

A Typology of Building Forms

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Abstract. Buildings are usually classified according to their function, structural system or building materials. A classification of buildings according to their forms has not received sufficient attention. This is partly due to the extreme difficulty of such a task. All the few attempts that have been made to classify buildings according to their form, suffer from serious shortcomings. In this present attempt, I have found it necessary to study both the abstract forms of buildings and the types of their exterior surfaces, in order to arrive at a meaningful classification scheme for building forms. A matrix of 8 types of forms and 12 types of surfaces results into 96 possible building forms. Currently there may not exist examples of every different possible form, but the classification scheme provides a useful framework for studying building forms that could be useful for students and practitioners of architectural design.

Introduction

Buildings have been classified in many different ways, depending on the nature of the study, and the purpose of the classification. In building type studies, for example, buildings are classified according to their functions. The purpose of building type studies is to compare the methods by which different architects have responded to similar client needs (building task), under different economic, social, technical and site constraints. Hospitals are studied together, and so are schools, houses, office buildings, stadiums and so on. The differences in the design approach among the designers can be very instructive.

Students of structure, on the other hand, classify buildings according to their structural systems, differentiating between load bearing wall systems, post and beam construction,

cable structures, thin shell structures, etc. Similarly, those interested in the mechanical aspects of buildings could possibly classify them according to the type of air-conditioning system used. Architectural historians have found it useful to classify buildings according to 'styles' i.e., common physical characteristics that tend to predominate in certain regions, during particular historical periods. A typical historical classification of buildings may include for example: Ancient Near Eastern, Greek, Roman, Early Christian, Byzantine, Islamic, Romanesque, Gothic, Renaissance, and Modern. Each one of these may be further classified into a number of secondary styles to take account of the large degree of variation within each style.

All of these classification methods are very valuable for the understanding of different aspects of architecture. However, one aspect that has not received its full share of attention from architectural theoreticians is the aesthetics of building appearance and the visual impact a building has on the observer. Architectural form has been discussed by countless architectural theoreticians, from the Roman times until the present. However, no systematic effort has been made, to my knowledge, to classify buildings primarily according to their visual impact on the outside observer.

A reasonable question could be posed in this regard: What is the usefulness of building form classification scheme that could justify such efforts? One obvious benefit would be to expose the readers, whether they are students or practicing architects, to the full variety of building forms that they could consider while designing their buildings. A systematic exposure would help them consider additional alternatives to the ones they are habituated to use through force of habit or lack of exposure. As in the case with all scientific inquiry, breaking down a complex phenomenon into a number of components is of great value for understanding the phenomenon. Hence, classifying building forms will certainly be a useful tool for analyzing building forms and understanding the various factors that differentiate one building form from another.

In this paper we shall first review the literature related to form classification. Next we shall discuss the concept of form complexity and the factors that contribute to form complexity. Building form is discussed next and the factors affecting complexity of building form: surface factors and form factors. Finally, we shall construct the proposed classification of building form based on the interaction of surface factors and form factors.

Review of Literature

Many authors have written on architectural aesthetics and architectural form. Some of the well known writers who discussed architectural form include the Roman theorist Vitruvius [1] who in 40 BC wrote the first surviving work on architectural aesthetics, Alberti [2] who lived during the Renaissance period and was greatly influenced by Vitruvius, Ruskin [3] whose work appeared in the middle of the 19th century. Among

modern authors one can point out Scott [4], Zevi [5], Arnheim [6], Rasmussen [7], Gaudie [8], Scruton [9], to name only a few. Most books on architectural aesthetics tend to be commentaries on various visual aspects of architecture, such as scale and proportion, rhythm, texture, light and color and the effect of projections and cavities. Architectural form is usually discussed in relation to these elements.

On the other hand, very few authors have attempted to arrive at a typology of building forms. The few authors who wrote on the subject tended to concentrate on abstract form, that is, the form of any three dimensional object regardless of the material it is made of or the uses it is put to. Buildings, however, have much more complicated forms because of the variety of building materials used and the different ways of combining them and because building form classification is due to many reasons, most important of which is the extreme complexity of the subject matter. It is very difficult to devise a classification scheme in which any building, from a simple shelter to an intricate multistory building, can be logically and easily categorized purely from a visual point of view.

One notable illustration is Ching [10] who attempted a rather elaborate form classification scheme. He differentiates between regular and irregular forms and later classifies architectural form into three main categories: platonic solids, additive forms, and subtractive forms. Platonic solids are simple shapes such as the sphere, the cylinder, the cone, the pyramid, and the cube. Additive forms result from adding simple forms together, while subtractive forms are regular forms from which parts have been taken out. He further breaks down additive forms into five categories: (1) centralized forms which require the visual dominance of geometrically regular, centrally located forms such as sphere, cylinder, or polyhedron, (2) linear forms which are a series of forms arranged along a line; (3) radial forms which are linear forms that extend from a centrally located core element in a radiating manner; (4) clustered forms which are a group of forms attached together in different ways; and (5) grid forms which are repetitions of identical forms along a grid plan.

While the above classification scheme is useful as a general outline, it is not refined enough to take into account the significant differences among the variety of building forms covered by each of the above categories. The effect of surface treatment on the overall appearance of buildings is not given sufficient consideration in this scheme. In addition this scheme is not exhaustive, i.e. many building forms are not included in this classification. For example, a building such as a Pompidou Center would not fit into any of the categories of this scheme. Furthermore, Ching's classification scheme seems to be based on the horizontal projection of the building (floor plan), while the visual impact of a building on the viewer is not strongly linked to its floor plan, since an observer can see only a portion of the exterior mass of the building at any one moment. A passerby will probably be unable to tell whether a building has a 'clustered form' or a 'centralized form.'

Martinssen [11] classified buildings into the following categories:

1. The cave, e.g. Egyptian temples carved in rock hill-sides,
2. The crystal, e.g. monuments such as the Egyptian pyramid and the Greek Doric temple,
3. Tunnel and tube, e.g., Romanesque churches,
4. The post (e.g. towers) and the pit (e.g. wells, graves)
5. The box and the cage (most buildings are boxes. They could be cylindrical or polygonal sided, or in fact any convenient geometrical form or combinations of forms, but the interior shape must be deduced from the exterior appearance, p. 67)
6. Cages, (a Greek temple is a box within a cage).
7. The hive (free form enclosure such as huts, domed churches) and honeycomb (modern buildings with repetitive units),
8. The cell and cluster (non-geometric design, e.g. Ronchamp chapel).
9. Scaffold and skeleton, e.g. gothic churches.
10. Bridges (e.g. Ponte Vecchio in Venice) and barricades (fortresses, prisons, monasteries).
11. The tent and the canopy, e.g., geodesic hemisphere, tents, timber-vaulted churches, hangers and sport stadiums.

This classification also does not appear to be systematic. Many different categories of building are grouped under the heading Box, while the same building (Doric temple, for example) is classified simultaneously as a cage and a crystal.

