RICE UNIVERSITY

PLASTIC FORM
IN ARCHITECTURE

by

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THE ABSTRACT

THE SEARCH FOR PRINCIPLES UPON WHICH TO BUILD A THEORY OF ARCHITECTURE REVEALS THAT PLASTIC FORM IS THE FORM OF THE HIGHEST ORDER -- NOT BECAUSE IT IS BEAUTIFUL, ALTHOUGH IT POSSESS A BEAUTY THAT LASTS AS LONG AS THE FORCES THAT CREATED IT, BUT BECAUSE IT IS THE MOST EFFICIENT MEANS TO FUNCTIONAL REQUIREMENTS. THESE FORCES ARE CLASSIFIED AS:

NATURE FORCES - Gravity Force
                  Wind Force
                  Water Force
                  Earth Force

SENSUAL FORCES - Sonic Force
                Visual Force
                Tactile Force

BEHAVIORAL FORCES - Personal Force
                     Circulation Force
                     Sociological Force

They are not listed as a hierarchy of forces, although Nature Forces should be considered as primary. Because these forces do exist in the shaping of form, their understanding is therefore a prerequisite for the designer. Before form may be created the forces that give form must be considered.

Primitive man found Gravity Force to be the primary form giver to his dwellings. His materials were those of compressive strength (mud, ice) and their resultant forms were therefore compressive stress forms of similar shape. Later, when tensile strength materials were developed, forms of great beauty emerged as tension structures. Both compression and tensile strong
materials were shaped by the Gravity Force to produce Plastic Form.

Plastic Form is also produced by the Wind Force. As the wind shifts the desert's form so it is the prime determinent in the shape of racing car and aircraft. The Water Force has shaped the surface ships of the past with great beauty and will become the prime force determining our sub-aquatic cities of the future. The Earth Force determines the shape of man's objects as they are placed upon and within the earth.

Now consider Sensual Forces. Man's visual, sonic and tactile requirements also produce Plastic Form. As the Sonic Force has shaped our ear, so it shapes our theatre. Visual Force relates to man's sensitivity to light and how Plastic Form is shaped in consideration to light. The most intimate of all forces is the Tactile Force. This force gives Plastic Form to all objects man touches - from the coke bottle to the chair.

Consider the Behavioral Forces or those forces resulting from man's co-existence with himself and other men. The Personal Force is the expressive force of man. When strengthened by experience and knowledge the designer may then create Plastic Form of his will. The movement of people produce the Circulation Force that shapes homes, theatres, cities. The Sociological Forces involved within the city are the most complex of all.

With thorough understanding of these ten forces an environment of unity, beauty and efficiency may be created through Plastic Form.
PLASTIC FORM IN ARCHITECTURE

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INTRODUCTION

Although there is no agreement on the classification of form among architects and architectural historians, it is my contention that form can be categorized into three divisions:

SKELETAL FORM is the result of rectilinear approximation of forces acting upon and within an object.

PLANAR FORM is the result of individual planes defining space based purely on the Personal Force.

PLASTIC FORM is the result of forces shaping an object to its most efficient form.

This investigation focuses on the latter. Plastic Form is a design approach that uses the surrounding forces upon an object to give it form. Plastic Form is therefore a direct result of the reason for its existance. It is basic; it is direct; it is honest.

Many of today's most exciting and stimulating buildings are the result of a great understanding of the principles of Plastic Form; Frank Lloyd Wright's Guggenheim Museum, Philip Johnson's Roofless Church, Kenzo Tange's Olympic Stadium in Japan, Eero Saarinen's Trans World Airlines Terminal and Le Corbusier's Chapel of Notre-Dame-du-Haut, Ronchamp. Even the "frame maker", Mies van der Rohe, succumbed to Plastic Form in a small residence of 1954. Although all of these buildings are Plastic Form in nature, each illustrates a different principle in form making. The principle followed in each building was used to determine form making decisions throughout the design.
process. Many times these principles are lost or forgotten not only during the design period of a given form but may be forgotten from one civilization to the next. The purpose of this investigation is to re-establish and state these principles which will serve as guides for future form development and also as a bases for understanding and judgement of historical forms.

Not only does Plastic Form exist as a design form in the field of architecture but exists more abundantly and with more quality in the other fields of design. These related design forms will be used to help illustrate the principles involved in Plastic Form in architecture.

The first phase of this investigation will cover the basic form giver -- GRAVITY. The balancing of forces due to gravity is the first consideration in architectural form's history.
GRAVITY
GRAVITY FORCE

A prime lesson in Plastic Form is found in structures of pure compression. In the beginning, form grew from the earth and was plastic in shape as the earth.

"While still dwelling in caves, man learned to make utensils of wet clay, he burnt them hard for use. Except for this faculty he was not more then another animal. Still clinging to the cliffs, he made whole caves out of wet clay and let the sun bake the cave hard. And so, ages ago, man moved into his first earth-built house."\(^1\)

Frank Lloyd Wright

Wet clay will efficiently resist gravity while in compression -- but when tensile forces are created, the structure collapses. Therefore, these early dwellings were as flowing in shape as the earth they were made from and became three-dimensional diagrams of pure compression force within the structural walls.

