scheme dating from 270 B.C. Each span measured 200 feet. It was also in China that wrought iron first received structural employment, for a wrought iron suspension bridge is known to have existed at Chingtung in Yunnan well over a century before the design of iron suspension bridges was even considered in Europe.

The absence of tensile materials led in the west to the continuous development

of what might be termed compressional architecture. Vast spaces such as the Pantheon, the 83 foot wide throne room at Ktesiphon or the central area of St. Sophia could only be built by creating compressive members of quite exceptional size; the 142 foot dome of the Pantheon is carried on walls 20 foot thick, the arch of the Sassanian palace buttressed by walls 24 foot across and the dome of St. Sophia 107 foot wide carried on piers 25 foot by 60 foot.

In Europe this development reached its most articulated form in the cathedrals of the Middle Ages in which an attempt was made to concentrate structural forces at right angles to the building so that the actual envelope could be as open as possible. Though an intricate three dimensional effect was achieved it consisted basically of the juxtaposition of pierced vertical planes at right angles to each other. Further structural development required wider scientific knowledge both in terms of space geometry and statics and the invention of new materials. This knowledge the Renaissance began to provide.

As in so many other fields of scientific thought, Leonardo da Vinci was the first to formulate some of the problems. By discussing the concept of force and considering the properties of the parallelogram of forces, Leonardo may be said to have established the study of mechanics. It thus became possible for Simon Stevin working in the Netherlands, a century later, to think of force as a vector and to begin to employ the methods of graphical analysis which were to be so fruitful in the 19th century. It was left to Galileo to perform experiments which had immediate potential application in building. Prevented by the Inquisition from further study of astronomy, Galileo devoted his last years to a work on mechanics in which he employed for the first time the concept of moments. He came to the correct conclusion that the resistance moment of a rectangular beam was directly proportional to the width but varied as the square of the depth, though he erroneously placed the neutral axis at the bottom of the beam and

computed the value of the resistance moment as $bd^2/2$, that is to say three times its correct value of $bd^2/6$. As a result of this preparatory work Hooke and Bernoulli were able to do their researches into elasticity, Parent to find the correct value of the resistance moment of a rectangular beam and, very much later, Euler to make his important contribution on the buckling of struts. This body of work together with certain mathematical concepts such as that of maxima and minima and of minimal deformation and certain practical tables such as those of Hooke or Parent for oak and pine beams published in 1707, formed the bulk of the available knowledge and part of it was known to a handful of the more scientifically minded architects of the Renaissance.

During this time, that is to say from the 15th century onwards, the dome seems to have been both a technical challenge and an aesthetic necessity. Its design often led to the scientific use of tensile materials. Brunelleschi was only able to fulfil his ambition of putting a dome on a drum over S. Maria del Fiore in Florence by incorporating a wooden chain at the springing. This chain, mentioned but not described by Vasari, acted as a tensile ring carrying most of the horizontal thrust. The same principle was used by Giacomo della Porta and Domenic Fontana at St. Peter's where three iron rings were built in and of course by Wren who employed a wrought iron chain at St. Paul's. A further five rings were added to St. Peter's in the middle of the 18th century after an exhaustive analysis of the faults had been made; an analysis which incidentally provoked a celebrated scientific controversy of the time during which it was still possible to say that as Michelangelo knew no mathematics and was yet able to design the dome, so its restoration did not need the help of mechanics or mathematicians.

The real practical technologists of this period were however the clock and instrument makers of the 17th and 18th century. Apart from their interest in the production of metal springs they fashioned in miniature a large number of

devices in wood and brass, many of them newly invented, which were to be used later on the large scale machinery of the Industrial Age. Moreover they built up a tradition of skill and invention which had far reaching results on late 18th century technics. It is symptomatic of the period that when Watts wanted to have his first steam engine built, he went to an instruments maker.

The scientific knowledge accumulated during the latter half of the Renaissance could not really come into its own until it could be applied to materials amenable to analysis. This meant that the materials had to conform to a degree of uniformity which made some approximation between calculated and actual behaviour possible. Wrought and cast iron, two long known and manufactured materials which were brought into widespread use as the result of the scarcity of timber and the exacting demands made on materials towards the end of the 18th and the beginning of the 19th century, were the first to answer the problem.

This combination of mathematical theory with new technical processes and organisation revolutionised the potentials of the building industry in a startlingly short period of time. The first cast iron bridge in Europe, having a span of 100 feet, was put up at Coalbrookdale in England in 1776; by 1801 it was possible for Telford to plan, using moreover an acknowledged and patented system, a 600 foot single span bridge over the Thames. For over a thousand years masonry structures - other than bridges - had spans whose upper limit was about 140 feet, but by the middle of the 19th century spans surpassing that of St. Peter's became commonplace : 1846 - Lime Street Station, Liverpool, 152 feet; 1854 - New Street Station, Birmingham, 212 feet; 1865 - St. Pancras Station, London, 243 feet; spans which were achieved with a great economy of material by the design of shallow trussed metal arches in which components were clearly

differentiated and each made of the material most suitable : those in tension of wrought iron, those in compression of cast.

Progress in tensile structures now also became possible and proceeded at an exceptional rate. Suspension bridges which had been a rarity during the Renaissance and which were used occasionally in the 18th century became general at the turn of the 19th. James Finley built a chain suspension bridge in 1796 and by 1810 they were numerous throughout the United States. In England Samuel Brown erected a whole series starting in 1819 of which his Union Bridge at Berwick-on-Tweed was the most famous. About the same time Telford was building his two important suspension bridges at Bangor over the Menai Straits and at Conway Castle. The first wire suspension bridge of any size was built at Geneva in 1822-23 by Dufour and Seguin and had two spans of 130 foot each. Only ten years later Chaley erected a spectacular suspension bridge over the Saane at Fribourg in Switzerland which spanned 810 feet. It originally consisted of four cables each composed of 1056 3mm wires with a 21 foot wide wooden platform suspended between them. And only a quarter of a century after the first bridge at Geneva it was possible for Charles Ellet to build a 1010 foot span over the Ohio near Wheeling in West Virginia.

Yet further developments were made at once possible by the introduction of the Bessemer process in 1855 which opened an era whose most startling monuments occurred at the Paris Exhibition of 1889 - the Eiffel Tower and the Galerie des Machines. This period of high-Victorian prosperity and sheer space conquest gave way in turn to what might perhaps be dated as the most recent phase in building technology.

This, the most recent phase, is characterised by extreme economy of means,

lightness of structure and the use of isotropic materials whose behaviour can be forecast with a high degree of accuracy. It is a movement made possible by the introduction of exceptionally strong steels, of aluminium and its numerous alloys and of plastics. This movement moreover can be discerned over the whole field of technics and it had its widest application in the aircraft industry where the design of strong yet light structures was vitally important. The movement demands however for its fulfilment the full use of the industrial process, that is to say the concentration of the means of production by power tools within a controllable area, a process which showed itself as early as the 17th century in the textile industry but is only now affecting the building trade.

At the same time new methods of mathematical analysis are being developed, the most significant of which is perhaps that the effect of time on structures is being considered. A structure is, as D'Arcy Thompson says of natural forms, an event in space-time and its behaviour has been found to conform to certain plastic laws; in other words the concept of dynamics has been introduced into building calculation.

Probably the most noteworthy feature of the present phase is that with the exception of clay products most building materials in general use are stronger in tension than compression. Or, to put it another way, that a large number are "too strong" in compression, that is to say that the size of the strut is governed by slenderness ratio rather than maximum permissible fibre stress. If therefore the latent strength of materials is to be fully used new design solutions become necessary.

The suspension bridge, the classic tensile design, shows many of the characteristic features of the now generally possible tensile structures. Its dead load to span ratio is very low and it thus became the only practical method of spanning exceptionally wide distances. Erection is on the whole easy, as

normally there is no scaffolding required; after the first light element has been taken over (as by a kite at Clifton) chains or cables can be slung between the towers and the deck placed without requiring support from below. Moreover the clear separation of tensile and compressive components makes, aerodynamic considerations apart, computation comparatively simple and observed and calculated behaviour conform reasonably closely.

The most important feature of tensile structures in general is however the ease with which they are able to collect forces at a small number of points, the compressive components, without at the same time making the intervening members bulky; a fact which creates a new freedom of space articulation. It is significant that when Le Corbusier designed the Temps Nouveaux Pavilion he used a tensile structure to support a weather-proof envelope under which he was able to dispose his exhibition elements at will. It is precisely this ability of tensile structures to hold up with maximum economy a climatic filter which is most likely to have far reaching effects on the organisation and appearance of buildings.

In terms of organisation this is in a way a return to the oldest of tensile structures, the tent - a moveable light-weight weather-proof cover which served as shelter for a large variety of activities. Under today's technology the size of the "tent" is almost limitless; it becomes a transparent umbrella which by acting as climatic filter only, divorced from the load bearing structure, allows of a continually changing arrangement of spaces underneath it by the quick assembly of machine-made space dividing and service components.

In terms of appearance an equally radical change is foreshadowed. Masonry structure was almost by nature three dimensional, space carved rather than enclosed by planes. The 19th century type of vertebra structure, composed of almost one-dimensional struts, was by contrast two-dimensional in effect.

Depth could only be achieved by the juxtaposition of planes and as long as these planes were part of or closely related to the load bearing structure any condemnation of "flat-bosomed" architecture was but a vain cry in the wilderness.

The clear differentiation now possible between climatic control, load bearing structure and space division creates a new and full three-dimensional freedom which has barely begun to be used. While the wall served as column, weather excluder and enclosure, this freedom was of necessity limited.

The new structures are still at an experimental stage; when imaginatively developed and fully articulated they may yet create, structurally, a kind of "Gothic" in reverse; spatially, a freedom far greater than that of the most billowing Baroque.

Chapter III

The Present Social and Technical Demands

In addition to the changes in the design of the actual load bearing structures which have just been described, an equally radical change was set in motion in the production of building materials by the logical consequences of the industrial revolution. Parts are increasingly being made by the now established means of industrial processing - the assembly line and the specialisation of tasks. A glance at the pages of Sweet's Catalogue over even the last ten years will show how great the rate of increase has been. It becomes clear, however, if comparison is made with other manufactured goods, that building materials must, if they are to satisfy economically the standards of performance demanded, be wholly and not randomly industrially mass-produced. This evolution in which only the machine product can satisfactorily compete in price and quantity has already occurred in the manufacture of almost every other useful artifact and will, almost certainly, be accentuated even further by the use of automation. In fact a great many of the products which are virtually synonymous with quality - watches, fountain pens, radios, refrigerators, motor cars, trains, aeroplanes - can moreover only be made by machines. Our standards are therefore being more and more set by the precision in manufacture and high usefulness in consumption of the industrial product. The house is associated with neither quality nor cheapness. Nor is it yet industrially mass-produced.

Attempts made so far have not been highly successful. There has probably been too great an emphasis on simplifying the methods of manufacture and erection, while considerations of shelter as an object of use and of emotional content were neglected - or if considered at all, outworn concepts too readily

accepted. The case is perhaps in many ways analogous to the typography designed at the Bauhaus in the 1920's : the sanserif types were developed as a result of certain thoughts about simplifying the drawing of letters and the ease with which type faces could be cast, but it has recently been shown that from the point of view of legibility, the serif characters, such as Baskerville or Times Roman, are to be preferred, since in use the space between the letters is as important as the letter itself.

Inadequate research is of course characteristic of house design despite the fact that personal consumption expenditure for housing exceeded \$14,000,000,000 in the U.S.A. in 1947. Considerable work has been done on schools, hospitals or industrial buildings but very little on the home. Perhaps the most highly successful use of industrialised building methods can be found in the design of the post-war schools of the Hertfordshire County Council in England which were evolved as a complete synthesis of new educational concepts, the social role of the school and an industrial building technique. As a result the Hertfordshire achievement is probably the most significant architectural contribution made in Europe since 1945. Nothing comparable has yet been attempted in housing.

Yet it is obvious that such an attempt must be made. Our social standards demand the creation of homes in larger and larger quantities. Adequate environment is probably the prime physical need of our societies and yet the most inadequately satisfied. In terms of numbers alone the position is frightening. Professor Wheaton in his "Preliminary Estimate of Housing Needs 1955 - 1970" has shown that even if new construction is at the rate of 2.0 - 2.4 million homes a year, 5 million substandard units will remain in the U.S.A. in 1970. In the peak production year of 1950 however only 1.4 million homes were constructed; given the same rate over the next 20 years, 17 million substandard

homes will still remain inhabited in 1970. The rate of production has to be doubled if the next generation is not to inherit a legacy of slum housing. Professor Wheaton suggests that "2 million to 2.4 million homes a year is an economically feasible goal", that "indeed, unless we can achieve and maintain a higher level of housing production, we will be unable to maintain full employment and an expanding economy." In terms of quality no adequate assessment has yet been made. It is not difficult however to make some conjecture from even a casual view of the public and private projects now being built. Few can be described as anything but obsolete.