A more recent attempt at the classification of building form is offered by Krier [12]. He starts from 18 basic forms (Fig. 1) which results from the intersection of three primary building types and six primary architectural forms. He then subjects these forms to 5 operations to arrive at 90 different forms. These operations are (1) kinking, bending, (2) dividing and breaking, (3) segmentation, fragmentation (Fig. 2), (4) addition, stringing together, accumulation, stacking, layering, and (5) penetration, superimposition, interweaving. As in the previous classification schemes, the main concern here seems to be the layout of the building and not the visual impact of the building on the outside observer. This is evident from the sketches which Krier uses to illustrate the different types of building forms. Forms A1 and C1 in Fig. 2, for example, are likely to be seen as similar forms by an outsider who does not see the interior layout of the building. The same observation can be said of forms A3 and C3, A5 and C5. It seems that Krier uses 'building form' to mean building internal layout.

Theories of perception would seem to be relevant to the study of factors that affect the way we see different forms. There are many theories of perception, perhaps the most relevant for the perception of architectural form is the Gestalt theory. Norberg-Schulz [13] work is an attempt to apply Gestalt theory to the perception of architectural form. It suffices to say Gestalt theory emphasizes pattern recognition, as a full exposition of this theory is beyond our concern here. Commenting on the speculative nature of perception

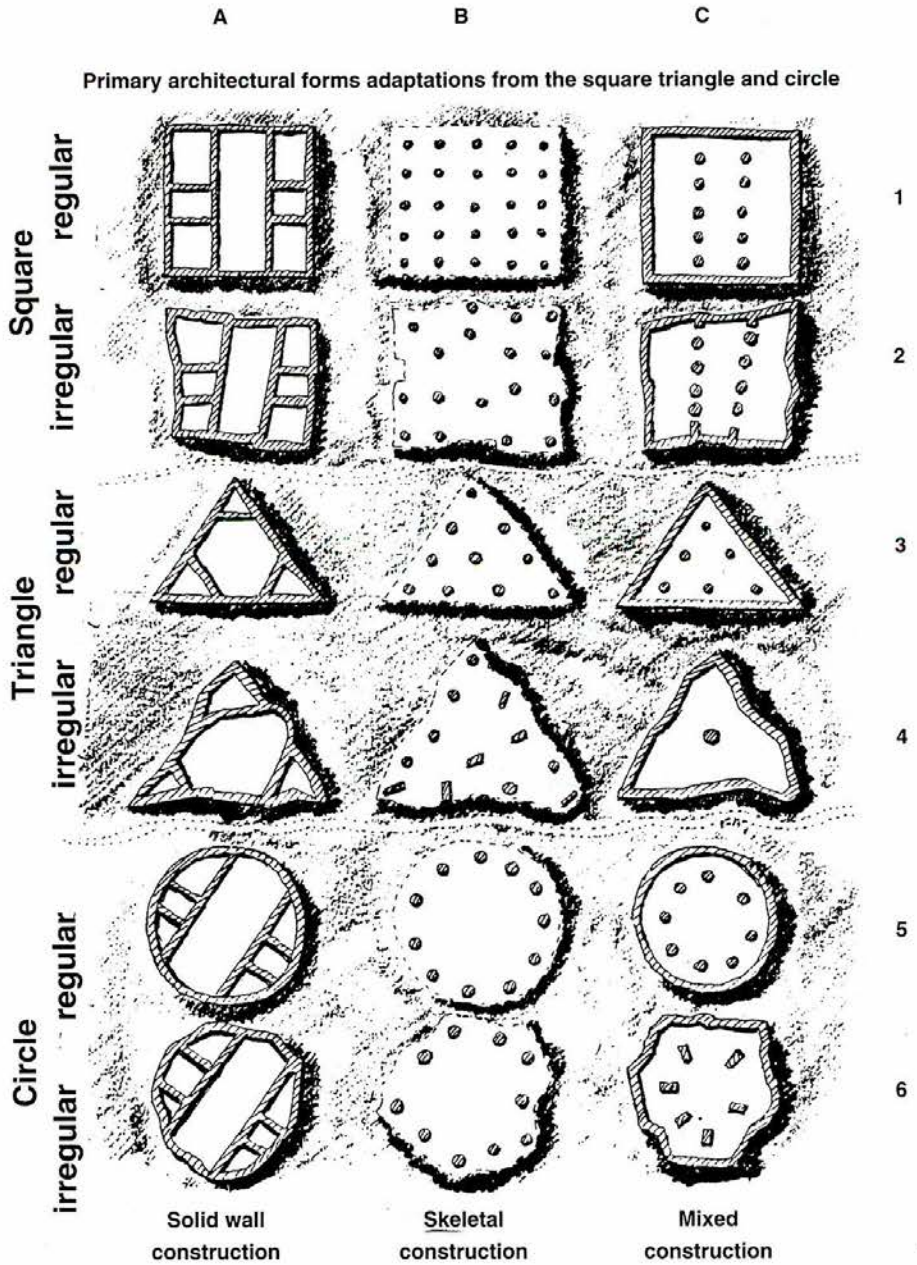


Fig. 1. Theoretical examples of primary building types, according to Krier [12, p. 56].

Primary architectural forms adaptations from the square, triangle and circle

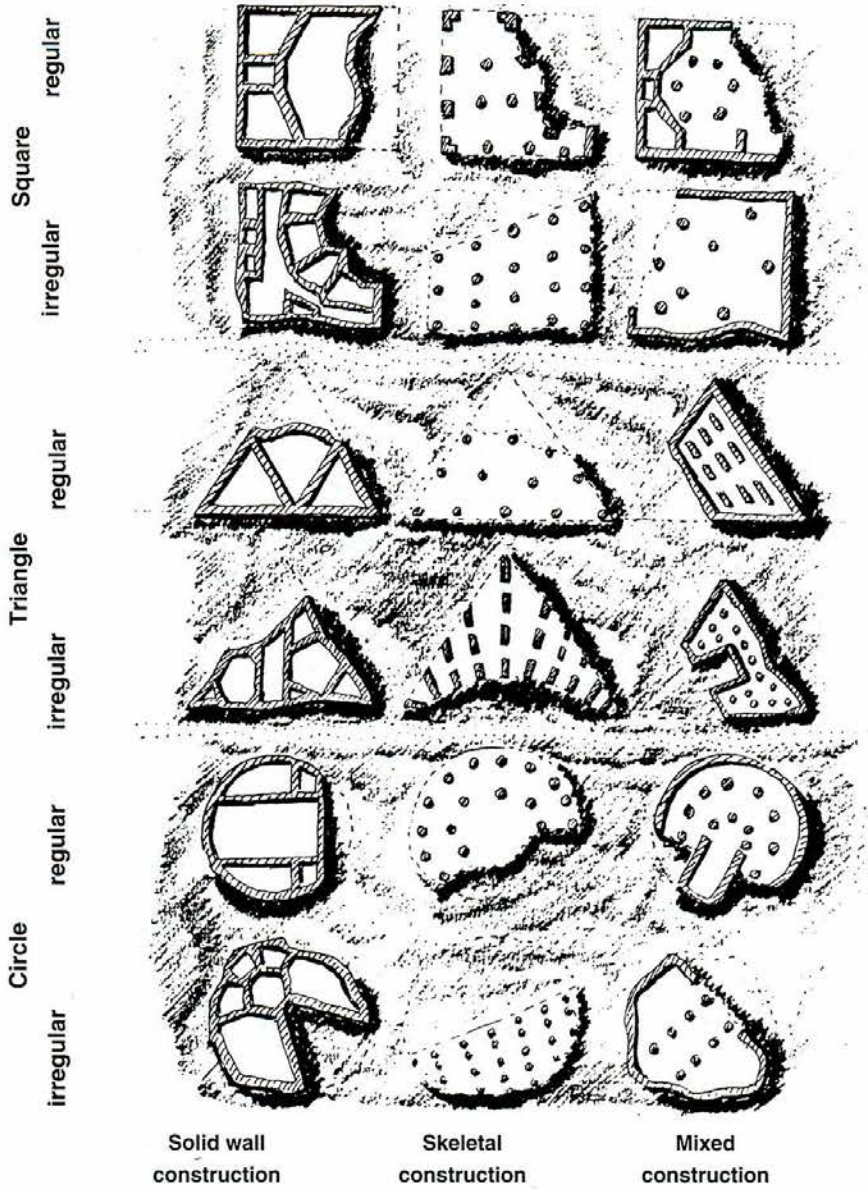


Fig. 2. Theoretical examples of building fragments, according to Krier [12, p. 62].