From the ground grew the building; thicker at the base where the compressive stresses are greatest and growing thinner and meeting itself at the top - one material - one property - a composition of compressive strength.

Although opposite in climate and geography than the early mud huts, there grew similar forms from the ice of Alaska. Ice, too, possessed little tensile strength and must find its strength in compression. The igloo, as well as the mud hut, therefore finds its form in the same stressed shape -- natural Plastic Form.
The curved surface of the igloo is the smallest geometric volume that may cover a given area, thereby diminishing the amount of required interior space to be heated, while in the mud huts, the ceilings are much higher than the human environment zone and as the heat rises into the upper part of the hut, it is released through an opening in the top center. These similarly shaped dwellings are both structurally and environmentally economical and efficient. Although primitive, their creators' knowledge of material and environmental understanding produced Plastic Form of such sophistication that similar forms are used today.

The forces of compression always increase as the structure gains weight toward the earth connection. Even sand (no tensile strength when dry) can gain considerable height by simple piling on top of itself. The problem is that the base becomes proportionately large. There could possibly be a direct connection between the resultant shape of the Egyptian Pyramids to the angle of repose of Egyptian sand.

According to La Belle Brussin:

"(Primitive man's) intimacy with earth has, in turn, expressed itself in a unity between the form he has molded and the earth from which he has molded it."^2
The needs of a new Roman Empire gave Plastic Form a new scale of enclosed space. There emerged a society whose social needs required large interior and exterior spaces for mass meetings. The Roman Empire grew from the Etruscan towns as a world power -- but not the power to create materials in quantity and quality that possessed tensile strength. The Roman architects were destined to use the basic compression covering based on the same principles as the ancient mud hut. Their contribution was the demonstration of stone's great compressive strength. The span of the Roman Panthenon (142 feet, 6 inches) remained the largest domed space until recent times. Although grand in scale, it follows the principles of the mud hut, even to the opening of the roof at top center for pressure and heat exhaust. The principle remains true today as demonstrated in Houston, Texas' Astrodome Stadium where the exhaust port is at the apex of the structure.

Although still using the tensile weak materials of brick and stone the Gothic Age produced a compressive architecture of great sophistication. The needs of the church required great height and much light -- it needed a new expression.

A new brittle architecture of great plastic qualities resulted. The greater compressive strength of stone enabled the form giver to substract all material that did not directly and efficiently support itself and the load above.
Antoni Gaudi took the Gothic Period to its end and clearly expressed in his forms the learned laws of an age.

"He finds in nature the rules and guidance that should define and govern the architectural elements. The roof like a mountain has ridges and slopes, the vaulting is like a natural cave of parabolic section."^4

Josep Sert

Antoni Gaudi's experiments in pure compression resulted in Plastic Form of great sensitivity. The section of his Sagrada Familia Cathedral shows a structure enormously high and light. Its lines of force are much like those found in nature -- always balancing the opposing force and doing it simply, directly and economically. Even the major interior columns lean toward center to meet directly the downward, outward thrusts of the roof -- spilling down from column to column and growing with strength, finally thrusting deep into the ground to rest.
Gaudi's Pare Guell archade retaining wall reflects not only the downward force of gravity but the angular force of the repose of soil. The two forces combine to form a vector that is equally opposed in direction by the wall and column of the structure.

"...his insistence on using brick and stone instead of steel -- there he remained the medievalist."\(^\text{6}\)

Josep Sert

Again Plastic Form found its expression through a deep understanding of a given material. This was to end the age of great
With the perfection of steel fabrication, Plastic Form was also changed. Because of steel's lightness, compared to its compressive strength, new developments in form occurred. The Buckminster Fuller Dome emerges as the new 20th Century compressive form. As the Romans expanded the primitive mud hut to a 142 feet, 6 inches dome -- Fuller has expanded it almost without limit. He even proposed to cover Manhattan Island with a transparent protective dome.

"Doubly curved thin-shell structures support much more efficiently even than singly curved or cylindrical structures and arches. They are used when large unobstructed floor areas are desired."7

Building Construction Handbook

It is still basically the ageless compressive structure geared to the mass production methods of contemporary machinery. The domes of Buckminster Fuller are composed of relatively small geometric elements. Each element is rigid either in itself or by
virtue of its conqueity with similar elements around it.

"The whole structure is thus a rigid framework under compression...the ideal statical form of the short hollow tube, which is subject only to direct compressive stress, makes possible an extraordinary reduction in weight -- about 1/300th that of other types with identical dimensions." 8

**Carl Condit**

The construction of compression forms is still an active part of modern architecture. The most recent development is in foam plastics. The plastics work well, also, in compression and therefore appear as "igloo" shapes of great lightness and insulating qualities. The rapidly built structure is generated about an arm of plastic supply that results in the ancient form. Materials of the same structural properties will result in similar forms; possibly of different scales but remaining as like forms.