Most take little account of the social patterns which have emerged as the result of changes in personal income or the widespread use of birth control measures, to name but two examples. More important still, most are built in such a manner that there is no possibility for dwellings to adapt themselves to the rapidly altering needs. How rapid this rate of change is in terms of space requirements alone, can be seen from the variation that has occurred in household size during even the last fifty years.

Household by size for the United States 1790, 1900, 1940, 1947, 1949

Size of Household	Percent distribution				
	1790	1900	1940	1947	1949
One-person	3.7	5.1	7.7	7.3	8.0
Two-person	7.8	15.2	24.8	27.2	27.2
Three-person	11.7	17.8	22.4	22.9	24.1
Four-person	13.8	17.2	18.1	18.9	19.2
Five-person	13.9	14.4	11.5	11.1	10.4
Six-person	13.2	11.1	6.8	5.8	5.5
Seven-person or more	35.8	19.2	8.7	6.7	5.5

A.P.H.A. "Planning the House for Occupancy"

Architectural design and construction should be flexible enough to adapt itself to such mutations without on the one hand requiring vast outlays of

capital expenditure or on the other continuing to inflict obsolete or inadequate shelter on the population. That such shelter has adverse effects on its inhabitants has been shown by a great many social studies. An apparently trivial but common example may illustrate that this is not only a matter of sanitary codes but also of spatial arrangements. Dr. Paul Lemkau has stated to the American Public Health Association that "irritations lead to non-productive expenditure of energy which in turn ends in over-fatigue, feelings of frustration and eventually an attitude of giving up. The refrigerator which can be placed in only one position in a badly planned room is an example. If its door opens the wrong way, each time it is opened, there are useless, resented and most fatiguing extra steps involved in walking or squeezing around it to get at the contents. Irritability thus induced is not confined to the refrigerator, but is likely to spread into a mood of irascibility to be touched off by other situations. Such series of events are common enough to indicate that wherever the sequence can be interrupted it is advisable to interrupt it for the sake of the mental health of the family. In this sense, the design of houses and furniture becomes a mental technique of great importance." And the position has been perhaps best summarised by C.-E. A. Winslow, Chairman of the Committee on the Hygiene of Housing, who has said that "the frustration which results from overcrowding, conflict between the desires and need of various members of the family, fatigue due to the performance of household duties under unfavourable conditions - these are health menaces quite as serious as (if less obvious than) poorly heated rooms or stairs without railings. The sense of inferiority due to living in a substandard home is a far more serious menace to the health of our children than all the insanitary plumbing in the United States."

It would seem that both the demands of consumption and the techniques of manufacture require the production of shelter in great numbers; there is no conflict between what is necessary and what is possible. For the essence of the industrial process is quantity production and the essence of the physical shortcomings in Western society is not food but shelter.

To this need, the prefabrication of building components would appear to provide simultaneously a technical answer and an intellectual concept, for it alone deals in terms of mass-production. It must be emphasised however that it is not suggested here that prefabrication will at once provide spectacular economies in house building, that it will halve the price or even reduce it by a third or fifth; only that prefabrication is at present the most likely method to provide housing which will quantitatively and qualitatively adequately meet the demands of shelter. It is felt that only through the use of industrially produced components, can the varied and exacting demands of climate control, of illumination, of visual and aural privacy, of warmth, of food preparation and child care, or of cleansing be satisfactorily met. The design of some of these components will be suggested in Part II.

The house is however more than an individual shelter, it is part of a complete environment, part of the essential congregations of people in a comparatively restricted number of locations. An industrialised architecture has therefore to deal with towns and not with buildings; with the creation of an environment rather than a series of unrelated units. It becomes important thus to consider these design concepts in relation to the likely urban patterns, a relationship which if "town as home" is believed to be the dominant building, is of first importance.

Chapter IV

The Emerging Form of the City

Prefabrication is not dependent on a particular urban form; nor is it likely to create one by its presence. The structure of cities is shaped by forces other than the composition of their parts. It is important therefore to discover the trends that influence the form of metropolitan areas and to see their relation to an industrialised architecture.

The significant characteristic of both the technical and social trends appears to be that of localisation. This grouping of particular and special activities within defined areas is most likely to have visible influence on the structure of cities. Localisation as an urban force has always been at work : it has produced the markets and cathedral precincts of the medieval towns; the governmental and royal complexes of the renaissance; the business and office agglomerations of the 19th century. Its effect is becoming however more pronounced and diversified as time goes on. Both the scale and scope of localisation of activity is now greater than it has ever been in the past and is likely to increase rapidly in the near future. Its influence on cities can be most clearly shown by a few examples.

The Victorian child played in the garden of its prosperous home, watched on its swing solicitously by its nurse maid, or chalked hop-scotch marks on the alley sidewalk. Social forces since the last century have taken the garden swing and the street game into the playground, a designated area within the city set apart for that purpose only, concentrating within it the otherwise scattered

play activities of the children of the neighbourhood. The playground, the totlot, the recreation field are now accepted urban forms.

On the other hand the technical forces which have determined the development of transportation have created a diversification which has made the localisation of movement within defined channels essential. It was possible for the packhorse and the pedestrian to share a paved space; it becomes impossible for the motor car, the railroad, the aeroplane and the pedestrian to co-exist within a defined area. The greater the speed of transportation the greater its need for defined channels. The car is being localised on the elevated or depressed highway; the railroad has long had its specially mapped route; the aeroplane demands clearly delimited and highly localised points of arrival and departure. The mounting speed and number of cars is likely to make essential a further and further clear cut separation of their movement from pedestrian flow. Similarly the increasing use of helicopters and the possibility of vertical take off aircraft for passenger flights will demand specialised locations near or within urban centers. Each demand will make strong impressions on the city, especially in terms of spatial arrangement. Particularly air travel with its absence of effect on the space between the points of take off and alighting may radically change the urban pattern which in the past has been so strongly controlled by the routes of communication. Localised points rather than defined channels may in future determine the areas of movement as far as the town is concerned; the railroad cuts surgically through the city, the streets with their cars set a flow pattern for traffic and a series of hurdles for pedestrians, the aircraft above the city leaves the ground arrangement unaffected except at specified localities.

Similar trends can be discerned in the fields of production and distribution. The mills of the industrial revolution which collected in a single building

serviced by steam or water-power the scattered cottage industry have in turn given way to the grouping of factories in the industrial trading estate. It was at one time thought that the cost of distributing cheap electric power would lead to a revival of rural industries. Instead factories have remained near the large centres of population on which they depend both for manpower and consumption, and have only moved from central urban sites to trading estates on the perimeter. The use of automation is unlikely to alter this pattern; it will more probably concentrate the means of production in areas with advantageous climates and thus still further increase the degree of general localisation. The placing of factories in special areas of the city is likely to clarify not only the landuse pattern but to remove from the townscape certain visual elements which have until recently played an important role within it. This of course will be particularly true of the great manufacturing towns of America and Western Europe which will become urban types associated with a particular epoch.

In terms of power production the trend is equally clear. During the Victorian era the only localised power production process was that of carbon gas and the great gas tanks, bulbous forms contained in gothic tracery, became conspicuous landmarks in the city. Since then electricity has increased the degree of localisation and reduced the separate units producing power from coal. The great power stations, often the size of several cathedrals, have become strong visual elements in the cityscape. They can be found at the edge of the water in every great city - New York, London, Boston, the cities of the Rhine to name only a few. In England they have become the most dominant artifact of this decade. Where electricity is derived from waterpower an intense degree of localisation has occurred within rural areas. The production of electricity from atomic power at selected and shielded centres; from heat exchange processes through heat pumps located at points with advantageous heat sources like rivers

or the sea; from the action of tides or winds at geographically suitable locations or from large solar collectors is certain to still further increase this already developed localisation of power production.

In the field of distribution again the increased mobility of the consumer has enabled retailers to group themselves in convenient complexes. Both the general store which catered for the day to day needs of a small section and the more specialised shops have come together in the "regional shopping centres". Personal purchasing is becoming a more localised activity. The visual variety provided by local shops and the break up of the urban pattern into comparatively small and recognisable service areas is likely to disappear. Instead large sections of the town will probably be serviced by a single shopping complex which may rely on bringing its goods before the public eye on mass means of communication such as the newspaper, the radio and especially television.

The few examples quoted so far may be sufficient to illustrate the trend and effect of the localisation of activity. This trend, it is believed, will increase both in degree and scope, not least because the population curves suggest that the form "town" as such will become more and more widespread; cities will not only change, but grow, and with them the visual forms they represent, whatever these may happen to be.

The form suggested by an increase in localisation is one of grouping of clearly defined areas carefully related to each other functionally and spatially. It is an urban pattern with a "coarse grain". The haphazard agglomeration of shapes that accompanies multiple land use and the close proximity of varied activity is certain to give way to separated areas devoted to specialised purposes. A richness of urban life, a sense of excitement from the juxtaposition of differing scales is likely to be lost. The pleasure derived from the nearness of a vegetable market to a cathedral or opera house, of a timber yard

wedged between office buildings or of a cemetery on Wall Street must find satisfaction in new forms. Visual richness may have to be achieved not through a fortuitous sense of immediacy but a careful arrangement of each specialised area and the sense of surprise, contrast, variety achieved by moving from one such area to the next. Pleasure will come through ordered progression and may well be of a type not normally associated by us with cities. The urban form can still however remain the visually most exciting artifact so far created.

Within the areas of housing, of industry, or of shopping, prefabrication can perform three important functions : social, technical, and visual.

Socially, industrially produced components allow, in view of their closer engineering tolerances, an ease of handling and a degree of demountability which makes change more possible. Each area can therefore be in a continual state of internal development adjusting itself to varying needs. It should not be necessary in future for homes to be occupied in a manner quite different from that for which they were designed; the vast and inefficient process of conversion which for example took place among the brown-stones of Manhattan, the stuccoed Regency houses of London or the brick buildings of Boston's Back Bay must not be repeated. Changes in family structure, in size, in cultural habits or social standing all demand simultaneous changes in the shape of the environment. The ability to vary that environment becomes thus essential. Mechanical devices already allow of a delicate control of temperature, humidity, air-flow, illumination. A similar effortless control must be approached in terms of space. Adverse conditions of temperature or lighting affect not only body comfort but reduce personal efficiency and have lasting physical and psychological effects. As was suggested in the last chapter, adverse conditions of spatial organisation have effects in no way less harmful. Any system of prefabrication must therefore, if it is to be socially valid, allow for the manipulation of space to be performed simply.

Technically, this demands some co-ordination of dimensions. Man's vertical space demands are far more restricted than his horizontal ones. The height of any domestic space can reasonably be confined to a very small range; three given heights between 7'-6" and 12'-0" should for example adequately take care of a large number of situations. The length of that space however must be far more varied. In terms of prefabrication, it must be composed of a series of units building up to the desired length, or the complete space can be manufactured in advance. The latter solution, though most common in practice, is extremely rigid in use, permitting of little planning variations or later change. It is therefore considered unacceptable for a system which is to permit considerable space control. Horizontal dimensions of the components will thus also have to be co-ordinated by either being multiples of a given unit or by belonging to an arithmetic series of numbers. However, if the separation of the various elements of buildings can be achieved as suggested at the end of Chapter II, structure, screening and equipment may each have their own modular system with only a small number of specified points of contact. Modular co-ordination will be discussed more fully in Part II when design concepts are considered.

Visually, prefabrication can provide the variety, richness, colour, pattern and space articulation which these single use areas of cities undoubtedly demand if they are to provide the excitement associated with urban forms. Chaos must however not result. The modular control and the selection of materials amenable to machine production which are inherent in prefabrication, unquestionably provide some cohesion. This can be reinforced and a visual excitement created by juxtaposing these geometric machine-made parts against the irregularity and freedom of plants and the ground. A very simple and clear articulation should be made by using natural materials such as stone or brick near the ground only, really as part of the landscape, and posing against them in the vertical plane

the precision of prefabrication. This is both technically advantageous and visually satisfactory. In the urban scene prefabrication in no way hinders the creation of related spaces. On the contrary by keeping certain elements either identical or similar not only can a visual continuity be provided but the effects of space as such become more marked. Prefabrication can become part of townscape and one of the elements in the design of urban areas. It must be recognised however that its visual quality will be different from that associated with masonry or concrete. Where the traditional materials provide the sculptural quality of space carved, of voids hollowed out, of mass and rigidity, prefabricated components have the visual richness of the addition of parts, of the frequent juxtaposition of planes on a faceted object, of small areas of colour close to each other - contrasted or harmonised, of change and repetition achieved simultaneously. If an analogy is to be found in painting, it might perhaps be said that the architecture of the 1920's and 1930's - of the Villa Savoye or the Tugendhat - had as its painters Braque, Picasso and Leger, and that that of prefabrication - of the Hertfordshire schools for example - is more easily identified with Mondrian, with Miro, and especially with Klee.

It was suggested at the beginning of this chapter that prefabrication itself cannot mould urban form; given however certain notions of the changes and variety within buildings made possible by a system of co-ordinated components, altered concepts may have to be applied to both architecture and city planning. The field of activity of both may have to change.