theories Lang [14] writes that the coexistence of contradictory theories of perception shows the conjectural nature of our understanding of the perceptual processes. There are, however, a number of matters on which there is agreement. Perception is multimodal; movement plays a major part in environmental perception; we learn to differentiate finer details and broader classes of environmental phenomena with experience; the Gestalt laws of visual organization may not be the basis of perception, but they may well be ways in which we order the environment; the Gestalt concepts of *field forces* and *isomorphism* and thus the architectural concepts of the universality of *expressiveness* of lines and planes are open to serious question, and the way in which we look at the environment depends on our purposes and experience. In summary, theories of perception as they exist now have some relevance to perception of building form but they are by no means definitive and easy to apply.

Complexity of Form

Before examining building form, we can arrive at some useful observations regarding abstract form, particularly the factors that affect its complexity. Complexity of form refers to the difficulty of comprehension of the form as perceived by the average observer. It is affected by two main factors: (a) the degree of the observer's familiarity with the form, and (b) the amount of visual information a form presents to him or her. A cube might appear to most observers as being less complex than a tetrahedron (triangular pyramid), even though it has more surfaces and therefore more lines and vertices than a tetrahedron. This is because people interact more with boxes than with pyramid-shapes in their daily life. The difficulty of comprehending a form, on the other hand, increases with the increase in the amount of visual information that it presents to the observer. When people are equally familiar with two forms, the one that presents more visual information (i.e., greater number of surfaces, lines, vertices, textures, colors, details) will require from them greater mental effort for it to be comprehended.

We can group the factors that affect the complexity of abstract form into two main categories: factors relating to the two dimensional aspects of form (i.e., qualities of its surfaces), and factors relating to the three-dimensional aspect of the form (i.e. the way it occupies space).

Two dimensional factors

The two dimensional factors affecting complexity of the form include the degree of flatness of the surfaces that make up the form, the amount of visual information (details, patterns, colors, textures) that is present in these surfaces, and the degree of similarity among the surfaces of the form.

The degree of flatness of the surfaces

A flat surface is generally simpler than a curving one, all other factors being equal. This is because it is easier to see a flat surface than a curving one. Also the play of light

and shade on a curving surface is likely to be more intricate than that on a flat surface. Curvature increases the amount of interest that a surface presents to the observer, making it more complex than a flat surface. In addition, a surface with many projections and/or voids will present more visual information to the viewer than a flat surface.

Surface details, patterns, colors and textures

A sphere whose surface is decorated with some geometric pattern, will appear to be more complex than a sphere painted in one color with no decoration. Color can add interest to a surface. Thus, the larger the number of colors present in a surface, the greater the visual stimulation it offers and the more complex the form is. Similarly, a textured surface will contain more visual information than a smooth surface and will therefore appear more complex.

The degree of similarity among the surfaces of a form

Suppose we have two forms, one with identical sides and one with different sides. The form with identical sides will appear less complex since it offers less visual information and requires less mental effort to comprehend the form.

Three dimensional factors

The three dimensional factors affecting the complexity of form relate to the number of surfaces that a form has, the number of identifiable sub-forms present in the form, their individual complexity and the manner in which sub-forms are combined.

The number of surfaces in the form envelope

The greater the number of surfaces in form's envelope, the greater the amount of information it offers to the observer. The number of surfaces also affects the number of edges (lines where surfaces meet) and vertices (points where lines intersect). As such, the more surfaces a form has, the more visual information it contains, and the more complex it becomes.

The number and complexity of sub-forms

When we have two forms in proximity but physically separated by space, we shall consider them two distinct forms. However, when they are physically combined, they form a single form, consisting of two sub-forms. A form becomes more complex as the number of its sub-forms increases. Similarly, the complexity of the form increases with the complexity of its individual sub-forms.

Methods of combining sub-forms

The cube and the cylinder, for example, can be combined in many different ways. They can share a point, a line, or a plane, or a volume (becoming interlocked). Each of these combinations affects the complexity of the form in a different way. In addition, interlocking of forms can be done in so many different ways, each having a different impact concerning the overall complexity of the form. If the major axes of the two

sub-forms are parallel the level of the complexity is slightly lower than it would be if they are not. The magnitude of interlocking is another factor. The greater the volume shared by the two sub forms, the less identifiable they become, until a point is reached where the resulting form cannot easily be traced back to its original sub-forms. A form of this type is difficult for the observer to relate to his mental repertoire of forms and is therefore perceived to be complex.

Complexity of building form

Let's turn now to the more specific topic of building form. In addition to the factors outlined above which affect the complexity of any form, there are specific factors that affect the complexity of building form. They relate to the delineation of outside space and inside space. Before we dwell on these factors, however, we shall first define what we mean by "building". A building is a structure whose primary function is to provide shelter from the elements for humans or for their properties, regardless of the functions that actually take place inside. For our purposes, a building must have some part of it visible above ground. This excludes a shelter that is totally underground. To simplify our task, we shall also exclude buildings whose shape is meant to resemble a specific object for advertising or anecdotal purposes, such as buildings in the shape of shoes or hamburgers and the like.

Up to now, we have been considering abstract forms whose visible envelope is made of solid two dimensional surfaces. Building envelopes, however, are rarely completely solid, since they must contain openings for lighting and ventilation. Even in cases where the windows are inoperable, natural light from outside the building penetrates it through the glazing. There is a certain degree of spatial inter-penetration between a building and the space surrounding it. The greater the inter-penetration of inside and outside space the more difficult it is to perceive the form. The boundaries between the building and the outside can be blurred in many ways. The factors that influence the delineation of outside space and the spaces contained by the building envelope are numerous. They include: the degree of physical enclosure, the amount of glazing and the degree of transparency of glass, wall recessions and projections, and the use of non-enclosing elements as a building envelope.

The degree of physical enclosure

Buildings come in a wide range of physical enclosure. On one extreme there are buildings with no walls at all. An example of this type is Pilgrims Terminal at King Abdulaziz Airport in Jeddah (Fig. 3). Here, the roof is the only space defining element. Other examples include shaded car parks and green markets. Some buildings have walls on three sides only; one side (or more) is left without a wall. Sport stadiums belong to this group and so do many bus shelters. One can also mention enclosures, such as cattle enclosures, that have walls but do not have a roof. Most buildings, however, are roofed and fully enclosed from all sides.