Tension stresses produce an entirely different Plastic Form than those of compressive stress. The first pure tensile Plastic Forms were found in Oriental suspension bridges. Originally they were invented in China, about the first century B.C. and were built with cables of rope. Iron chains were used in bridges some 500 years later but never appeared in Europe during classical or medieval times. The first oriental suspension bridge was published in Europe by Fansto Veranzio in 1595, but none were built there until 1741 when an iron-chain footbridge was constructed across the River Tees in Durham County, England. 9 The United States picked up and claimed leadership in tension bridge structures by 1800.
The tension structure is economical for long spans as in bridge construction. Its beauty and architectural implications were expressed by Lewis Mumford on viewing the importance of the Brooklyn Bridge built in 1870. Mumford argued that the designers, John and Washington Roebling expressed a new perfected form.

"What monument of any architecture can speak its story more clearly and more forcibly than this gossamer architecture?...This aerial bow, as it hangs between the busy cities,...is perfect as an organism of nature. There was no question in the mind of its designer of 'good taste' or appearance. He learned the law that struck its curves, the law that fixed the strength and the relation of its parts, and he applied the law...the designer of the Brooklyn Bridge has made a beautiful structure out of an exquisite refinement of utility in a work in which the lines of force constitute the structure."
"In this structure the architecture of the past, massive and protective, meets the architecture of the future, light and aerial, open to sunlight, an architecture of voids rather than solids... In its absence of ornament, it refusal to permit the steel to be other than its own unadorned reality, the Brooklyn Bridge pointed to the logic and aesthetics of the Machine."  

Lewis Mumford

Plastic Form was now released from its compressive mass and could resist opposing forces with the strength of tension. This "organism of nature" was not to become an architectural form giver until 65 years later. Tension structural form appeared in the Century of Progress Exposition at Chicago, Illinois (1933-1954). The building was the Travel and Transport Building. The architects of this rather sensational tour-de-force were Edward Bennett, Hurbert Burnham and John Holabrin. The building was a 306 feet wide rotunda and 120 feet high. The Plastic Form tension structure was not pure in form as the early suspension bridges for the principle was that of tension members holding a dome. They sought to have stability and lightness. Compared to contemporary works of suspended construction, the transport building seems primitive in the absence of full exploration of the potentialities of high-tension steel cable.
The two decades of the 1950's and 1960's have provided many refined examples of architectural Plastic Form that resulted from tension construction. Bruce Goff designed a Norman, Oklahoma residence on the principle of a radiating spiral of tension members supporting a spiral roof. As span requirements grew, technology helped to solve the need with graceful, tension structures. Eero Saarinen designed his Hockey Rink at Yale with tension principles of which he must have learned in his earlier General Motors Institute of Technology tension Stairways. Next came Kenzo Tange's Olympic Stadiums combining the principle of Goff's spiraling and Saarinen's tension roofs to produce Plastic Form of great vitality -- and great span. More important that the ease of span in tension structures though, is the great clarity and beauty that result in these Plastic Forms.
Tension structures may also be designed to be additive -- that is, to have the ability to grow and expand. Saarinen's Dulles Airport, in Washington D.C., is an example of such a structure. The constant tug of war within the structure becomes the structure's source of life. Each element within the structure must add to this tension to produce full consciousness of the form's reason for existence.

Another Plastic Form that is the slowest to emerge as a contemporary type is the membrane structure. Related to the primititive tent, the structures strength is in its ability to resist tension. Economy and efficiency of membrane structure in meeting external forces makes it a basic form type, for the skin on our bodies follows the same principles of membrane strength in tension.

On tents:

"The magnificent structures that have been the pride of the monarchs of Western Asia for thousands of years, fabrications huge in size, very costly, and even if not permanent, often of extraordinary beauty."12
The German architect, Frei Otto, is becoming the leading designer of light-weight membrane tension structures. He achieves his elegant and sophisticated Plastic Forms by stretching a tent "skin" over cables or wire mesh. The German Pavilion at Montreal's Expo '67 will be the latest development in this type of structure.

The membrane tension structure is Plastic Form because it illustrates directly and clearly the forces upon the form and the resisting forces within the skin. Membrane structures are difficult to support and therefore are today's least advanced light structure. As new problems of membrane structures are solved the now rare form may become the light-weight structure of the future -- Plastic Form possessing the balance of forces that animates its existence.
Human skin is basically a tension membrane structure. The skin rises and falls, finding its form by the internal and external forces acting upon it. The beauty of human form has been worshipped by man. The first sculptural object produced in Paleolithic Man was a representation of the female form (this Paleolithic female nude shows the result of gravity upon even the membrane structures of the human form). A form that expresses early man's love of the female, Plastic Form. This love is expressed by philosophers of all ages. Its purity is found in the longing of all form shapes to be curved.

