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Hyun-Tae Jung

To cite this article: Hyun-Tae Jung (2018) The Impact of Measurement Research on Prefabrication and Modulation in SOM's Postwar Housing and Office Buildings, Technology| Architecture + Design, 2:2, 196-205, DOI: [10.1080/24751448.2018.1497368](https://doi.org/10.1080/24751448.2018.1497368)

To link to this article: <https://doi.org/10.1080/24751448.2018.1497368>



Published online: 29 Nov 2018.



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Hyun-Tae Jung
Louisiana State University

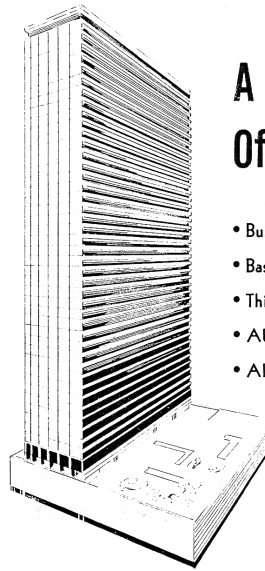
The Impact of Measurement Research on Prefabrication and Modulation in SOM's Postwar Housing and Office Buildings

Skidmore, Owings, and Merrill (SOM) committed to innovations in prefabrication and modulation of construction in the mid-twentieth century. This paper examines SOM's collaboration with the John B. Pierce Foundation in the 1940s, which advanced the firm's technical and theoretical expertise on prefabricated housing and large-scale office buildings. The Pierce Foundation conducted research on prefabrication and ergonomics, and carried out physiological and psychological research in the domestic environment. Their extensive measurements of objects, building parts, and human activities in the domestic environment were crucial to SOM's advancements in modulated office design. The Union Carbide Headquarters (1960) illustrates the impact of the measurement of physical and spatial dimensions on the modern corporate office building.



◁ Opening Image. Lobby. Skidmore, Owings and Merrill, Union Carbide Building, New York, 1960. (Credit: Ezra Stoller/Esto)

▷ Figure 1. Sketch by Nathaniel A. Owings, "A Radically New Conception of Tomorrow's Office Building." (Credit: Stamats Communications, Inc)



A Radically New Conception Of Tomorrow's Office Building

- Built on a site eight times larger than the floor plan of the building above the third floor
- Basement, second and third floors used for parking
- Third floor level an outdoor park with real grass and trees
- Above third floor a straight shaft, no setbacks
- All year air conditioning, sealed sash, acoustical ceilings, permanent sunshade controls
- Exterior materials requiring no painting or tuckpointing
- Windows washed with vertical type of automatic squeegee run on tracks

By **NATHANIEL A. OWINGS**
Architect, Skidmore, Owings and Merrill
 New York, Chicago and San Francisco

In the 1950s, the American architecture-engineering firm Skidmore, Owings, and Merrill (SOM) gained worldwide recognition for designing sleek office buildings that provided clients formal and spatial embodiments of the businesses they held. SOM elicited great excitement from the general public, corporate leaders, and architectural communities alike, and several of SOM's buildings became institutional icons. Most notable of these were Lever House (1952), Manufacturers Hanover Trust (1954), Connecticut General Life Insurance Company Headquarters (1957), Inland Steel Building (1958), Union Carbide Corporation Headquarters (1960), and Chase Manhattan Headquarters (1961). The firm pioneered a new trend for office design using glass-and-metal curtain walls for skyscrapers that are viewed as icons of post-WWII American architecture.