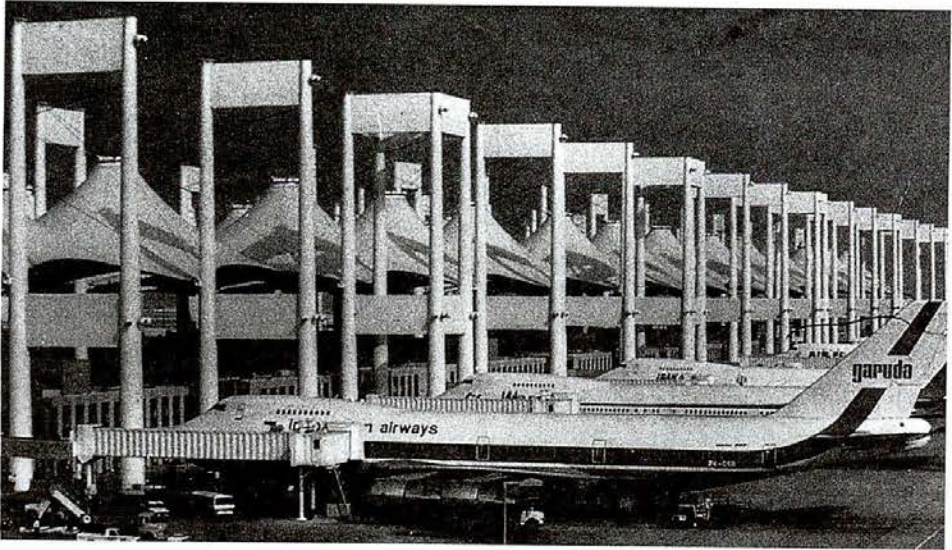


Fig. 3. Haj Terminal, King Abdulaziz Airport by SOM [21].

The amount of glazing, and the degree of transparency of glass

Unlike other building materials, glass allows light rays to penetrate it, thus permitting people outside a building to see through the glass wall into the inside of the building and vice versa. This inter-penetration has a profound effect on the visual impression a building leaves on the outside observer. The degree of visual inter-penetration depends on the ratio of glass areas to the total area in the walls, the level of transparency of the glass used, and the difference in lighting level between the inside and the outside of the building, as well as the presence of curtains, screens and shading devices in the walls.

Wall recessions and projections

Sometime the walls of a building are partially projected or recessed to add interest to the exterior of the building. The lower floor of some buildings is recessed to provide some protection to the passerby from the elements. The necessity of supporting the upper floors requires, in some cases, the existence of a colonnade in the ground floor. The columns of the colonnade offer a partial definition of *outside* and *inside* space.

Non-enclosing elements as a building's envelope

There are buildings, whose visible envelope is not made up of planes. One notable example is the Pompidou Center in Paris. Here, the visible envelope is dominated by linear elements such as pipes, struts, conduits, and the like. In some buildings the visible envelope is dominated by free standing planes that do not contribute to enclosing spaces. They are like a freestanding sculpture.

Typology of building forms

It can be argued that building form results from the interaction of two main factors. The first factor is the overall three dimensional form of the building (i.e. whether it is a box or a cylinder or a combination of the two, for example). The second factor is the type of building envelope, i.e., enclosing surfaces that separated the inside from the outside and define the form (if the walls are solid or in relief, glazed, textured, etc.). These two factors are responsible for creating the overall visual impact that a building has on the observer. Therefore, by studying the interaction of form and building envelope we can arrive at a reasonable typology of building forms. In section 5.1 we shall attempt to classify building envelope types, then in section 5.2 we will study types of form and finally in section 6 we will try to synthesize the two and arrive to a typology of building form.

Types of building envelopes

A building's envelope is usually composed of the roof, the walls and the floor. The floor is normally hidden from the eyes of the outside observer except in the buildings that are raised on stilts from the ground. Similarly, the roofs of many buildings are not visible to the passerby. Hence, in the majority of buildings, the walls are visually the most dominant part of the building envelope.

We can classify building envelopes into two main types: wall dominated and roof dominated. The first type is the most common. In this type of building envelope (e.g. buildings with flat roofs), the walls are the most visible part of the building. The roof does not play a significant role in the overall visual impact of the building because it is partially or completely hidden from the sight of the passerby below. A building can have all its walls of the same character or it can have walls of different characters. Of course, the larger the number of walls types that a building has, the more complex its building envelopes becomes.

In the second type, the roof dominates the building and is visually prominent. Here, we can distinguish three different cases. In the first one, the building has no walls at all (e.g., canopies such as the Hajj terminal in Jeddah airport). In the second case the building is partially enclosed either because there are no walls in one or more of the building facades or because the walls do not reach all the way to the ceiling (Fig. 4). In the third case the building is fully enclosed but the roof is visually very dominant because it is huge in comparison with the walls, largely projects over the walls and/or if more elaborately detailed than the walls (Fig. 5).

Walls can be classified into five main categories with regard to their exterior appearance: (1) solid walls, (2) transparent walls (usually built of glass or other transparent materials), (3) recessed walls, composed of surfaces at different levels, some recessed in relation to others, (4) walls dominated by non-enclosing elements, and (5) composite walls (composed of two or more of the above wall types). Chart 1 summarizes types of building envelopes while the following sections explain walls types.

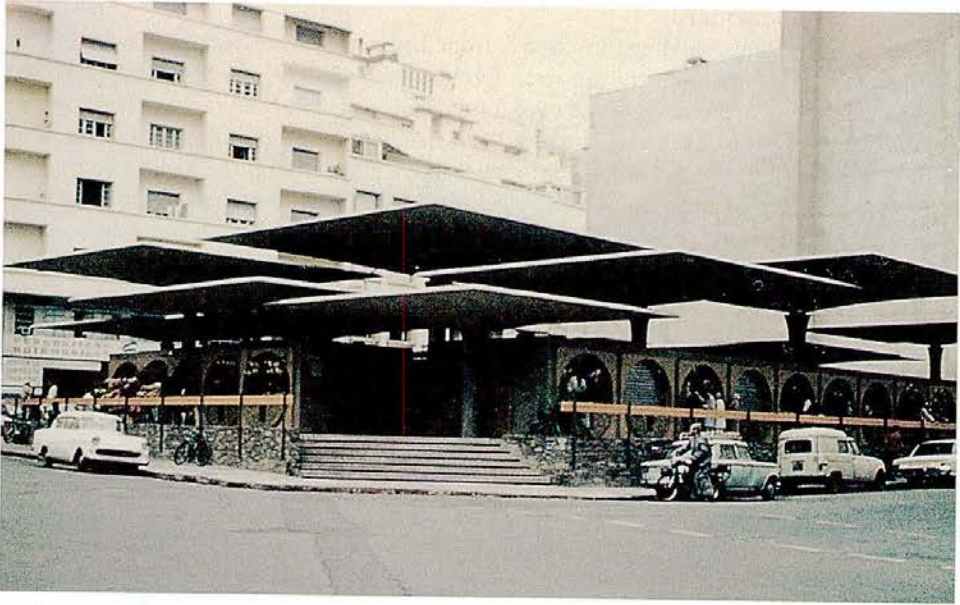


Fig. 4. An example of roof dominated building, partial enclosure: A vegetable market in Casablanca, Morocco.



Fig. 5. An example of roof dominated building, full enclosure: Sharja (UAE) Post Office building.