"...it is as if there were a natural law which ordained that to achieve this end (man must) refine the curve of a piece of furniture or a ship's hull, or the fuselage of an airplane, until gradually it partakes of the curve of a human breast or shoulder."13

A. de St. Exupery
The membrane strength of canvas has helped propel the ships of early empires. Lessons of Plastic Form can be learned in the study of sail forms. The force of the wind transmitted into the sail becomes a captive force that is given to the ship for propulsion. The ship in turn uses this transmitted wind force to surpass the water force and there the inbalance of motion occurs.
WIND FORCE

I remember seeing my first Grand Touring racing auto. It was Ford's GT Mark I. As I ran my hand along its body, it was as if the wind force had shaped the metal and fiberglass about the auto's separate functions, creating a form of great beauty. Sensuous to the point of wanting to be touched and therefore understood. The air flow form split the on coming wind, driving the nose of the machine down during great speeds, providing greater steering control. As the wind moves toward the rear, it is taken into the engine area behind the seats by a nostril like opening -- beautiful and direct. This highly sophisticated form functions because of its accepted Plastic Form due to Wind Force.

Architecture, too, is shaped by Wind Force. When great heights are sought, the wind must be appeased and resolved within the structure. The Eiffel Tower is a three dimensional stress diagram due to an equal horizontal Wind Force. A modern, but less sensitive Plastic Form is Skidmore, Owings and Merrill's John Hancock Building for Chicago. Because of its great height (one-hundred stories) it looks awkward in its truncated shape resulting from the attempt to resolve the Wind Force. As greater and greater heights are achieved, the Plastic Form will become more clearly expressed.

Designing with considerations for Wind Force in smaller structures has recently been studied by the Sea Ranch Developers
of California. Their development site is located on the coastal bluffs north of San Francisco. Among other ecological surveys of the area, Wind Force was thoroughly investigated to later be used by the developer architects in dwelling designs.

"Behavior of wind over obstacles was studied to determine most suitable angle of roofs. Just as a rock carries wind up and over a slanted surface to provide a protected area to its right, so the houses could be shaped to guide the patterns of the wind. The Esherick houses were subjected to wind-tunnel studies, whose results influenced the final designs. Sod roofs were added on some of the structures to further integrate house & landscape."¹⁴

Sea Ranch Developers

Wind Force maps were compiled showing wind conditions at all points of the site. The survey showed both average direction and force of wind.
This new understanding of Wind Force gives designs more unity within this area, a unity of forms shaped by a common force -- the Wind Force.
WATER FORCE

The field of water pressure forms have not been expressed in contemporary architecture for it is still in its primitive stages. Pressure shaped vehicles have resulted in forms of symmetry where all forces of pressure are resolved directly in the curved outer shell -- a shell of structural compressive strength. The bubble is the shape of water forms and of future dwelling forms of subaquatic habitation. All forces are resolved on the sphere for all forces are equal about the skin.

Experiments in underwater forms have resulted in new roles for ancient materials. Glass has proven to be the strongest of materials in compression. The greater the pressure upon glass -- the stronger it becomes. This one fact may lead underwater cities to be a collection of glass spheres that reflect the natural bubble forms of air in water. Because of the great forces involved in under-water dwelling, Plastic Form will be the only form strong enough to exist. Every joint and unit within the under-water city will require great understanding of stress -- no arbitrary forms -- no margin for structural dishonesty -- a pure new form architecture is therefore awaiting the under-water dweller.
EARTH FORCE

There are primarily two ways in which Plastic Form results from Earth Force. One occurs when the earth takes the form of the dwelling (i.e. berm architecture); the second is when the dwelling takes the form of the earth (i.e. Italian hill towns). Both recognizes earth as a form giving force and either caresses or is caressed by the earth.

The troglodytic town of Pantalica in Sicily dates back 3000 years. The town is nearly perpendicular and is cut directly into the stone bluffs. It is formed of multi-storied apartments connected by interior passages. The town has continually been occupied since its birth.15

Below earth and within earth dwellings are the most primitive of all Plastic Forms. The amenities related to troglodytism satisfy many of man's needs. Even today, there exists underground towns and villages complete with factories, schools, hotels, and government offices. Below ground dwellings prove to be clean and free of vermin, warm in winter and cool in summer.

The Western adaptation of troglodytism takes the form of berm architecture. Frank Lloyd Wright became interested in this area and designed dwellings in which the surrounding earth became their plastic container.

"The berm-type house, with walls of earth, is practical – a nice form of building anywhere: north, south, east or west -- for here you have good insulation -- great protection from the elements; a possible economy too, because you do not have to finish any outside below
window level...I think it an excellent form for certain regions and conditions.  

Frank Lloyd Wright

Again expressed as Earth Form is a home by Philip Johnson; The James Geier House near Cincinnati, Ohio. An underground house, it has a sod roof where ponies will graze on the grass. Of glass and concrete, it expresses a romantic, and very human approach to architectural form. The earth rises from the lake and curves around the house -- protecting its contents -- parting to allow water, also, to hold the form. The Earth Form is entirely plastic for it does not possess the sharp corner junctions that many times imposed by today's architects.