If a continuous adaptation of urban environment is assumed, this process may occur in a number of ways. It may be no more than the haphazard alterations continually performed in a shanty town or the movement of units in and out of a

trailer camp. It can also however be a gradual process of change set against the more stable background which includes both the functionally and symbolically more permanent elements of the urban scene. If a sense of community is desired, some stability of background becomes essential for this sense only becomes possible if there is a functional necessity for interaction which itself is usually only occasioned by situations which have a degree of permanence. This aspect of stability should find some symbolic architectural expression which will at the same time make the historical continuity of a particular town a reality. For history not only builds the town, but should be read from it.

The clear separation of the various elements of a building which has already been suggested, makes this division of variable and semi-permanent easy to achieve. It is suggested that structure, services and the routes of communication be established as relatively fixed and that screening, that part of a building intimately in contact with people, be changeable. What is suggested is an arrangement of platforms on the ground and in space, connected to the supply and disposal lines and determining the paths of circulation, on each of which the prefabricated components are disposed freely.

Technically, this makes for structural independence of the individual house units. Each is related only to its own datum so that changes within it leave neighbouring units unaffected. Moreover if a new datum is established at each level, dimensional tolerances of the loadbearing structure need not impinge on the machine-made parts. The service lines of the structure could of course be omitted if "autonomous self-circulating cores" were provided. At present however these still suffer from the disadvantage of not being completely independent, relying as they do on the delivery of small amounts of fresh water and the occasional removal of the dehydrated waste. Urban planning having just freed itself from the tyrannical demands of the garbage disposal truck by the

invention of the Garchey system, it would seem a pity to make it now dependent on the movement of the water cart. It may at the moment be more desirable to provide self-circulating systems communally or to make modifications in the self-circulating cores which would allow their attachment to very simple and flexible supply and disposal lines. They might usefully also be operated in conjunction with communal solar collectors or heat pumps.

Socially, the disposition of elements on these platforms whether on the ground or at a higher level must be such as to provide a real freedom of choice. Studies of housing communities have shown that social contact and communal satisfaction are to some extent dependent on the relative position of houses and the paths of circulation. Social groups are thus formed and particular patterns of living established. Families should however be free to choose whether or not they desire to be influenced by these chance social contacts, the effects of which are, as William Whyte has shown, more far reaching than at first thought. It should be possible through a personal manipulation of space to take part equally effortlessly in group activity or to become a deviate without at the same time being branded as an outcast. Architecture has not only to shelter man from the physical elements, it has also to protect and enhance his personal contacts. It has in addition, if it is his immediate shelter, to adapt itself to his personal psychology. Different spatial feelings are demanded not only functionally but emotionally.

In terms of the wider social organisation, the use of prefabricated elements may also be of some importance. About three quarters of the population of the United States have changed their address in the ten years between 1940 and 1950. In view of such an extreme mobility of population it may be advantageous to have also some mobility of shelter. R. Buckminster Fuller has suggested that in a mobile civilisation housing might be provided, like the telephone, on a rental

basis by companies throughout the country who install it quickly when and where needed and remove it again when no longer required. Although this suggestion was made in connection with autonomous dwellings, the method would be equally applicable to the prefabricated components which constitute the immediate personal shelter within the established framework. In view however of the large amount of personal property which would still be moved from place to place, and which in any case through its familiarity provides some of the satisfaction received from the immediate environment, it may be more reasonable to suggest family ownership of the screening elements, equipment and storage units and public ownership of the platforms on which these components are to be placed. Housing elements might perhaps be considered more as furniture, as some of the simple moveable objects of use, rather than as the permanent and rigid walls which circumscribe our actions.

A great deal of population movement obviously happens within comparatively small areas, from the city to the suburb, from a smaller to a larger house within the same neighbourhood, and thus the problems of adapting the dwelling to a radically different climate are not likely to occur. Many of the moves however are from one climatic region into another, in the United States for example, from the East Coast to the West, from the North to retirement in the South, from the farms of the Middle West to the towns of the East. Adaptation to climate becomes essential.

This, it is believed, can be achieved by varying the actual arrangement of the screening components rather than by providing alternative ones. Both in New England and in Florida the weather is after all composed of sun, precipitation and air movement and these only differ in the two localities in amount, intensity and seasonal distribution. Complimentary changes can be brought about in the arrangement of the house to exclude or admit the weather. In traditional

buildings for example overhangs, shutters, fly screens, glass windows and shades can be found throughout the country, it is only their size and relative position which differs from region to region. How this adaptation can be made will be discussed in greater detail in Part II. The extreme variables of climates will be modified, as is already largely the case, by mechanical weather conditioning equipment. This will probably in any case, if the conclusions of Tamas Vietorisz, recently published by the Albert Farwell Bemis Foundation, can be substantiated in practice, be more economical than elaborate structural devices and certainly provide greater comfort.

If the same components are to be used in widely differing climates it should also become possible for manufacturers to produce in the quantities required by industrial processes. Le Corbusier once visualised that "prefabricated houses will come from the U.S.A. or from Sweden, as dates from Biskra, cod from Iceland or spices from the East Indies." In the immediate post-war period Sweden sent timber houses to England and at present Great Britain has an expanding export trade in prefabricated dwellings, particularly to Australia and New Zealand. It is believed however that this market as well as the market of the American producers could be expanded and the usefulness of the product increased, if instead of specialised units, standard components were to be manufactured. A widening of the market would, as it has done in every other industry, bring in turn a rationalisation of production and a lowering of costs.

The creation of two distinct parts to housing - one variable and private, the other permanent and public - may affect the role of both architects and city planners. The traditional domain of the architect is the design of the single building and that of the city planner the subdivision and allocation of urban

land. It could therefore be argued that the placing and arrangement of the permanent platforms should be decided upon by town planners. Not only however does this arrangement demand skill in spatial manipulation but the architect must, if he is to create an architecture relevant to the age, deal with more than single buildings. The town is the dominant building and the relation of spaces within it is one first architectural problem requiring solution. It falls to the urban planner, assuming the localisation of activity, to decide on the disposition of these areas and to formulate values and establish performance standards to which the architect must adhere. Through performance standards the planner can not only adjudicate between two moral rights, the freedom of the individual and the safety and well being of the community, but decide on ends and administrative means, though not necessarily on three dimensional concepts. The clear formulation of these values and standards is probably the first duty of every planner and the task requiring most immediate attention.

The social and technical forces, determined almost wholly by the dominant philosophy of the age, are shaping the city into a particular general form. Within the given form a great many choices are still possible. The first choice is between the creation of a fixed or mutable environment. If in addition, change in the physical environment is accepted as a corollary to change in social habits and personal feeling, an altered architectural concept is required. It is further believed that at present only the use of industrially produced standard building components can conform to the concept of variable space. Future techniques or social upheavals may well make the last statement obsolete. In the meantime however it is considered important that the design of these components be based upon not only considerations of economic expediency but also on those of social necessity and personal needs in a wide variety of situations. It was the object of the first part of this paper to place these needs in their proper context, it is the aim of the second to attempt to show some of the concepts which might underlie their detailed design.

A review and formulation of the town planning standards and values mentioned at the close of the last chapter is being undertaken by Rhoda Brawne in "Urban planning standards: a study of theory and practice" (M.I.T. thesis for M.C.P. degree 1954) who also suggested many of the points expressed in the foregoing paper.

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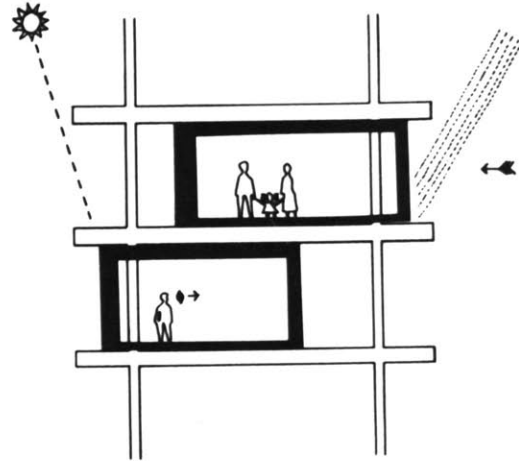
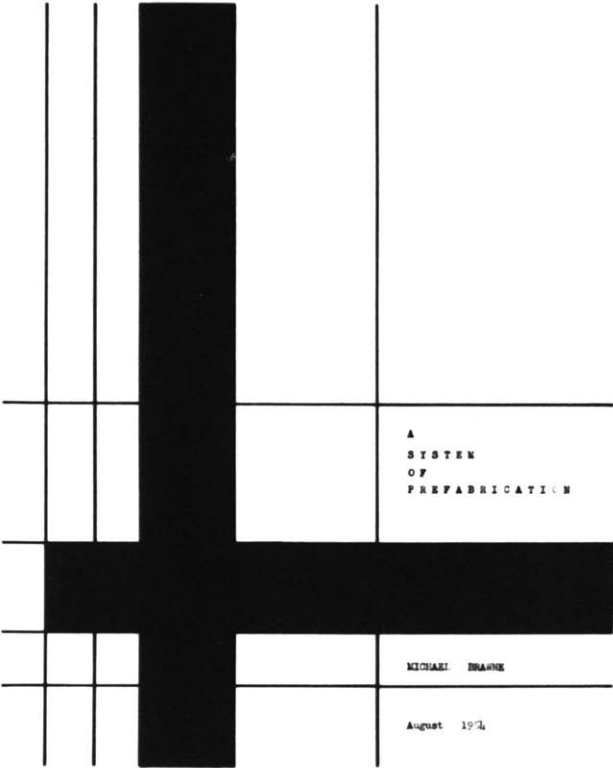
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This system deals with industrially produced components. Assembled these will provide variable shelter. The components form only the immediate enclosure which are independent of each other. Each shelter is placed on a level structural platform on the ground or within a building which then becomes datum level for that shelter. It is further suggested that components be considered as moveable personal property and that the platforms be part of the more permanent urban structure.

2 General



sun



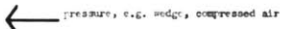
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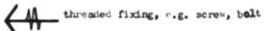
precipitation



view



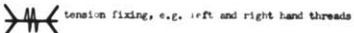
pressure, e.g. wedge, compressed air



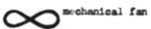
threaded fixing, e.g. screw, bolt



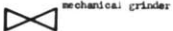
compression fixing, e.g. left and right hand threads



tension fixing, e.g. left and right hand threads



mechanical fan



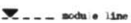
mechanical grinder



electrical wiring



sliding motion

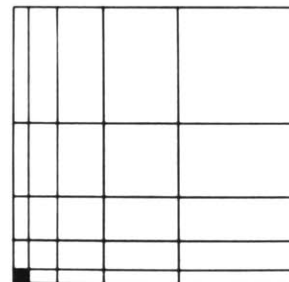


module line

3 Symbols

Fibonacci series :

1 2 3 5 8 13 21 34 ...

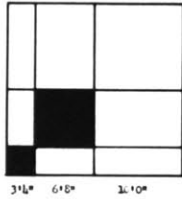


Series 1 :

1'0" has been taken as the first term in this series

Screen sizes must conform to the rectangular dimensions outlined.

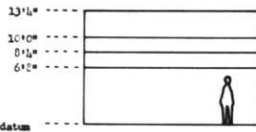
4 Module



Series II:

3'4" has been taken as the first term in this series

Screen sizes must conform to the rectangular dimensions outlined.
3'4" x 4'4" and 6'8" x 6'8" panels form the floor and ceiling grid.



Height dimensions are taken from both series

Floor and ceiling dimensions are multiples of 3'4" thus :

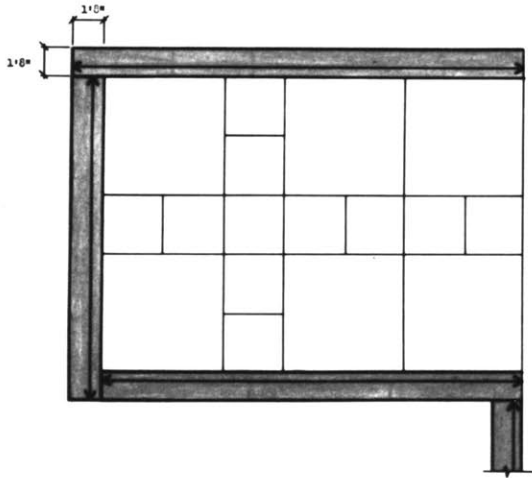
3'4" 6'8" 10'0" 13'4" 16'8" 20'0" . . .