Chart 1: Envelope types

1-	Wall dominated	
1-1-	Solid	
1-1-	Flat	
1-1-1-	Plain	
1-1-2-	Textured	
1-2-	Relief	
1-2-	Recessed planes	
1-3-	Transparent	
1-4-	Dominated by non-enclosing elements	
1-5-	Composites	
1-5-1-	Solid/Glass	
1-5-2-	Solid flat/Solid relief	
1-5-3	Solid flat plain/Solid flat textured	
2-	Roof dominated	
2-1-	No walls	
2-2-	Partial enclosure	
2-3-	Complete enclosure	

Solid walls

A large majority of buildings have a simple interface with the surrounding space. They have perpendicular walls with few openings for windows and little or no recessions or projections. These buildings have flat walls. A flat wall could be plain if it does not contain much surface ornament or it could be textured, if it contains ornaments whether in the form of painted, patterned, or inscribed patterns. What differentiates a patterned wall from a plain wall is the existence of greater amount of visual stimulation in the wall surface. We can distinguish three different sources of surface visual stimulation: (a) shade/light patterns produced by small projections and recesses as in the case of stone walls and brick walls, (b) patterns produced by edges and textures that do not project much from the wall, such as window frames, structural elements, brick and stone courses, and textures of different materials, (c) decorative patterns painted on the surface deliberately to provide visual stimulation.

When the textural treatment of the wall involves projections and recessions that create a relief we have a different effect from that produced by a textured wall. In this case we shall describe the type of wall as relief wall. Projections and/or recessions must be of minimum magnitude before a wall is perceived as a relief wall. Naturally, the proportion of the projections or recessions to the area of the wall is an important factor. It determines when projections and/or recessions of a certain magnitude cease to appear as a two-dimensional pattern and begin to take as a three-dimensional relief pattern. A 20 cm projection on the surface of 20 sq. meter wall is likely to be more noticeable than the same projection on 200 sq. meter wall.

Recessed walls

As the name implies, in this type of walls, the wall is an elevation is made up of several planes at different levels. This could be because some floors are projecting beyond others. Walls of the same floor can also be located at different levels because of functional or aesthetic reasons. An example of recessed walls is shown in Fig. 6.



Fig. 6. The Mausoleum of King Hassan II in Rabat, Morocco, an example of recessed walls.

Transparent walls

Glass walls usually look rather opaque from the outside during daytime. At night, however, they assume the appearance of a transparent wall when lit from the inside. During daytime they have a smooth reflective surface that reflects nearby buildings and could offer a glimpse of what is happening inside. At day or night transparent walls offer to the observer a different feel than that of solid walls.

Walls dominated by non-enclosing elements

In this case the wall itself is not clearly seen since it is covered from the outside with many non-enclosing elements in the form of lines or planes that do not enclose space. Non-enclosing elements could be structural members such as columns or beams (Fig. 7), mechanical fixtures such as pipes or conduits (Fig. 8), or purely ornamental elements that have no specific functions other than decoration (Fig. 9).

Composite walls

A composite wall is made up of different types of walls. Many combinations are theoretically possible. However, the most important combinations are the following:

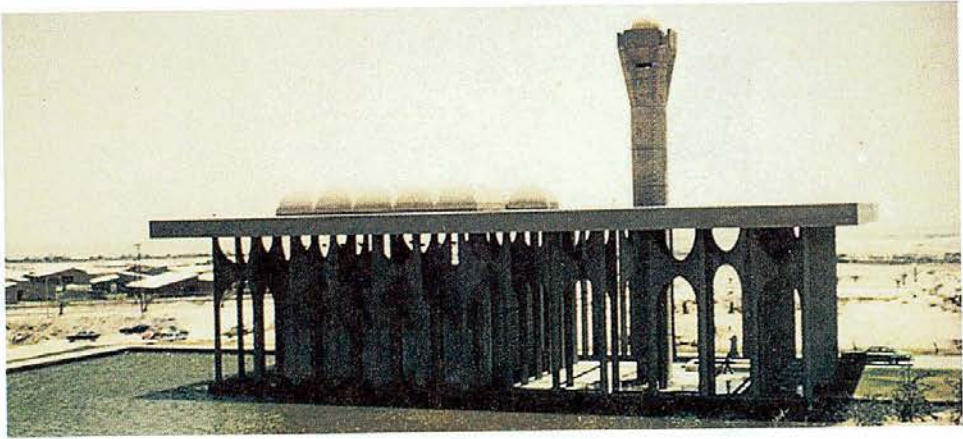


Fig. 7. The Mosque of King Fahad University for petroleum and Minerals, an example of walls dominated by structural non-enclosing elements.



Fig. 8. The Pompidou Center in Paris by Richard Rogers and Renzo Piano, a wall dominated by non-enclosing elements (mechanical and structural) [16, p. 375].



Fig. 9. A Buddhist Temple in Tokyo. The wall of the tower is dominated by the horizontal lines of the multiple roofs whose main function is ornament.

- A) Solid/glass: parts of the wall are glazed other are solid (Fig. 10)
- B) Solid flat/solid relief (Fig. 11)
- C) Solid flat plain/solid flat textured.

This wall exploits the aesthetic qualities of the contrast between plain wall and textured wall. Traditional Moroccan architecture takes great advantage of this contrast. (Fig. 12)

Types of form

We can classify forms into four main categories: rectilinear form, curvilinear form, composite form, and organic form. Rectilinear form can be further subdivided into single, multiple and combined. Curvilinear forms can also be classified into three similar categories. Composite form, on the other hand, can be one of several possible combinations. Chart 2 shows the different types of forms, while the following sections explain them.

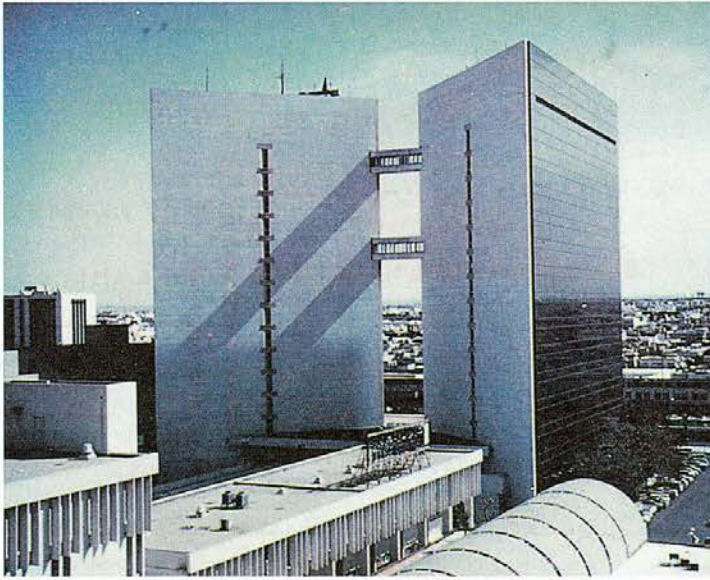


Fig. 10. The offices of King Faisal Charity Foundation, Riyadh designed by Kenzo Tange. Here an entire wall is glass while another entire wall is almost solid. More common, however, are cases where areas of glass and solid materials are present in the same wall.



Fig. 11. A commercial building in Frankfurt, Germany. This is an example of a relief wall, where flat areas are contrasted with projections or cavities.



Fig. 12. An example of a wall design utilizing contrast between plain and textured walls.