The walls within these earth dwellings should oppose as a retaining support much like Gaudi did in his Parc Guell retaining wall previously discussed. Vectors must be opposed and balanced -- the structure will then take on a new vitality of Plastic Form.

Man's desire to make his dwelling upon the earth and take
on the earth's inherent nature is as old as Plastic Form as the village is a social form unit.

"Man's physical freedom manifests itself no doubt in his ability to choose the place on earth where he wants to live...neither privations nor danger will deter man from selecting a spot that provides him with the exhilaration generated by a superb landscape."

Bernard Rudofsky

Frank Lloyd Wright loved the Earth Force and used it to create forms of great beauty and natural understanding. One of his most famous residences is Falling Water in Bear Run, Pennsylvania.

"The house is an abstraction of the spectacular site: a steep wooded slope in a forest glade, studded with outcropping rock, large boulders, and looking down upon a rushing stream that falls in cascades making pools on different levels."

Steen Rasmussen

As he walked upon the site, he stopped at a boulder, nestled against the hill beside the stream.

"Here will be the hearth for the fireplace, and the broad chimney tower will rest on this large stone. All other rooms and levels will be related to it."

Frank Lloyd Wright

Larger proposals of Plastic Form beauty have recently been submitted by a new generation of architects. The winner of Progressive Architecture's 1966 Design Awards was such an Earth Force solution. The Urban Nucleus in Sunset Mountain Park outside of Los Angeles was designed to "reinforce the character of
the land." It provided a natural solution to the problems of high density by its earth shape. The architects were Pelli and Lumsdan.

Jury Comments:

"...this is how we'll solve the problem of density without destroying the ground on which we're building."

"There's a wonderful sense of void that you need; it really seems to flow down the side of the mountain so that it caps it with a kind of gentleness and really seems to go down the mountain like water does -- respecting the mountain. It's very beautiful."21

If man is eventually going to have to live in a demanding environment, one that is mechanized and efficient, then what happens in the community must become more closely allied with nature. Direct nature -- human closeness will be expressed as a Plastic Form -- an outgrowth of Earth Form.

"The natural Gardener..has made his Design submit to Nature, and not Nature to his Design."22

Stephen Switzer
Ichnographia Rustica 1718
Inca Amphitheater's of Muyu-way, Peru

SONIC
SONIC FORCE

Architectural Form exists to some as sonic reflection and reverberation; those who are blind will find the architecture created by Sonic Force exciting and life reflecting.

Sonic forms appeared early in history. The amphitheater of Muyu-uray, Peru was built by an Inca tribe of the Maras. Four theaters in the round and one in the form of a horseshoe comprise the complex. "As might be expected, the acoustics of all five theaters are superb."23 The largest seated approximately 60,000 people. "The lowest circular platform of the four theaters, which corresponds to the Greek orchestra, varies in diameter from 80 to 134 feet. Water pipes, one foot wide, carved into stone monoliths, carried spring water from a nearby mountain peak."24

These Plastic Forms were created on the principle that sound travels in a straight line and reflects from hard (stone) surfaces. These theaters contained all horizontal sounds that were reflected within the circular shape.

The Greeks, too, participated in outdoor theater and although half a world away, built similar Plastic Forms as the ancient Incas. The Greeks built their theaters within a sloping hill also, to stage the dramas they loved.

Today many examples of Sonic Force buildings stand. Their form directly reflects the architects understanding of sound. Frank Lloyd Wright also used sound considerations to give his theaters their resultant form. One of the most powerful of his Plastic Forms is in Dallas, Texas. This beautifully sensitive building reflects
the direct needs of the stage. It has a Guggenheim like concrete curved shell that reflects the external noises. A train passes just a few hundred feet from the stage and becomes silent.

"Sensitivity to the problems of acoustics came naturally to Wright. He had a vivid feeling for drama. In 1955 he was asked to build a new theatre for Dallas, Texas. Thus came the perfected form of the architects long consideration of the theatre. Seating is designed to go halfway around a circular stage. Vision and acoustics are uniformly excellent from every seat in the house."²⁵

Mrs. Frank Lloyd Wright

In relatively small structures, sound is not a great problem; but for large multi-use auditoriums, there exists Sonic Force problems that have not as yet been solved. The science of natural sound is still in its beginnings. On a discussion between architects and acoustical consultants:

"The acoustics consultant will help the architect determine the basic shape of the enclosure of the theatre. The over-all dimensions of the space will be determined on the basis of the reverberation time to be achieved."²⁶

On the field of acoustics:

"It is still a subjective field - different people like different qualities in sound."
On sounds role:

"An acoustical consultant is useless on a small building."