Floor and ceiling are always ringed by a track 1'8" wide so that screening

dimensions are floor dimension or floor dimension plus 1'8" thus :

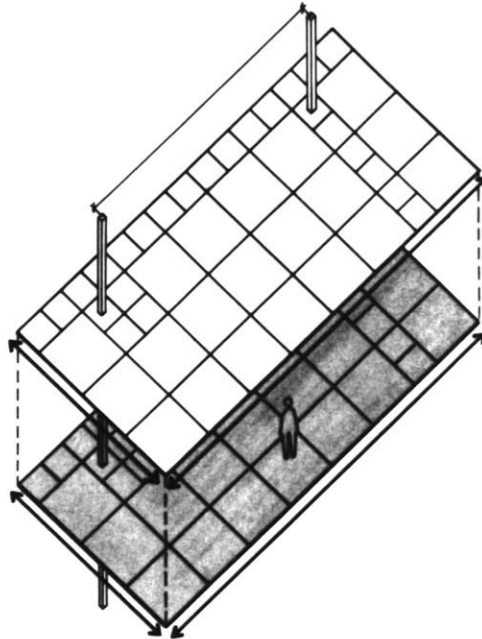
5'0" 8'4" 11'8" 15'0" 18'4" 21'8" . . .

5 Module



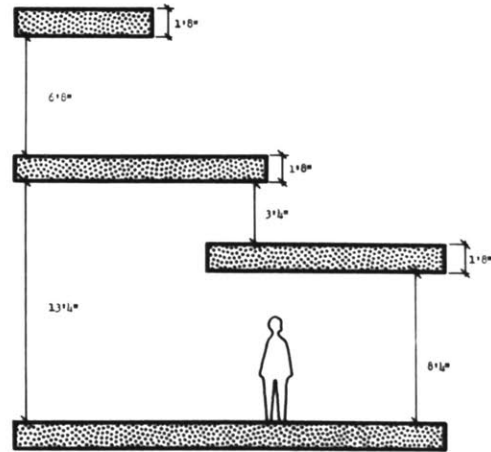
Screening is outside the floor and ceiling grid and always slides on a track 1'8" wide. Tracks form turbling junctions at corners and track lengths are always floor dimension or floor dimension plus 1'8".

6 Module



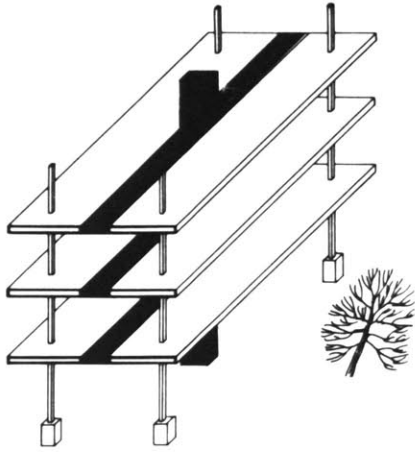
Floor and ceiling grids are identical. Dimensions that are multiples of 3'4" in both directions can be formed by the addition of 6'8" and 3'4" squares. Centre lines of the supporting structure of the permanent platforms must also be dimensions that are multiples of 3'4".

6 Module



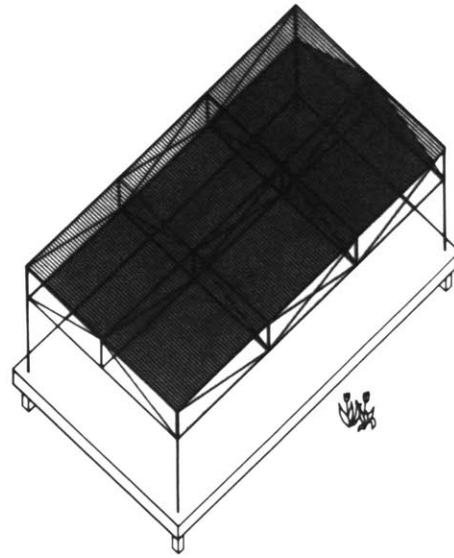
Floor thickness is 1'8" between ceiling and floor module to allow for variation in structural slab depth.

8 Module



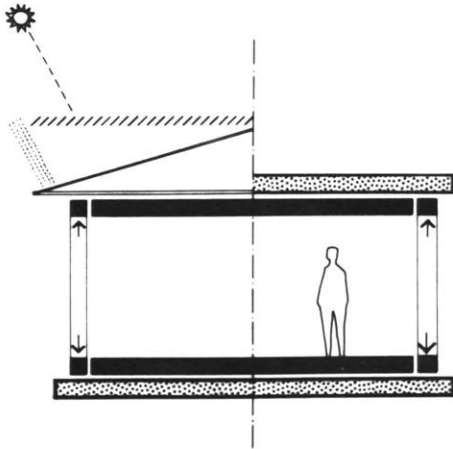
Horizontal and vertical service ducts form part of the permanent structures. Horizontal ducts lay out into at say 1.0m centres to which flexible service pipes from the individual boxes can be attached. Platforms may be erected by the lift slab technique and be made for example of concrete - in situ or precast - or beam steel as I.T.S., tubular metal space frame truss, plywood or polyester fibreglass box sections.

9 Structure



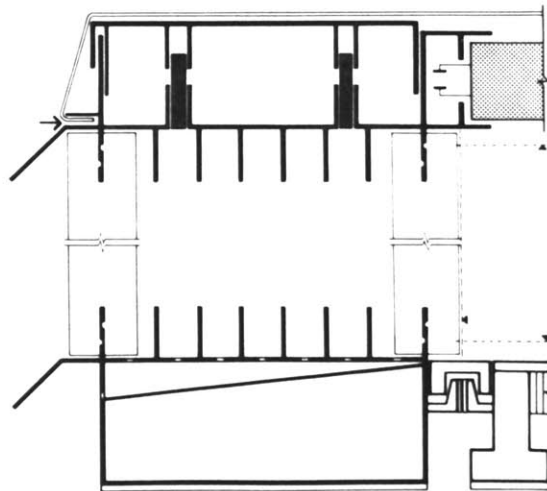
Single story structures may be placed on low platforms including the utility lines and are covered by a separate weather excluding cover. Suggested materials are, for the structure, tubular steel; for the rain-proof cover, a taut transparent polyester sheet such as Mylar D, and for the sun shield, wooden or metal slats, bamboo or aluminum thread cloth.

10 Structure



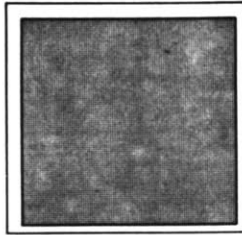
Floor, ceiling and screening elements are identical for single and multi-story buildings. In each case they rest independently on a structural platform and are pressed against the upper and lower surfaces of the structure.

11 Structure



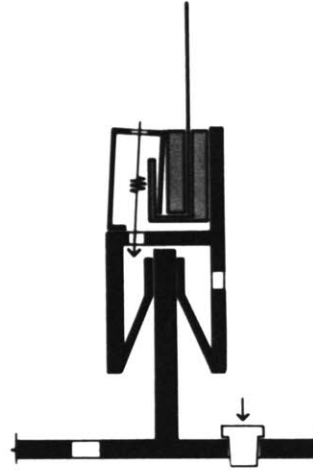
Outer screening is in the form of sliding doors. These move on the lower six upper and lower tracks. The two outer tracks carry columns which support the ceiling. The floor is wedged against the lower track box, the ceiling tensioned to the upper. A second box section fits within the upper track box and is pushed upwards to wedge the screening plane against the permanent structure. A water-proof membrane, which should be transparent in single story structures, covers the ceiling and is made taut as the two upper boxes are pushed apart.

12 Screening



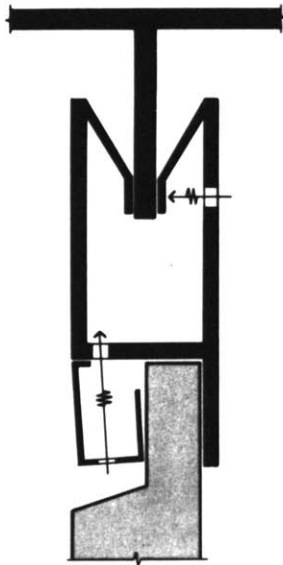
In elevation sliding screens are symmetrical about the diagonal so that they may be used either way up. The deep groove must be placed uppermost so that screens may be inserted by raising them sufficiently for the lower groove to clear the bottom track. Screen materials should be lightweight to make sliding easy. For transparency a polyester sheet could be used, for insect proofing and sunshading woven bronze wire or plastic coated cloth, and for openness and heat insulation a glass fibre filled honeycomb sandwich.

13 Screening



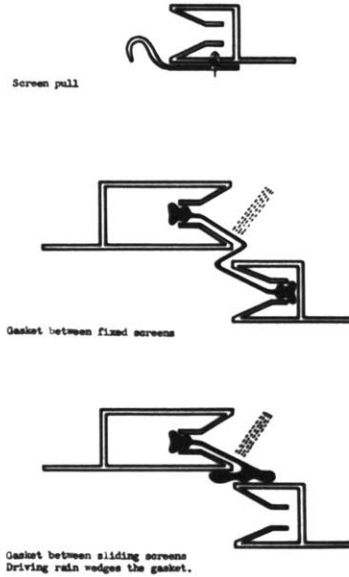
The full size section through the narrow groove shows a transparent sheet such as "Nylar D" being kept taut by the rocker-LT-70 glazing bead patented and used by Steelbilt, Inc. Spring action weather stripping against the track excludes draughts and driving rain. Deep holes in the lower track box on the inside of the screen are stopped with rubber corks unless permanent ventilation is desired.

14 Screening



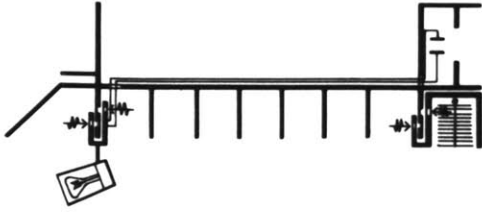
The full size section of the deep groove shows a solid insulating panel kept in place by the same glazing bead. If screens are not to slide they may be screwed to the track. This is also intended to provide part of the wind bracing.

15 Screening



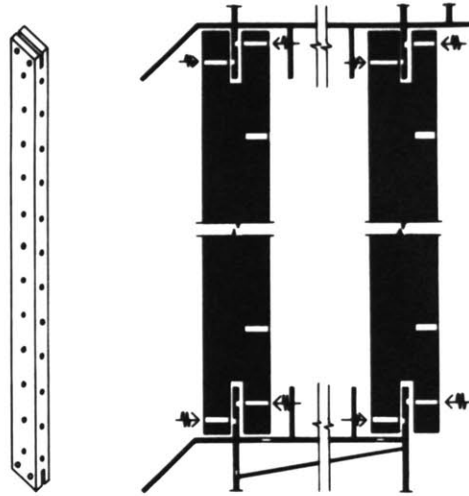
Gasket between sliding screens
Driving rain wedges the gasket.

16 Screening



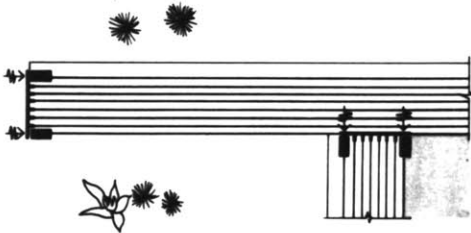
Outdoor lighting units may be screwed to the upper track. Outlets at 6'0" centres are provided in the upper track box and are connected to the ring circuit. Ventilation blinds, curtains or shades may be screwed to the inner track.

17 Screening

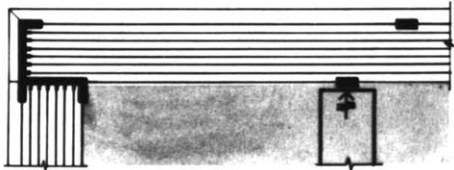


Columns to carry the ceiling load are screwed to the inner and outer tracks and position the upper and lower track boxes vertically. Columns are tapped at predetermined positions to allow of various attachments.

18 Screening

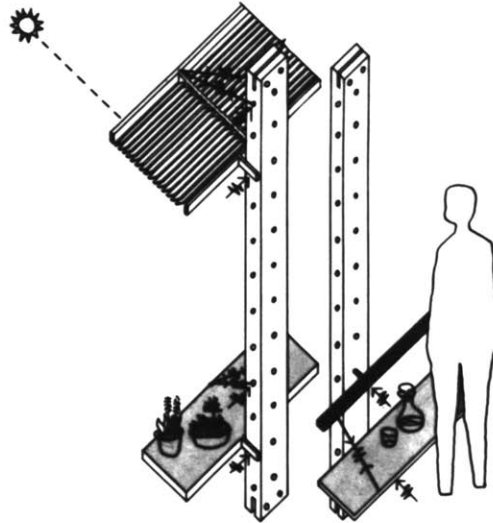


Screens may slide past the corner of a building so as to open inner spaces completely and to enclose outdoor ones. Closures are screwed to columns.



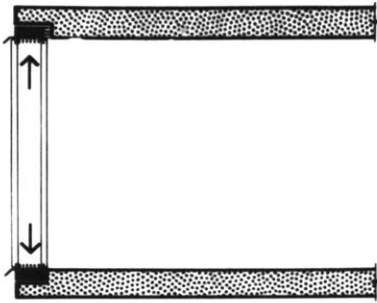
Corner columns join tracks at internal and external corners which are identical. Cupboards may be attached to the inner face of internal columns. External and internal columns need not line up.