Chart 2. Form types

1. Rectilinear
 - 1.1 Single
 - 1.1.1 Simple
 - 1.1.2 Modified
 - 1.2 Multiple
 - 1.3 Combined
2. Curvilinear (convex, concave or both)
 - 2.1 Single (sphere)
 - 2.2 Multiple
3. Organic forms
4. Composite rectilinear/curvilinear

Rectilinear forms

The most salient characteristic of rectilinear form is its flat surfaces, flat in the sense of not-curving. Generally, rectilinear forms are regular forms. Regular forms can be generated by extending or rotating a regular shape such as a triangle, a rectangle or a square or other polygons. A triangle is a regular shape; therefore, a form extruded from a triangle such as a triangular prism (e.g., King Faisal Charity Foundation, Fig. 10) or a pyramid is a rectilinear form. Rectilinear forms can be classified into single, multiple and combined.

Single rectilinear forms

Single rectilinear forms, as the name implies, are composed of one single mass, such

as a cube or a box. In some cases a single form is slightly modified to add interest to the form; one corner could be slashed, a roof overhang is added, the lower floor is recessed or extended and so on. In all of these cases and others the identity of the single form is retained despite the modifications. These forms are modified forms. The unmodified forms can be denoted as simple forms.

Single forms are easier to comprehend by the observer, especially if they are simple shapes. On the other hand a simple shape whose surfaces offer little to engage the eye can be rather boring. Glass box buildings are a prime example of this type of building.

Multiple rectilinear forms

This type of form is a collection of single forms that share one or more planes, (e.g., King Saud University buildings (Fig. 13). They can also be interlocked (sharing volume) as is the case in Habitat, the housing units designed by Moshe Safdie for Expo 67 in Montreal, Canada (Fig. 14).

Combined form

In a form of this type we have a central form appended to which are a number of forms. These forms are added together in an irregular fashion, without a clear relationship between the axis of these forms such as being parallel or perpendicular. The identity of the original form is obscured by the appended forms, to the point that the resulting form is not easily recognized. The resulting form has an irregular form, irregular in the sense that it is not easily traceable to its constituent forms. This type of building form is not very common. The sport center in Belgrade, Yugoslavia (Fig. 15) is an example of this form.

Curvilinear forms

By curvilinear forms we mean forms with curved surfaces: Since curvilinear forms are generally more expensive to construct than rectilinear forms, they are less common than rectilinear forms. Curvilinear forms are very varied and can be sub-classified according to a number of factors. We can start by differentiating between single forms and multiple forms. Single curvilinear forms may be defined as the curvilinear forms that have no inflection points, i.e., there is no change in the direction of the curve. The cylinder (Fig. 16) and the sphere are the prime examples of single curvilinear forms. The geodesic sphere at Expo 67 in Montreal (Fig. 17) which served as the US pavilion in that fair, is one of the rare examples of nearly complete spheres in buildings. It is more common to see a portion of sphere used as a sport arena or a stadium. An example of this is the sport arena in Rome that was designed by Pier Luigi Nervi (Fig. 18).

Multiple curvilinear forms include a wide variety of structures. We can differentiate between convex curvilinear forms, such as domes, and concave curvilinear forms, such as those of the cable structures in the Olympic Village in Munich, designed by Frei Otto (Fig. 19). In Kenzo Tange's Olympic Swimming Pool in Tokyo, the concave curves of



Fig. 13. Typical King Saud University buildings, an example of multiple rectilinear form.



Fig. 14. Housing in Expo 67 designed by Mose Safadie, an example of interlocked multiple rectilinear form [23, p. 387].



Fig. 15. A sport center in Belgrade, Serbia. This is an example of combined form, where the resulting form cannot be traced back to its constituent forms.

the roof are combined with the convex curves of the ring wall (Fig. 20). A curving serpentine structure with several inflection points, such as the Tuwaiq Palace in Riyadh (Fig. 21), could also be considered a multiple curvilinear form, although an argument could be made for its inclusion in the organic form category below. Other interesting and diverse examples of multiple curvilinear forms include the church of St. Francis in Brazil, designed by Oscar Niemeyer (Fig. 22). The Sydney Opera House by Jorn Utzon (Fig. 23), and Renaissance Center in Detroit Michigan which is basically a collection of steel and glass cylinders.

Organic forms

These forms almost defy description, save the fact that they resemble forms found in nature and that they are generally more complex than the rectilinear as well as the curvilinear forms discussed above. The mushroom-like house (Fig. 24) is an example of this. The work of Gaudi in Barcelona (Fig. 25) and many Indian temples (Fig. 26), which resemble hills and weathered rocks could also be classified in this category.

Composite forms

This group of forms include a number of possible combinations of different form types such as organic/rectilinear, combined/curvilinear and curvilinear/rectilinear. The latter combination is the most common of all composite forms. Many mosques and churches combine a large curvilinear element (dome) with a rectilinear building (Fig. 27).

A Typology of Building Form

It is difficult to give varying weights to the different complexity factors outlined in section 4. However, one can construct a 2 dimensional matrix of building forms where the rows are envelope types and the columns are form types. In the following table, complexity increases with the distance from the origin in both directions. We have tried to give examples, wherever possible, of the building form types that result from

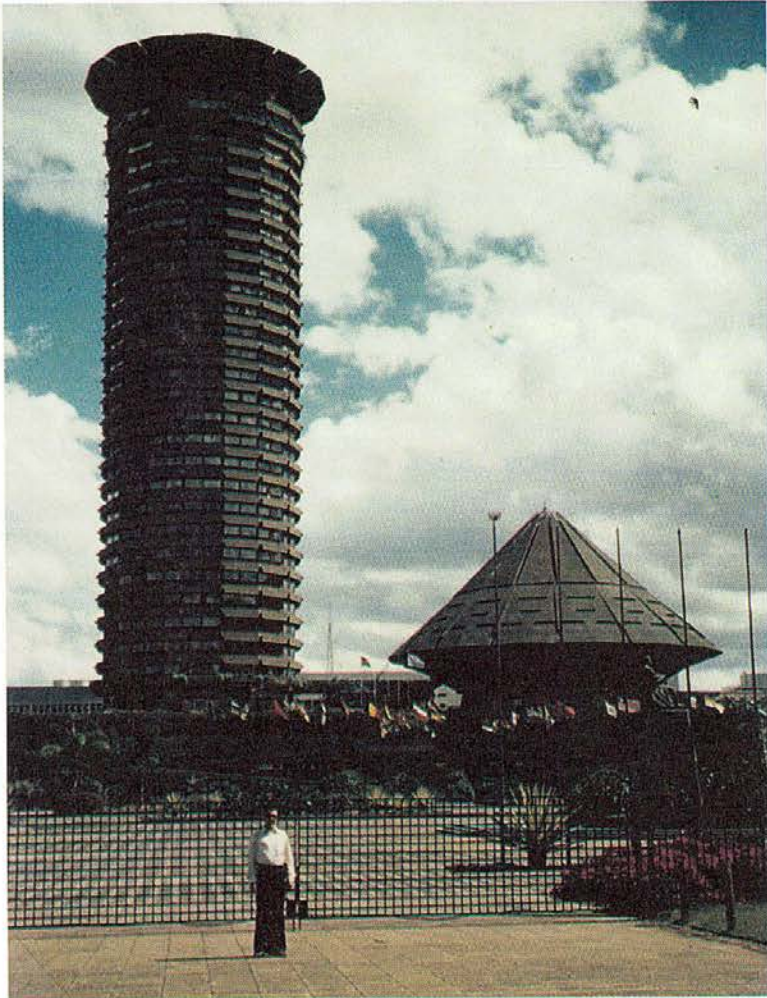


Fig. 16. An example of single curvilinear form, a cylinder and a cone at the Jomo Kenyatta conference center, Nairobi, Kenya.