"The engineer ties the strings to the instrument, but the general configuration of the instrument is the job of the architect." 27

The architect must be aware of sound quality; the disturbing almost unlimited cold echo of the hospital corridor -- the dead quiet of new fallen snow. Material existence shapes and controls the sound life, just as it shapes the light and the dark. These qualities of architecture express the personal strength and understanding of its creator.

As the science of sound is developed -- so will Plastic Form take on the learned knowledge of this form force.
VISUAL FORCE

The Visual Force is one of the most intimate with the architect, for it is the paint upon which he paints his spaces. Light is his life giver, for his forms will change against the moving sun (earth). As the seasonal light changes from glaring cold snow light - to yellow green spring light so his creation is bathed in change.

Light is not often a gentle force. It drives man into cave-like darkness for relief. In India, the light is sifted and filtered through ornamented screens of great delicacy to provide comfort within.

The first great light structure was the Gothic Cathedral. The structures had been refined to a point of maximum efficiency where the remaining skin of the building was glass light. Because of its symbolic nature, light has always been a form giving force in architecture.

This century's greatest light structure displays the mystic and beauty controlled light can convey.

Le Corbusier has created a church interior in Ronchamp which has the emotional appeal that is based on shadowed dimness of indirect lighting in which forms only vaguely reveal themselves.

"On entering the church the first thing that strikes you is that it is very dark. Gradually you become aware of the walls and you begin to realize that plane surfaces and regularity are no more to be
found inside the building than on the exterior. The very floor is like an undulating landscape of stone slabs in an irregular pattern. Between walls and ceiling there is a very narrow opening which admits just enough light for one to see the rough concrete ceiling against the white plastered walls. What appear to be belfry lights are actually windows which cannot be seen from the interior but which, from high up above the roof, shed a magic light over the curved walls of the apse so that the worshipper's attention is drawn towards it, towards its altar and up above where the light is brightest."

Steen Rasmussen

Louis Kahn spoke almost entirely of the Light Force during a lecture at Rice University, April 21, 1967. His proposed Fort Worth Art Museum is to be a plastic composition of light and structure. He stated that the color of light within a room depended directly on the rooms volume and shape. Silver light, blue light, green light, gold light all were to be refracted from natural light. Light (not servant space) has become his new form giving force. Probably he learned that if one designs for servant space (University of Pennsylvania Laboratory), the human needs suffer. His labs were intolerable, where no sun protection was provided. Aluminum foil now protects the laboratory technician from the sun. These very difficult lessons on glare has formed a new architecture for Louis Kahn.

"...front light is generally a poor light. When light falls on a relief at almost a right angle there will be a minimum of shadow and therefore of plastic effect. Why should not a building be conceived entirely as a piece of pottery or
lusture ware to respond constantly, diversly,
to the reflection of the sun?" 29

**Steen Rasmussen**

Plastic Form responds with more sensitivity to light for the
to the wall possess both light and all degrees to darkness as it turns
from the light into darkness. One of the best examples of this
is the curving travertine walls of Jones Hall in Houston, Texas
by Caudill Rowlett Scott.

Frank Lloyd Wright's houses were built on the so-called
open plan. There the walls and partitions do not go all the
way to the ceiling but leaves a light opening at the top. This
completely releases the light to flow into, through, and out of
the dwelling. This release of wall from ceiling was the beginning
of Planar Form that gave Mies van der Rohe his clearest archi-
tectural statement - the Barcelona Pavilion.

The science of light has developed to a high degree of
accuracy. Light quality within a proposed architectural form
may now be investigated through the use of sensitive light
instruments and accurate models. Rice University is a fore-
runner in apparatus design and techniques. My work with the
program's director, A. A. Leifeste, has broadened by under-
standing of this designer aid.

"With a method for comparing the lighting performance
of different building forms and fenestration schemes
during preliminary design, the utilization of
natural lighting can be increased and can become one
of the major design determinants for buildings -- an
especially important item in parts of the world in which natural lighting is the basic lighting system."30

A. A. Leifeste
Rice University

The data collected in the tests include: amount of light energy entering a structure, amount retained and distribution of light intensity at each point within the structure. The structure most shaped by light force is the testing room itself. The desire was to get a perfectly shadowless, even lighted surface. The dome, once again, proved the answer. As the light source floods the wall-ceiling, the dome becomes a blanket of light and the figures within the space cast no shadow on the wall. It is a most exciting example of a room totally shaped by light -- a pure Plastic Form.

"The hemispherical plastic dome, 14 feet in diameter, elliptical in section is 5 feet from spring line to zenith."31

A. A. Leifeste
Rice University

Washington University School of Architecture has also built a light study instrument. It was constructed to cast shadows on a given model at the angle of the sun at any time of day during the year. This becomes an invaluable tool in creating Plastic Form architecture from the forces of light.
TACTILE FORCE

The coke bottle, the door knob, the crystal glass, the telephone receiver -- each designed for touch -- each a clear Plastic Form expression. Skin is soft and sensitive and will wear out if constantly touching anything but smooth Plastic Form. I have worn through my finger skin many times while laying the rectangular brick or broken stone in masonry constructions. I know well the reasons for touchable Plastic Form.