19 Screening



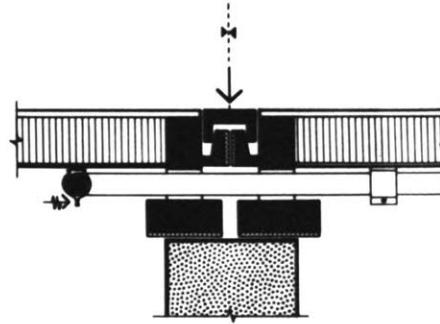
Louvers and flower sills may be attached to external columns; handrails and shelves to internal ones. Handrails are to be provided where transparent screening goes to the floor in tall structures.

20 Screening



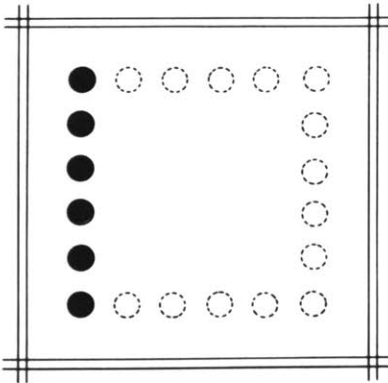
Where no finished floor or ceiling is required, the outer screening may be used alone. In addition to the wedging of the screening panels against the structure some mechanical fixing should be provided to account for suction due to wind loading.

21 Screening



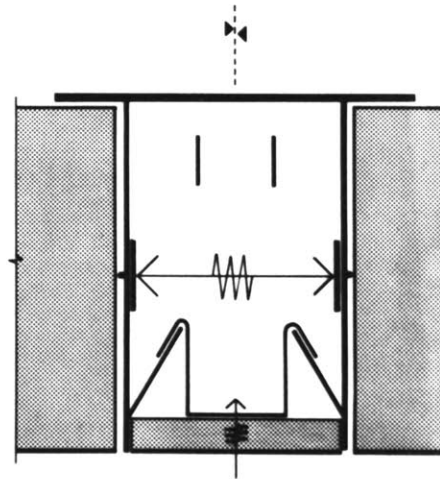
Floor panels are wedged to each other and rest on the structural platform. Flexible service pipes - possibly silicone plastic - are clipped to their lower surfaces. Suggested materials for the floor are resin bonded plywood on resin impregnated paper honeycomb.

22 Floor



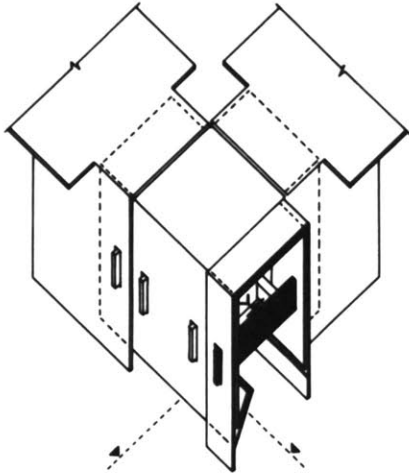
Floor panels are 3'4" x 3'4" or 6'8" x 6'8". Special 3'4" x 3'4" panels are drilled to take service outlets. Panels may be rotated within the grid so as to give more planning flexibility. Units such as kitchen cupboards, shower cabins, toilets etc. have service outlets at positions identical to those in the floor panel over which they are placed.

23 Floor



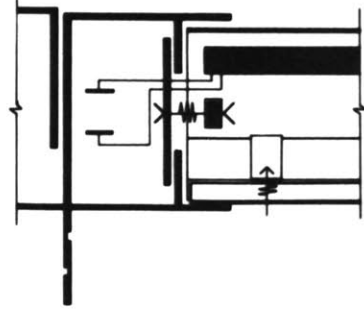
Ceiling panels, 3'4" x 3'4" or 6'8" x 6'8", are held in position by being thrust against by a compression fitting in the extrusion. Panels are of an extremely lightweight rigid material such as foamed styrene or Lee cyanide. Their lower surfaces may be lined with paper, wood veneer or fabric. Panels provide heat insulation and, unless, some interstitial sound absorption. Continuous electric wiring is provided in the extrusion.

24 Ceiling



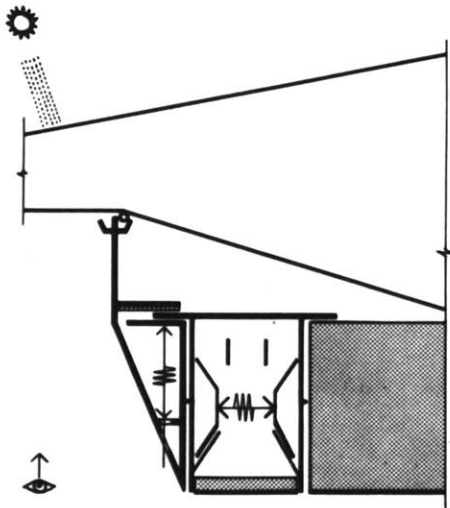
Lengths of ceiling extrusion are joined by telescopic junction boxes. Extrusions are tensioned to each other by tightening two bars slipped into the ends against a spring or rubber mounting held between them. Similar junctions are made in the track boxes of the outer screening.

25 Ceiling



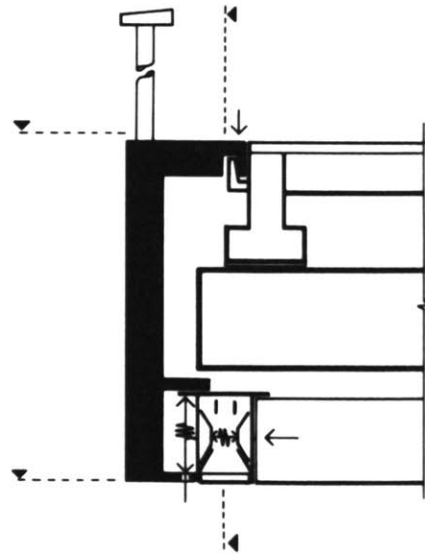
The ceiling extrusion fits within the inner end of the upper track box. It is tensioned to it by tightening two bars at right angles to each other against a spring fitting. The ring electrical circuit is joined to the ceiling wiring.

26 Ceiling



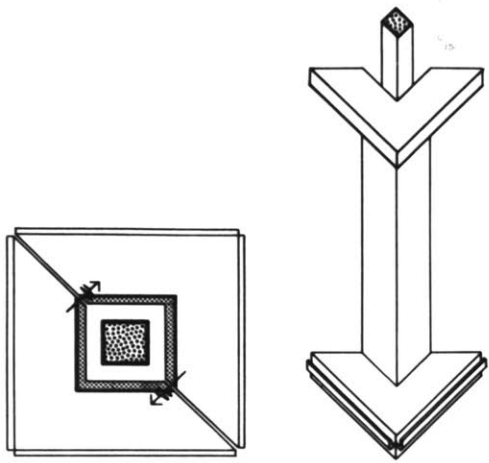
Openings in the ceiling of single storey buildings are trimmed by a section which by pushing on the lower waterproof membrane produces a tight surface. A condensation channel and a gasket mounting are provided.

27 Ceiling



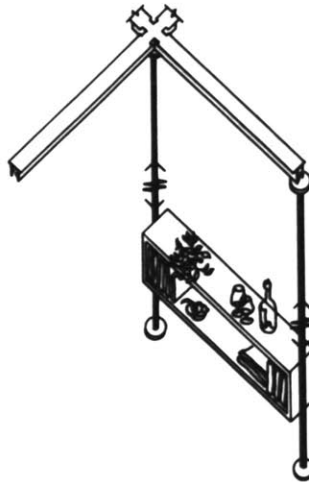
Openings between ceiling and floor are trimmed by a section which is pressed to the ceiling extrusion and wedged to the end of the floor panel. Clearance between it and the structural slab allows for dimensional tolerances. A gasket mounting is provided.

28 Ceiling



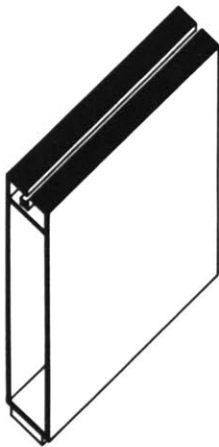
Columns of the platform structure are encased by a continuous floor to ceiling unit fitting within a 3 1/4" x 3 1/4" panel. The casing, lined with sound absorbing material, stands clear of the column so as not to transmit structure borne sound and to allow for dimensional tolerances. The two parts of the casing are screwed to each other. A number of opening sizes are provided to account for different column dimensions.

29 Ceiling



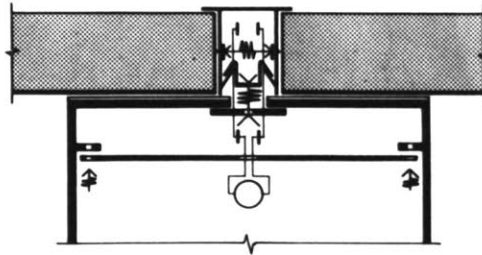
If the ceiling span increases beyond 10'0" in either direction unsupported by doors or cupboards as shown in diagrams 32 and 33, tubes pressing against floor and ceiling must be inserted. Tubes have left and right hand threads at one end which when turned pushes the round discs against floor and ceiling. Tubes may be inserted anywhere along the ceiling extrusion and may be coupled up to carry furniture fittings.

30 Ceiling



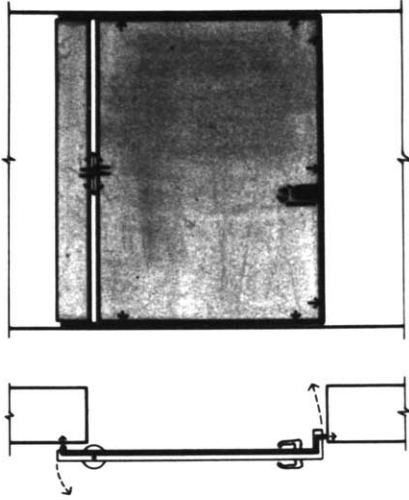
Cupboards, including kitchen units, have on their upper surface a continuous opening to permit their attachment to the ceiling extrusion. All space divisions where sound isolation is required are made by cupboard units which alone have mass and rigidity. Cupboards are tensioned to the ceiling which they help to support and to which they provide lateral wind bracing. They are also tensioned to the floor when placed over standard service outlets.

31 Equipment



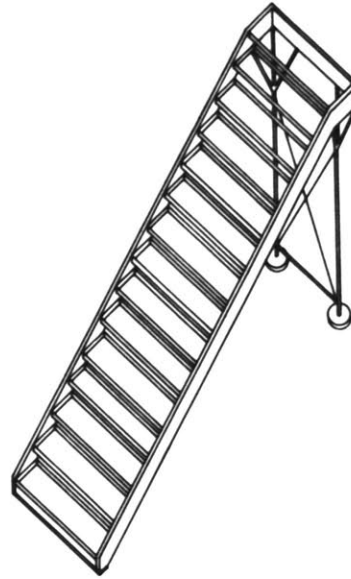
Cupboards are tensioned to the ceiling by tightening a bar against the ceiling extrusion. The ceiling electrical circuit is joined to the cupboard wiring. Cupboards, having only point contacts with the ceiling, need not be placed on floor and ceiling grid lines and may run at any angle provided they straddle one or more module lines.

32 Equipment



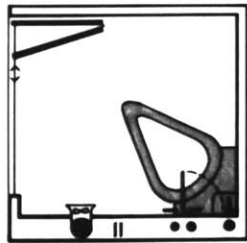
Doors are pivot hinged and free standing to allow for dimensional tolerances. The piston is in the shape of a tube pressed against the floor and ceiling, similar to that shown in diagram 30. The door is edged by a small rubber tube filled with compressed air. When the door handle is closed it presses against a piston which increases pressure in the ring tube and thus tightens the door against surrounding surfaces.

33 Equipment



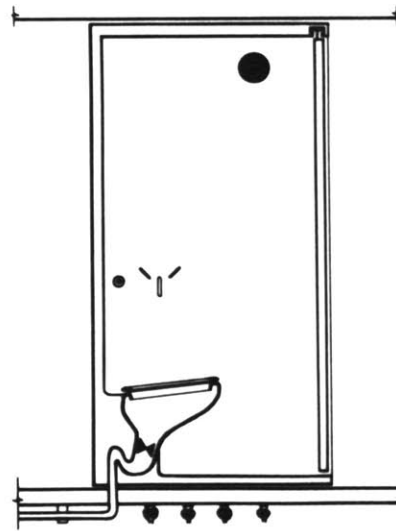
Stairs are free standing and self supporting elements only attached to floor and ceiling in a manner similar to the section shown in diagram 26. Treads have frames only so that various types of treads - wood, metal, carpet covered, etc. - may be inserted. Circular stairs fitting within a 60" x 60" square are also provided.