Fig. 17. The US pavilion in Expo 67, in Montreal, Canada.

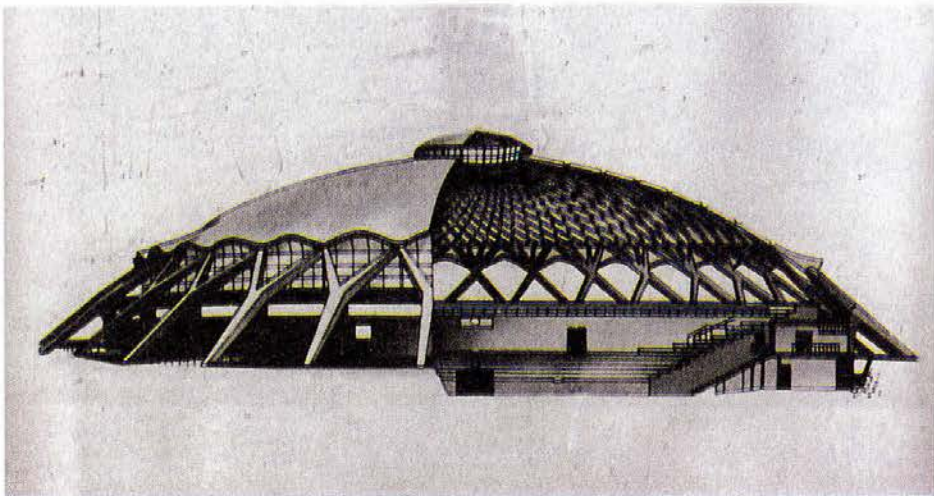


Fig. 18. The sport arena in Rome by Pier Luigi Nervi [17, p. 133].



Fig. 19. The Olympic Village in Munich, Germany by Frei Otto.

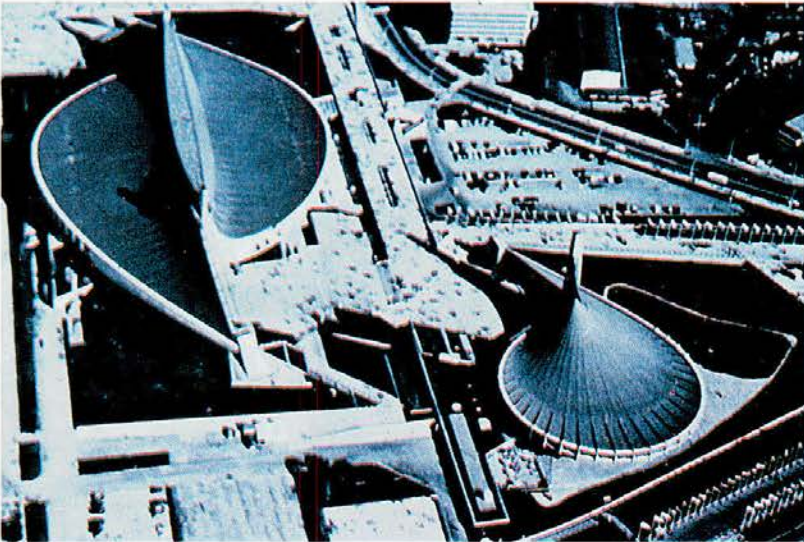


Fig. 20. The Olympic swimming pool in Tokyo, by Kenzo Tange [18, p. 145].

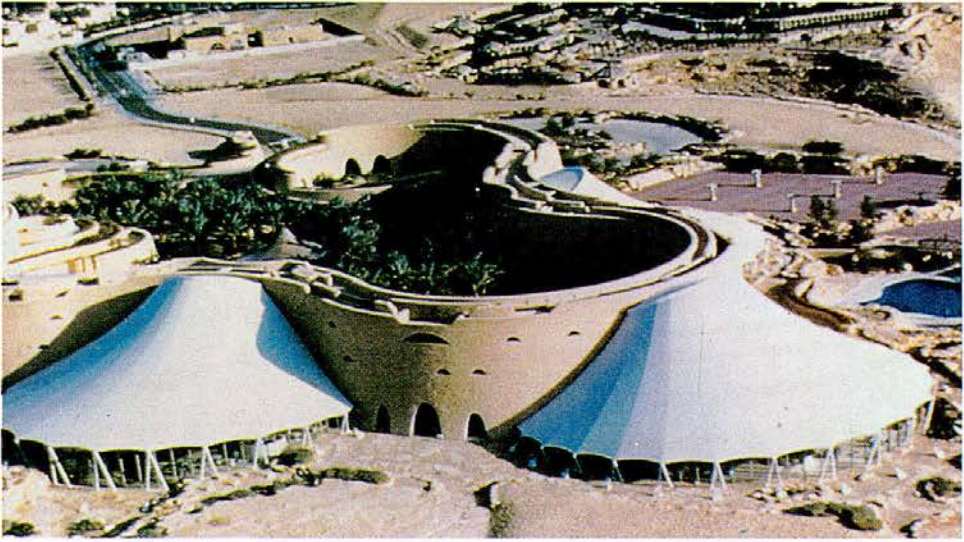


Fig. 21. Tuwaiq Palace, Riyadh by Al-Omrani [Riyadh Development Authority].

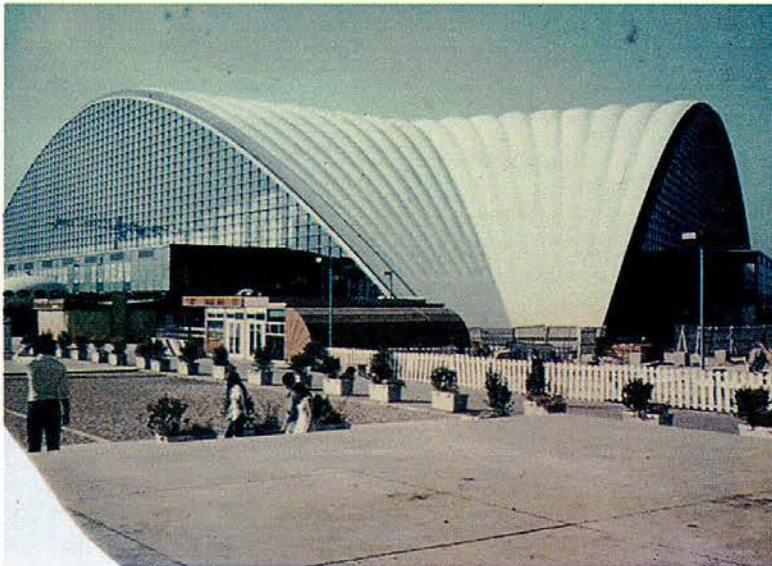


Fig. 22. The Defence Exhibition Center in Paris.



Fig. 23. The Sydney Opera House by Jorn Utzon [26, p. 185].



Fig. 24. A mushroom-like private house in Rochester, NY.