The area of furniture design illustrates man's Tactile Force on a form. Many things have been said about the comfort of seated man. Frank Lloyd Wright, who understood touch force equally as poorly as he understood Sociological Force, tells why his furniture was so difficult to design:

"My early approach to the chair was something between contempt and a desperation. Because I believe sitting to be in itself an unfortunate necessity not quite elegant yet. The only attractive posture of relaxation is that of reclining. So I think the ideal chair is one which would allow the would-be 'sitter' to gracefully recline.

"All my life my legs have been banged-up somewhere by the chairs I have designed.

"I have done the best I could with this 'living room chair' but, of course, you have to call for somebody to help you move it."32

Frank Lloyd Wright

Our modern classic chairs are Plastic Forms relating to the seated human trunk. The legs have also been withdrawn
under the chair to prevent "banged-up legs." Recent studies have also established the ideal placement of major body supports. "The major back support should be located between the fourth and fifth vertebra."33

Industrial Design 1966

Mies van der Rohe, Charles Eames, and Eero Saarinen each demonstrate a plastic solution to the basic problem of human support. The different shapes result from the different properties of the materials used. Mies used leather and steel, Eames - laminated rosewood, leather, and steel; while Saarinen used the new material fiberglass (combined with a steel base).

These chairs possess a classic beauty because they are sympathetic to the basic need of man combined clearly with the material properties used in their design. Plastic Form again is the result of a balance of force.
Philip Johnson's Roofless Church

PERSONAL
PERSONAL FORCE

Frank Lloyd Wright, Le Corbusier and Alvar Aalto each produced architectural form by self-expression. This self-expression motivation I classify as Personal Force; the force of man's personality on form.

One of today's most prominent architects in this area of Personal Force form is Robert Venturi. His architectural statements are strangely plastic in form and the result of forces that should be categorized as art. A pure force of expression, but expression that possesses unity in spirit and remains constant in its form.

"...an architecture of complexity and contradiction has a special obligation toward the whole: its truth must be in its totality or its implications of totality. It must embody the sort of unity described in poetry: 'Unity not of the sort to be achieved by the reduction and simplification appropriate to an algebraic formula. It is a positive unity, not negative: it represents not a residue but an achieved harmony. More is not less.'"34

Robert Venturi

Robert Venturi Residence
During the 1967 Progressive Architecture Design award jury the architecture of Venturi was heatedly discussed.

"...the possibility of putting roofs over people's heads in a way that makes them a part in all sorts of direct and indirect ways of their cultures."

"McKinn, Mead and White did the same thing, so this is nothing new. They reflected the art and the fashion of their time."

"I think it's a joke."

"...allusions to the pop life that would hopefully bring a set of architectural forms into a much deeper meaning for the people using them."

This clean cut -- direct self-expression force is becoming the vogue of the young designer. Without thorough understanding of their personal forces involved in this type of architectural creation, there will be no unity and no meaning but more trash to litter our cities. More contradiction is more contradiction.

There also exists a force that is emitted from within a piece of art; a kind of spirit that encircles the object and creates its own atmosphere. I know of one structure that is a direct expression of such a work of art.

During the winter of 1965, I talked with the sculptor Jacques Lipchitz. He had just finished a lecture on how sculpture and architecture were unrelated fields and should never be confused. I had just returned from New Harmony, Indiana where I had visited Philip Johnson's Roofless Church.
Under the undulating roof was one of Jacques Lipchitz's favorite sculptures (a work given to the state of Indiana). The sculpture appeared to be the seed from which the great roof had grown. When I asked Mr. Lipchitz the connection between the two forms he said, "I created the man, Johnson clothed him."

The client of a given structure also plays a large role in its resultant shape. The Personal Force of the client many times supersedes all other considerations and may result in an architecture not tempered by the other nine basic forces. It is the architect's task to educate the client in these matters. In the end, the architect takes the responsibility for the finished form.
CIRCULATION
CIRCULATION FORCE

Plastic Form has been the result of walking man since the beginning of architecture. Usually he does not take the straight line because of its depressing ability to predict oncoming events; there is no surprises in the straight line path. The art of procession is the art of predetermined experiences that change as the path changes and end with a sense of entry or escape - a reward.

The Guggenheim Museum is a clear circulation spiral that's total impact is in its plastic unity. The processional entry to the Guggenheim is diagonal, and the jump into the hundred-foot light spiral is the buildings life. Circulation holds the great light well that reveals itself to the viewer as a guide to where he has been -- where he is -- and where he is going. Its Plastic Form is purely the result of a circulation and processional force idea.

Philip Johnson often speaks of this form giving force.