34 Equipment



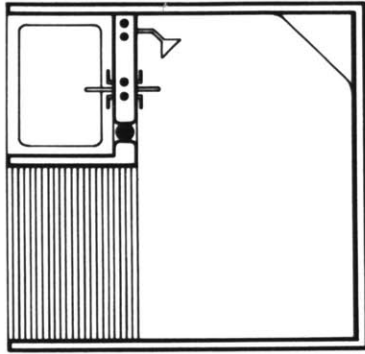
Toilet cabinets are 30" x 30" in plan. Folding sliding doors turning inwards are provided so that the cabinet may be an independent unit. A swiveling faucet above the toilet bowl is included for handwashing. Ventilation is entirely artificial and is by a high velocity exhaust fan using a smooth continuous 2" diameter tube. The fan works in conjunction with the light switch.

35 Equipment



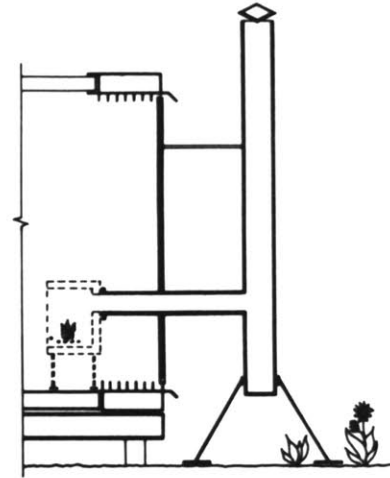
The toilet cabinet is attached to the standard service outlets of a 30" x 30" service type floor panel and may also be used to join the ceiling electric circuit to the main supply lines below the floor. The toilet bowl includes a water operated grinder and is similar to the bowl made by McPherson Inc., Chicago. Sewage may be disposed through a 1" diameter tube.

36 Equipment



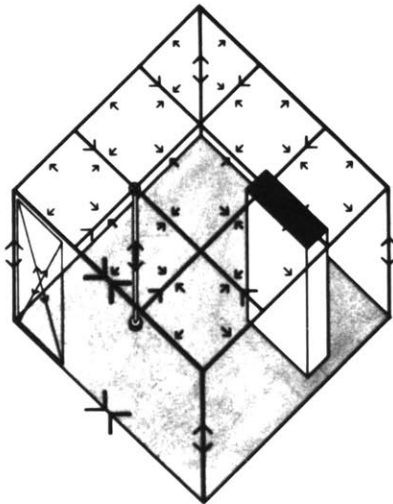
The shower and washbasin unit is a self contained element 5'0" x 5'0" in plan. The unit includes a high velocity fan and is attached to the floor service lines like the toilet cabinet. The shower floor measures 5'7" on the diagonal, and may be used as a bath. Forced hot air for drying purposes is provided below the slatted floor.

31 Equipment



An outer screen with a standard fire opening to take any kind of fireplace may be placed between the track boxes. The outside chimney is supported on an adjustable telescopic tripod and is staged to the panel.

36 Equipment

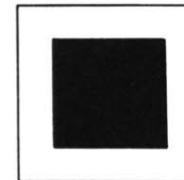


Floor and ceiling are rigid planes ring tensioned. They are kept apart by columns on the screen tracks and by tubes pressing against the upper and lower surfaces. Lateral wind resistance is given by rigid panels between the tracks and by rigid outboard units tensioned to floor and ceiling. The traced box thus created is then pressed against the upper and lower permanent structure.

39 Assembly



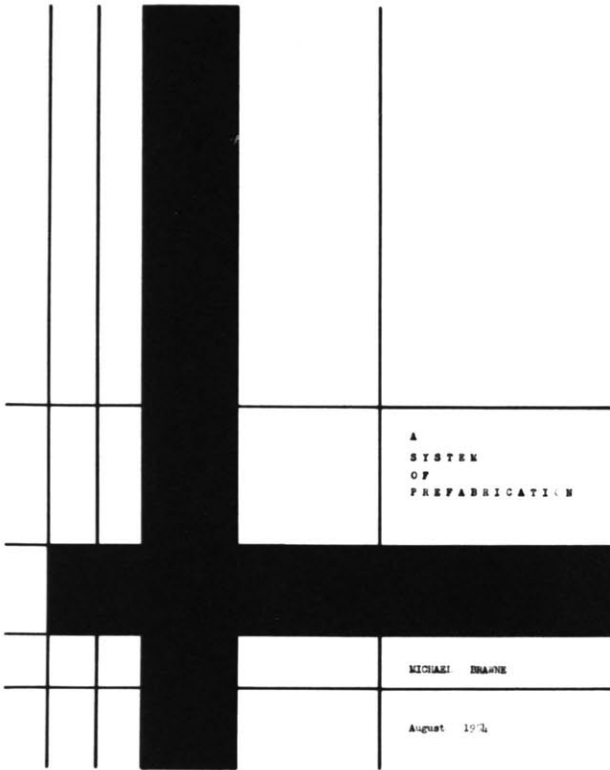
Diagrammatic plan and section of building in temperate zone



Diagrammatic plan and section of building in tropical zone

Adaptation to different climatic regions is made by altering the form of the building in plan and section. The same elements are used in both cases only their distance apart is made to vary. Where the distance is large a more gradual transition can be achieved. Extremes of climate are controlled by mechanical air conditioning.

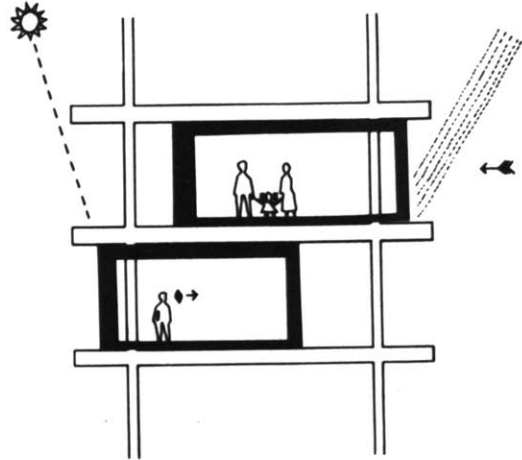
40 Climate



A
SYSTEM
OF
PREFABRICATION

MICHAEL BRAUNE

August 1974



This system deals with industrially produced components. Assembled these will provide variable shelter. The components form only the immediate enclosures which are independent of each other. Each shelter is placed on a level structural platform on the ground or within a building which then becomes datum level for that shelter. It is further suggested that components be considered as movable personal property and that the platforms be part of the more permanent urban structure.

2. General



sun



wind



precipitation



view



pressure, e.g. wedge, compressed air



threaded fixing, e.g. screw, bolt



compression fixing, e.g. left and right hand threads



tension fixing, e.g. left and right hand threads



mechanical fan



mechanical grinder



electrical wiring



sliding motion

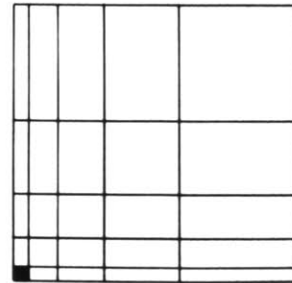


module line

3. Symbols

Fibonacci series :

1 2 3 5 8 13 21 34 ...



1'0" 3'1/4" 5'0" 8'0" 13'0"

Series I :

1'0" has been taken as the first term in this series

Screen sizes must conform to the rectangular dimensions outlined.

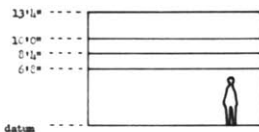
4. Module



Series II:

3'1/4" has been taken as the first term in this series

Screen sizes must conform to the rectangular dimensions outlined, 3'1/4" x 1'0" and 6'8" x 6'8" panels form the floor and ceiling grid.



Height dimensions are taken from both series

Floor and ceiling dimensions are multiples of 3'1/4" thus :

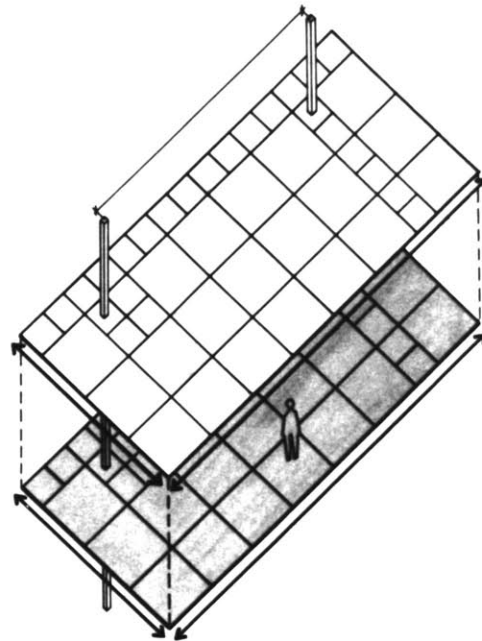
3'1/4" 6'8" 10'0" 13'1/4" 16'8" 20'0" . . .

floor and ceiling are always ringed by a track 1'0" wide so that screening

dimensions are floor dimensions or floor dimensions plus 1'0" thus :

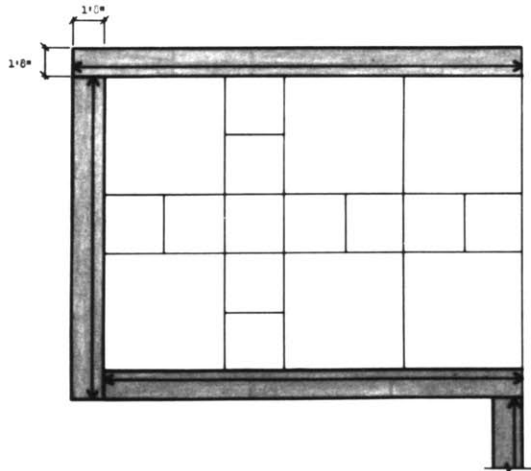
5'0" 8'1/4" 11'0" 13'1/4" 16'8" 20'0" . . .

5 Module



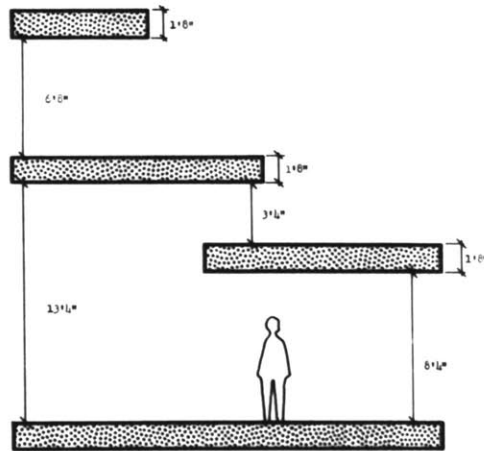
Floor and ceiling grids are identical. Dimensions that are multiples of 3'1/4" in both directions can be formed by the addition of 6'8" and 3'1/4" squares. Centre lines of the supporting structure of the permanent platforms must also be dimensioned that are multiples of 3'1/4".

6 Module



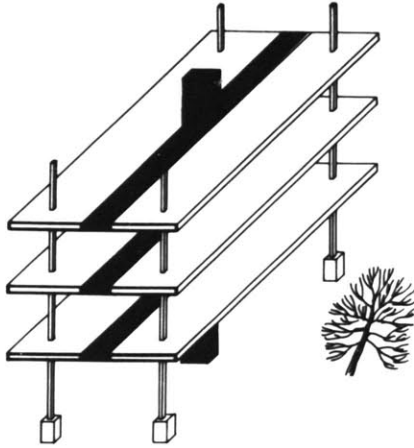
Screening is outside the floor and ceiling grid and always slides on a track 1'0" wide. Tracks form turbling junctions at corners and track lengths are always floor dimension or floor dimension plus 1'0".

7 Module



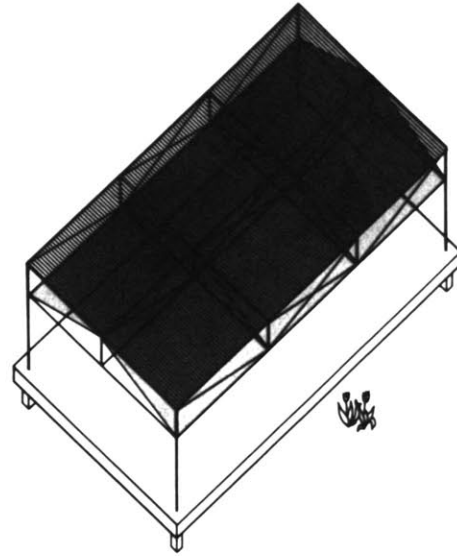
Floor thickness is 1'0" between ceiling and floor module to allow for variation in structural slab depth.