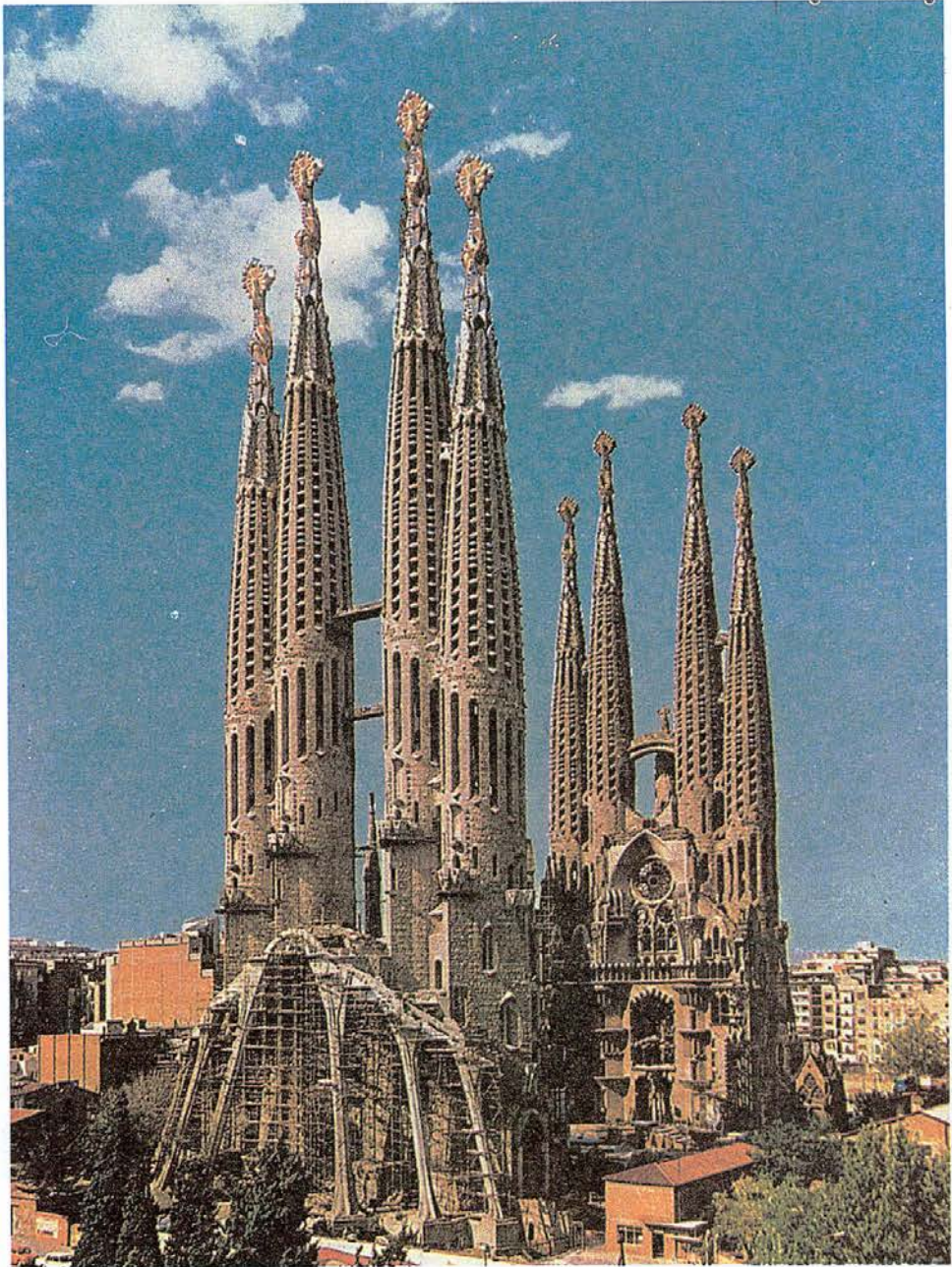


Fig. 25

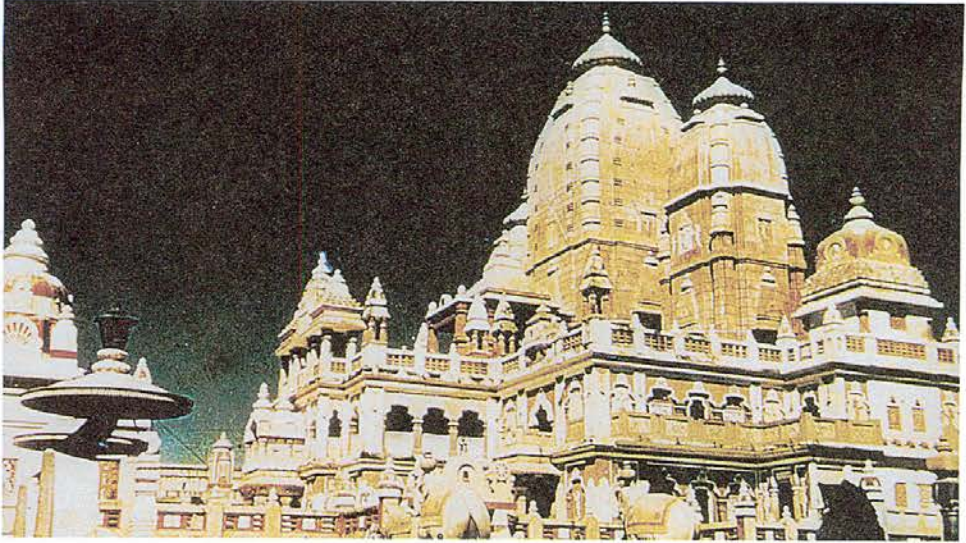


Fig. 26. The Hindu temple of Brahmewara in Orissa, India [20, p. 88].



Fig. 27. The Gand Mosque in Shah Alam, Malaysia.

intersecting types of forms and types of envelopes. There are 8 columns and 12 rows resulting in $8 \times 12 = 96$ cells that represent possible building forms. Of course, not all the building forms represented by the cells are significant or have actually built examples although theoretically it is possible to conceive examples for each cell. Due to space limitations only a small number of examples are given in the table. We do not claim that this matrix of building forms is the definitive method of classifying building forms, but we hope it will engender discussion in this field in which very little has been written.

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طريقة لتصنيف أشكال المباني

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ملخص البحث. تصنف المباني عادة حسب وظائفها أو نظامها الانشائي أو مواد البناء الرئيسية المستخدمة بها. لكن تصنيف المباني حسب أشكالها لم يتلقى الاهتمام الكافي، ويعود ذلك لصعوبة هذه المهمة صعوبة بالغة. والمحاولات القليلة التي نشرت لتصنيف المباني حسب شكلها كانت تعاني من عيوب كبيرة. في هذه المحاولة الحالية وجدت من الضروري دراسة الشكل المجرد للمباني بالإضافة إلى دراسة الأسطح الخارجية للمباني لكي يمكن التوصل إلى تصنيف مفيد لأشكال المباني. وتؤدي المصنوفة المكونة من ٨ أنواع من الأشكال المجردة و ١٢ نوعاً من الأسطح، تؤدي إلى ٩٦ شكلاً من أشكال المباني يمكن الحصول عليه نظرياً. وربما لا يوجد الآن أمثلة على كل شكل ممكن، لكن هذا التصنيف يوفر لنا اطار لدراسة أشكال المباني قد يكون مفيداً لطلبة العمارة والمعماريين.