"Architecture is surely not the design of space, certainly not the massing or organizing of volumes. There are auxiliary to the main point which is the organization of procession."36

The entry up the "baroque" stairs into the Mississippi Steamboat Promenade is of the essence of Plastic Form entry; so are the stairs up-to and down-from the upper balconies; so are the silhouetted moving people who form a living mural to the space. These plastic patterns all result from the Circulation Force.
Another great processional form is the entry and lobby of the Jones Hall for the Performing Arts in Houston, Texas. Its Plastic Form scoops up the people at the entry and gently distributes them to their seats. It is as if a great wind had formed the space. As the lobby space holds the Symphony Hall's volume, its fingers connect all parts to the whole -- the direction of main lobby is always felt for it is always toward the larger space. Caudill Rowlett Scott has given this building its strength and vitality by using this powerful Processional Force as a form giver.
Mas Van der Rohe's 1934 Residence
In a less abstract way, our highways and interchanges express the speed and direction of auto circulation - sometimes expressing itself with clarity and directness that results in great beauty. The architect must envy these great structures for they are not complicated as structures for human habitation must be. These Plastic Forms of circulation express an understanding of the forces involved and thus serve well.

An interesting development of auto circulation force appears as one of the rare examples of Plastic Form in the work of Mies van der Rohe. His 1934 project was a residential court house designed around, of all things, the auto. The rectangular composition is invaded by the curving thrust of the car entry. The sweeping curves are echoed throughout the composition. They seem to blend the interior spaces with the unity of one act -- the thrust force of the auto into the house proper.

"Mies has used a pseudo-functional problem to justify a space more subjectively determined than any he had yet proposed. Mies juxtaposes positive and negative intervals, counter-movements and distortions, admitting to architecture a kind of quality of space not normally considered appropriate to it. It is difficult to imagine how space could be used in a more painterly way."

Arthur Drexler

Mies used the not-so "pseudo-functional" force of auto entry-exit to give a plastic vitality to his normally classic Skeletal Forms.
SOCOLOGICAL FORCE

Probably the least clear, most complex, and of greatest importance are the forces that shape the modern city. Forces combine and internix creating new forces of never ending variety. Societies of less complicated nature are able to express with great clarity the forces within them. Possibly from them a bases for understanding can be found. Their Plastic Forms are clear -- their principles timeless.

The city begins by grouping the family cells together. The reasons for their grouping are complex. Basically, the desire to specialize in a field of interest and leave the less interesting work for others interested has been the grouping force. Coupled with this is the need for protection -- both military and religious or in other words, security both in the present and distant future.

The city also has the living force within that makes it grow and die at the same instant. As old cells die, new cells must take their place.

"...as man's needs change in time, he must fashion additional elements, allowing those which no longer serve a function to crumble back to earth."\(^{38}\)

La Belle Brussin

The tribe community illustrated displays such an organic principle. The ring is formed of huts that face inward toward the tribal chief. The cattle bins are kept on the interior also for protection from wild beasts. The chief is located in the nucleus surrounded by the protective huts of his many wives. On a smaller scale, within each family unit hut grouping exists the same forming
forces.

"...the organic growth of the compound structure can be traced by the physical use - patterns which have evolved in the internal courtyard and which reflect the growth of the family unit through the acquisition of new wives. The life span of the compound structure is dependent on the maintenance of the family as a viable economic unit and the plasticity of its form is an expression of the functional changes taking place in time." 39

Victor Greun

Victor Greun has taken a similar approach of organic plasticity organization in his ideas on future city forms.

"I can visualize a metropolitan organism in which cells, each one consisting of nucleus and protoplasm, are combined into clusterizations to form specialized organs like towns which, in turn, are grouped together to form cities and finally, in a still more highly developed organism, the 'metropolis of tomorrow.'" 40

Victor Greun

Is Victor Greun's metropolis of tomorrow valid as an approach to social city organization -- it does work on the village scale as in the primitive
village. Only the days after tomorrow will tell.

Admittedly, these are forming forces as real as gravity, wind or water. They must be studied as to their intensity and cause, only then will the city become a Plastic Form it is striving to be - not the Roman Grid of the Anonymous but the plastic fiber of human interaction.
SYNTHESIS

The understanding of the forces involved in Plastic Form architecture is basic to the design process. The magnitude of these forces exist in different degrees on all man created forms, and it is the problem of the designer to recognize which is to be the primary and which to play lesser roles in producing his form. This thesis is not only a theory of architecture, but involves the universal theory of all form creations.

The viewing of form as being shaped by Natural, Sensual, or Behavioral Forces has made the process of design much easier to understand. The student, for example, could build a philosophy of form creation from the understanding of the forces. These force laws should be taught to the beginning student of architecture just as the chemist was taught the elements before he could formulate compounds. It is my contention that the philosophy of architecture is really the philosophy of form creation based on the ten forces that dictate form.

To know why a line is curved rather than straight is a great revelation. While traveling, I met a sweet little Australian lady who was touring the Americas. After talking with her a while, I told her I was studying architecture. Her intelligent eyes began to glow as she asked me, "Why do you design all those boxes? Why don't you design buildings with curves, young man -- they're so nice."

I replied, "Because our rulers are straight -- I guess."
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