8 Module



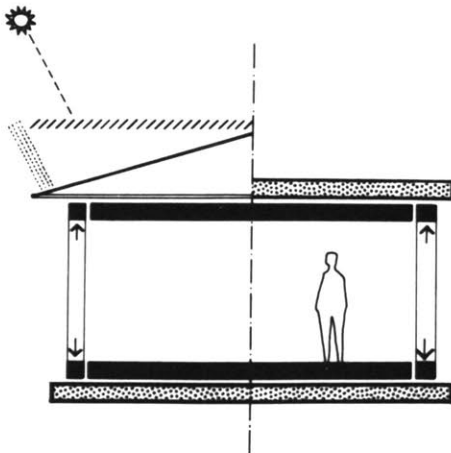
Horizontal and vertical service ducts form part of the permanent structures. Horizontal ducts have outlets at say 10'0" centres to which flexible service pipes from the individual homes can be attached. Platforms may be erected by the lift slab technique and be made for example of concrete - in situ or precast - I beam steel skeleton, tubular metal space frame trusses, plywood or polyester fibreglass box sections.

9 Structures



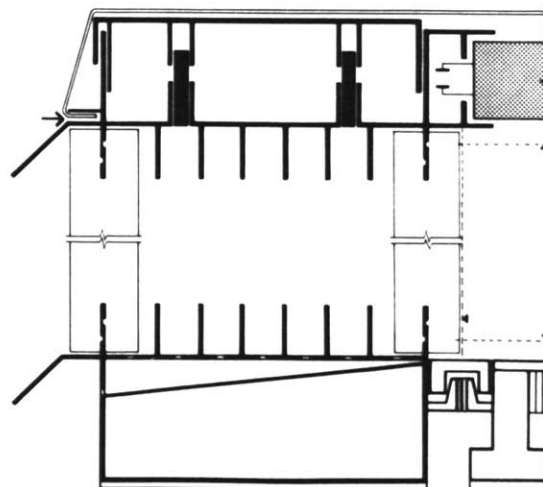
Single story structures are placed on low platforms including the utility lines and are covered by a separate weather-excluding cover. Suggested materials are, for the structure, tubular steel, for the rain-proof cover, a taut transparent polyester sheet such as "Mylar D", and for the sun shield, wooden or metal slats, bamboo or aluminum thread cloth.

10 Structure



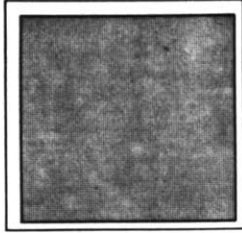
Floor, ceiling and screening elements are identical for single and multi-story buildings. In each case they rest independently on a structural platform and are pressed against the upper and lower surfaces of the structure.

11 Structure



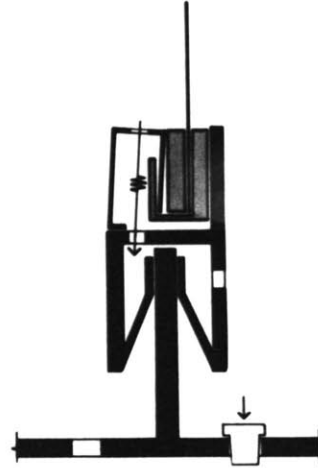
Outer screening is in the form of sliding doors. These move on the inner six upper and lower tracks. The two outer tracks carry columns which support the ceiling. The floor is wedged against the lower track box, the ceiling tensioned to the upper. A second box section fits within the upper track box and is pushed upwards to wedge the screening plane against the permanent structure. A water-proof membrane, which should be transparent in single story structures, covers the ceiling and is made taut as the two upper boxes are pushed apart.

12 Screening



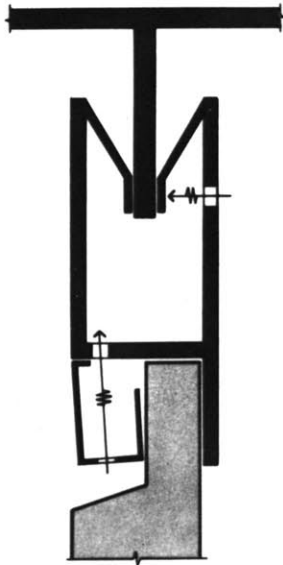
In elevation sliding screens are symmetrical about the diagonal so that they may be used either way up. The deep groove must be placed uppermost so that screens may be inserted by raising them sufficiently for the lower groove to clear the bottom track. Screen materials should be light-weight to make sliding easy. For transparency a polyester sheet could be used, for insect proofing and sunshading woven bronze wire or plastic covered cloth, and for openness and heat insulation a glass fibre filled honeycomb sandwich.

13 Screening



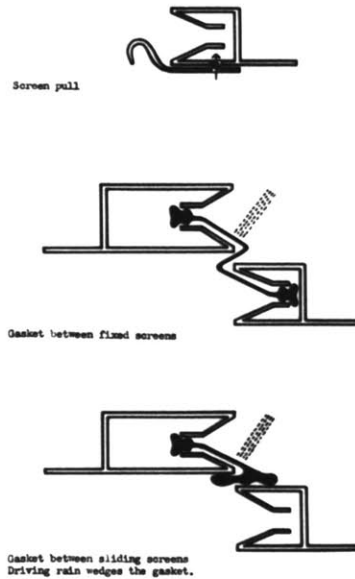
The full size section through the narrow groove shows a transparent sheet such as "Mylar D" being kept taut by the rocker-type glazing bead patented and used by Steelbilt, Inc. Spring action weather stripping against the track excludes draughts and driving rain. Deep holes in the lower track box on the inside of the screen are stopped with rubber corks unless permanent ventilation is desired.

14 Screening



The full size section of the deep groove shows a solid insulating panel kept in place by the same glazing bead. If screens are not to slide they may be screwed to the track. This is also intended to provide part of the wind bracing.

15 Screening

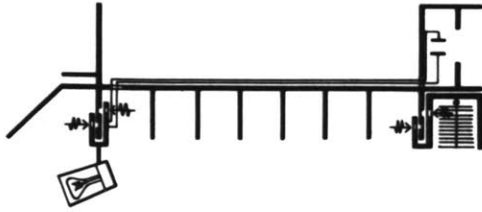


Screen pull

Gasket between fixed screens

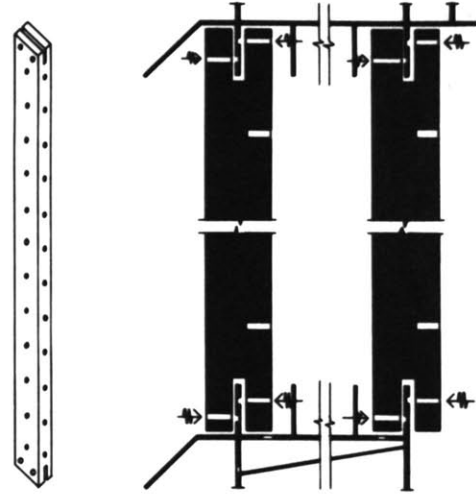
Gasket between sliding screens
Driving rain wedges the gasket.

16 Screening



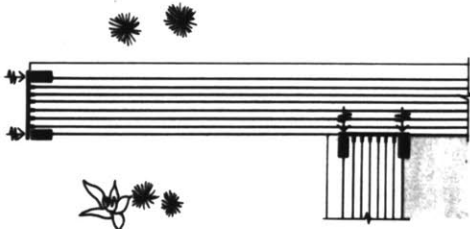
Outdoor lighting units may be screwed to the upper track. Outlets at 6" centres are provided in the upper track box and are connected to the ring circuit. Venetian blinds, curtains or shades may be screwed to the inner track.

17 Screening

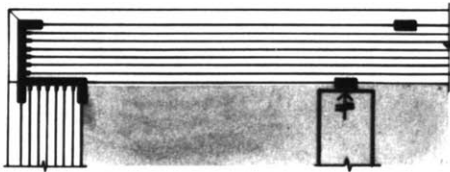


Columns to carry the ceiling load are screwed to the inner and outer tracks and position the upper and lower track boxes vertically. Columns are tapped at predetermined positions to allow of various attachments.

18 Screening

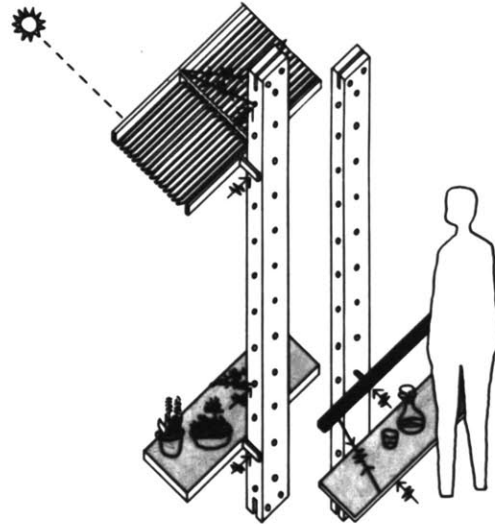


Screens may slide past the corner of a building so as to open inner spaces completely and to enclose outdoor ones. Closures are screwed to columns.



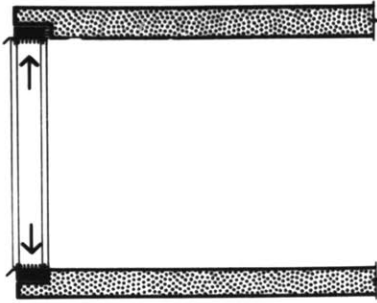
Corner columns join tracks at internal and external corners which are identical. Outboards may be attached to the inner face of internal columns. External and internal columns need not line up.

19 Screening



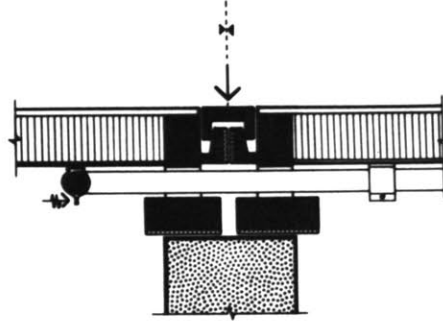
Louvres and flower sills may be attached to external columns, handrails and shelves to internal ones. Handrails are to be provided where transparent screening goes to the floor in tall structures.

20 Screening



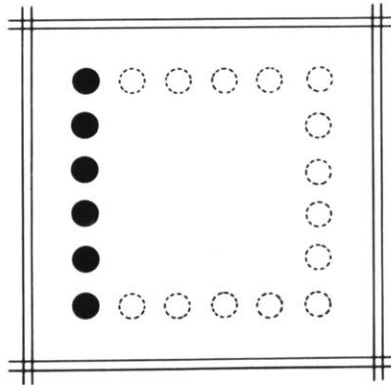
Where no finished floor or ceiling is required, the outer screening may be used as one. In addition to the wedging of the screening panel against the structure some mechanical fixing should be provided to account for suction due to wind loading.

21 Screening



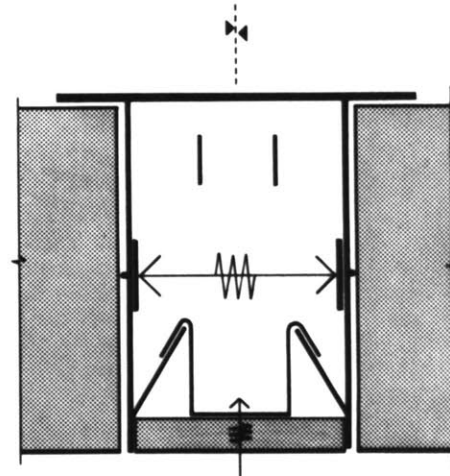
Floor panels are wedged to each other and rest on the structural platform. Flexible service pipes - possibly silicone plastic - are clipped to their lower surfaces. Suggested materials for the floor are resin-bonded plywood or resin-impregnated paper honeycomb.

22 Floor



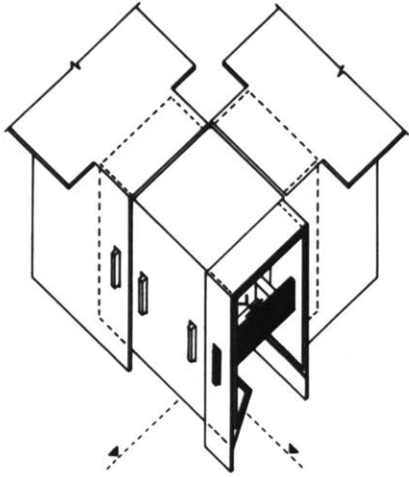
Floor panels are $3\frac{1}{2}'' \times 3\frac{1}{2}''$ or $6\frac{1}{2}'' \times 6\frac{1}{2}''$. Special $3\frac{1}{2}'' \times 3\frac{1}{2}''$ panels are drilled to take service outlets. Panels may be rotated within the grid so as to give more plugging flexibility. Units such as kitchen cupboards, shower cabinets, toilets etc. have service outlets at positions identical to those in the floor panel over which they are placed.

23 Floor



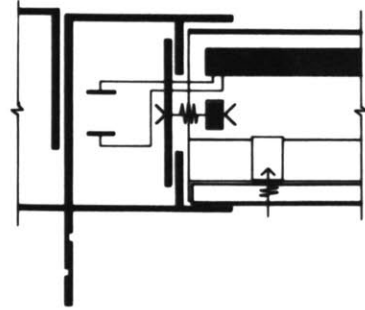
Ceiling panels, $3\frac{1}{2}'' \times 3\frac{1}{2}''$ or $6\frac{1}{2}'' \times 6\frac{1}{2}''$, are held in position by being thrust against by a compression fitting in the extrusion. Panels are of an extremely light-weight rigid material such as foamed styrene or iso cyanide. Their lower surfaces may be lined with paper, wood veneer or fabric. Panels provide heat insulation and, unlined, some interstitial sound absorption. Continuous electric wiring is provided in the extrusion.

24 Ceiling



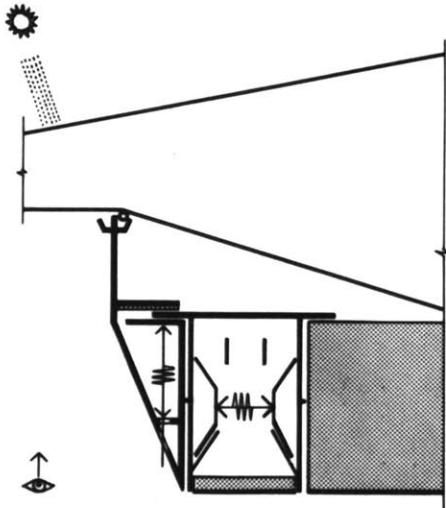
Lengths of ceiling extrusion are joined by telescopic junction boxes. Extrusions are tensioned to each other by tightening two bars slipped into the ends against a spring or rubber mounting held between them. Similar junctions are made in the track boxes of the outer screening.

25 Ceiling



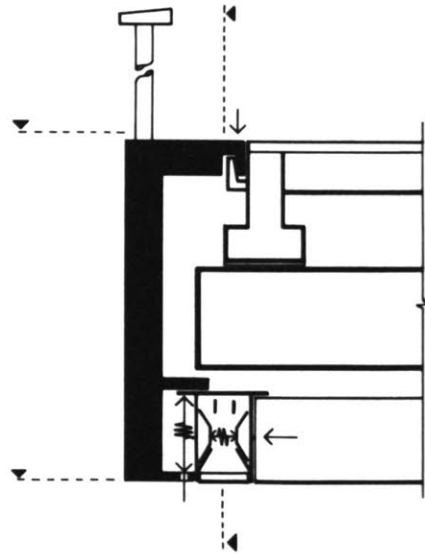
The ceiling extrusion fits within the inner end of the upper track box. It is tensioned to it by tightening two bars at right angles to each other against a spring fitting. The ring electrical circuit is joined to the ceiling wiring.

26 Ceiling



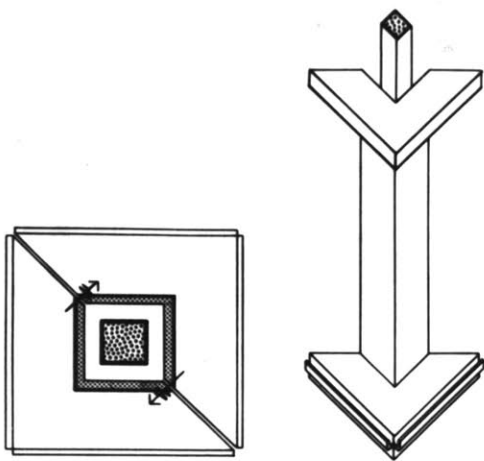
Openings in the ceiling of single storey buildings are trimmed by a section which by pushing on the lower waterproof membrane produces a tight surface. A condensation channel and a gasket mounting are provided.

27 Ceiling



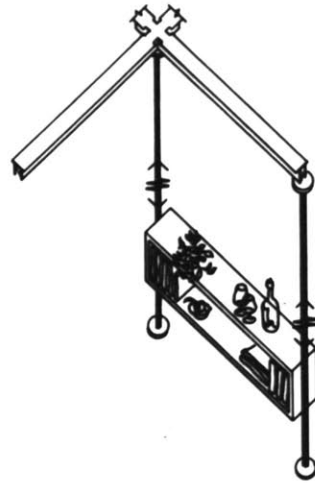
Openings between ceiling and floor are trimmed by a section which is pressed to the ceiling extrusion and wedged to the end of the floor panel. Clearance between it and the structural slab allows for dimensional tolerances. A handrail mounting is provided.

28 Ceiling



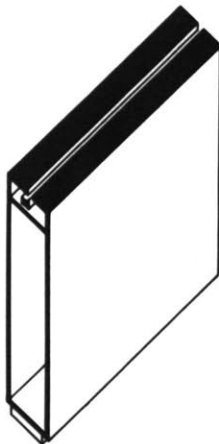
Columns of the platform structure are encased by a continuous floor to ceiling unit fitting within a "12" x 12" pane. The casing, lined with sound absorbing material, stands clear of the column so as not to transmit structure borne sound and to allow for dimensional tolerances. The two parts of the casing are screwed to each other. A number of opening sizes are provided to account for different column dimensions.

20 Ceiling



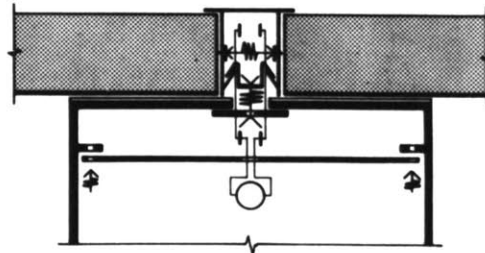
If the ceiling span increases beyond 1'-0" in either direction unsupported by doors or cupboards as shown in diagrams 32 and 33, tubes pressing against floor and ceiling must be inserted. Tubes have left and right hand threads at one end which when turned pushes the round discs against floor and ceiling. Tubes may be inserted anywhere along the ceiling extrusion and may be coupled up to carry furniture fittings.

30 Ceiling



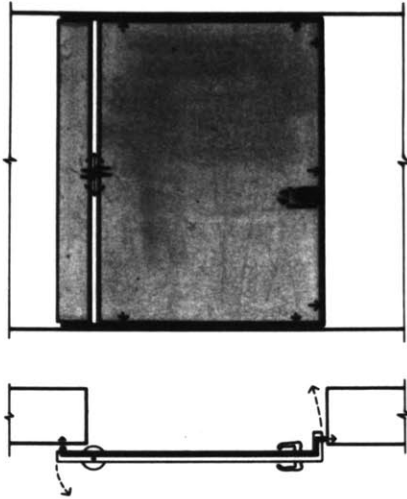
Cupboards, including kitchen units, have on their upper surface a continuous opening to permit their attachment to the ceiling extrusion. All space divisions where sound isolation is required are made by cupboard units which alone have mass and rigidity. Cupboards are tensioned to the ceiling which they help to support and to which they provide lateral wind bracing. They are also tensioned to the floor when placed over standard service outlets.

31 Equipment



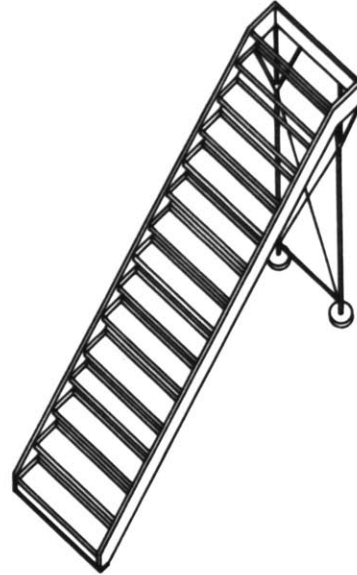
Cupboards are tensioned to the ceiling by tightening a bar against the ceiling extrusion. The ceiling electrical circuit is joined to the cupboard wiring. Cupboards, having only point contacts with the ceiling, need not be placed on floor and ceiling grid lines and may run at any angle provided they straddle one or more module lines.

32 Equipment



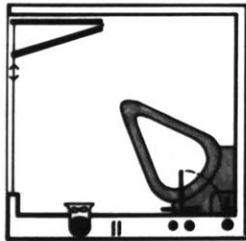
Doors are pintle hinged and free standing to allow for dimensional tolerances. The pintle is in the shape of a tube pressed against the floor and ceiling, similar to that shown in diagram 30. The door is edged by a small rubber tube filled with compressed air. When the door handle is closed it presses against a plenum which increases pressure in the ring tube and thus tightens the door against surrounding surfaces.

33 Equipment



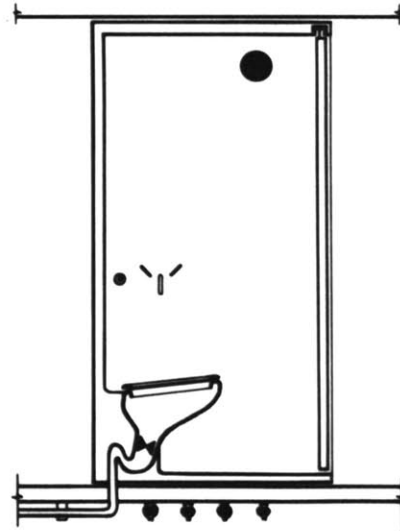
Stairs are free standing and self supporting elements only attached to floor and ceiling in a manner similar to the section shown in diagram 28. Treads have frames only so that various types of treads - wood, metal, carpet covered etc. - may be inserted. Circular stairs fitting within a 6'6" x 6'6" square are also provided.

34 Equipment



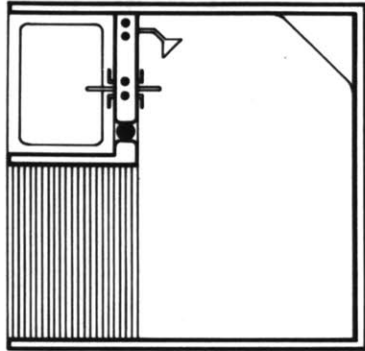
Toilet cabinets are 3'1/2" x 3'1/2" in plan. Folding sliding doors turning inwards are provided so that the cabinet may be an independent unit. A revolving faucet above the toilet bowl is included for handwashing. Ventilation is entirely artificial and is by a high velocity exhaust fan using a smooth continuous 2" diameter tube. The fan works in conjunction with the light switch.

35 Equipment



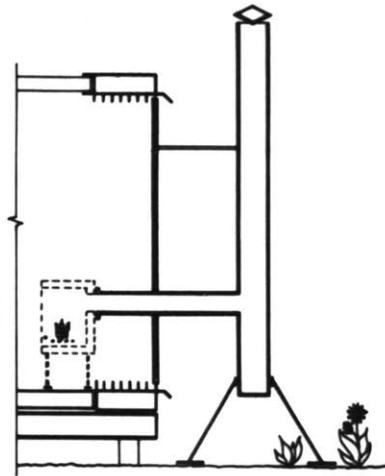
The toilet cabinet is attached to the standard service outlets of a 3'1/2" x 3'1/2" service type floor panel and may also be used to join the ceiling electric circuit to the main supply lines below the floor. The toilet bowl includes a water operated grinder and is similar to the bowl made by McPherson Inc., Chicago. Sewage may be disposed through a 1" diameter tube.

36 Equipment



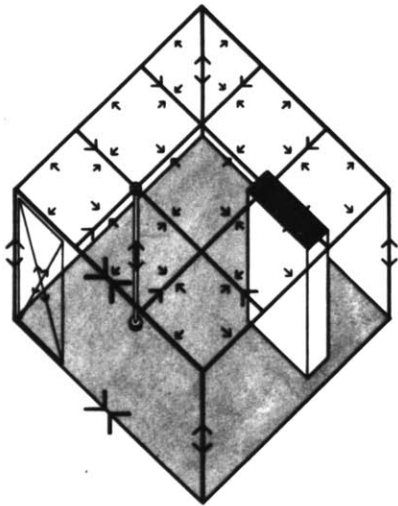
The shower and washbasin unit is a self contained element 5'0" x 5'0" in plan. The unit includes a high velocity fan and is attached to the floor service lines like the toilet cabinet. The shower floor measures 5'0" on the diagonal and may be used as a bath. Forced hot air for drying purposes is provided below the slatted floor.

37 Equipment



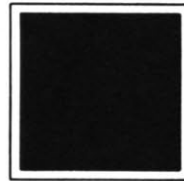
An outer screen with a standard fire opening to take any kind of fireplace may be placed between the track boxes. The outside chimney is supported on an adjustable telescopic tripod and is stayed to the panel.

38 Equipment

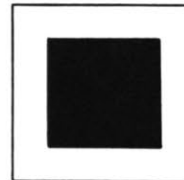


Floor and ceiling are rigid planes ring tensioned. They are kept apart by columns on the screen tracks and by tubes pressing against the upper and lower surfaces. Lateral wind resistance is given by rigid panels between the tracks and by rigid outboard units tensioned to floor and ceiling. The braced box thus created is then pressed against the upper and lower permanent structure.

39 Assembly



Diagrammatic plan and section of building in temperate zone



Diagrammatic plan and section of building in tropical zone

Adaptation to different climatic regions is made by altering the form of the building in plan and section. The same elements are used in both cases; only their distance apart is made to vary. Where the distance is large a more gradual transition can be achieved. Extremes of climate are controlled by mechanical air conditioning.

40 Climate