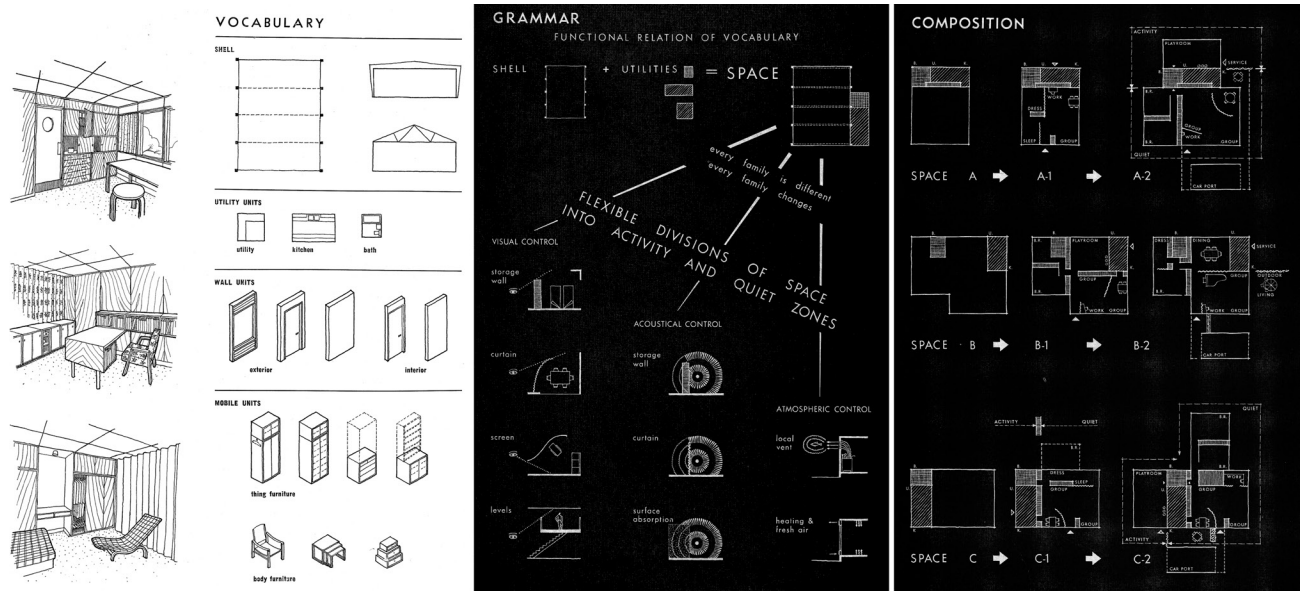
While individual buildings have been well documented, there has been little investigation of how SOM technically and spatially conceived and developed the modern office building and its interior space. To address this expertise, it is crucial to understand the firm's activities before and during the Second World War. In 1939, SOM, then a little-known design firm, began to collaborate with the John B. Pierce Foundation. Established in 1924 by John B. Pierce, the foundation was well known in the architectural community for its comprehensive housing and medical research. This initial collaboration introduced SOM to diverse fields of research previously unknown to the firm: ergonomics, psychology, and physiology in the domestic environment. While working with the Foundation from 1939 to 1944, SOM developed a scientific understanding of humans and their activities based on measurement research. Additionally, the firm advanced pioneering ideas about flexible space and prefabrication. This field of knowledge proved to be particularly fruitful in that SOM was, in the 1950s, able to synthesize these scientific studies to develop a modern concept of office space based on modularity. By discussing SOM's little-known research of the early 1940s, this paper analyzes the historical development of the technical and spatial advancements of glass-and-metal skyscrapers, particularly the Union Carbide Headquarters in New York City. Ultimately, this research is an illustration of how the systematic measurement of

domestic objects, human activities, and building components contributed to the creation and evolution of modern corporate office space.

The Institutional, the Dramatic, and the Utilitarian through Flexibility

SOM's iconic office space designs were the result of the firm's technical and conceptual experiments. These developments were clear in some writings of Nathaniel A. Owings, one of the founding members of the firm. In 1944, Owings presented a paper at the Illuminating Engineering Society Technical Conference in Chicago on active illumination for commercial space, also underscoring the importance of flexibility in equipment. He argued that "maximum flexibility is fundamental and one of the prime answers to the problem [of lighting]."¹ Owings maintained that it was crucial to furnish "ample and varied equipment—permitting an infinite variety of effects—effects producible with the minimum amount of maintenance labor."² Furthermore, referring to retail environments, Owings contended that, "Large scale effects can be obtained, vistas created, whole ends of floors becoming in themselves one dramatic lighting unit or area."³ Owings's "ample varied equipment" was not limited to lighting, but also included the physical structure.

In a similar vein, in 1948, Owings published an article, "A Radically New Conception of Tomorrow's Office Building," in the *National Real Estate and Building Journal* (Figure 1). Here, he concentrated on the technical and monetary factors of the glass-and-metal office building, believing that a new office concept would give urban workers a controlled indoor environment with air conditioning behind "fixed, flush continuous windows" and sound control through the "sealed sash and the acoustical treatment of the ceilings."⁴ He claimed that sealing all glass walls with inoperable windows was more economical than traditional windows because of installation and maintenance costs. Fixed windows would be washed with an automatic vertical squeegee that would run on exterior tracks. Owings thought the cost of cleaning windows would be significantly reduced with the introduction of this system. Exterior wall units made of modern materials such as aluminum, stainless steel, other alloys, and plastic would



△ Figure 2. Skidmore, Owings and Merrill, "Flexible Space."

be prefabricated in a factory to be installed quickly and economically. The lightest type of concrete slab construction on a steel frame would reduce dead loads. With these efforts, the office building would embody lightness "from its environment to its construction."⁵ Owings's ideal office would have "a simple, flexible, rectangular plan with the thinnest possible skin and the maximum amount of glass."⁶ The glass curtain was a crucial part of modern systemization and allowed internal flexibility, for a more pleasant and adaptable work environment.

Standardization and Prefabrication of the House

Ideas about lighting and urban office towers were extensions of the firm's studies on the standardization of buildings, which were first developed through measurement research on the house and domestic activities. The scientific analyses of domestic and office behavior, ergonomics, and fatigue were popular internationally, and famed studies in the early twentieth century include those by F. W. Taylor, Lillian and Frank Gilbreth, The Cambridge Psychology Laboratory, and Margarete Schütte-Lihotzky's Frankfurt Kitchen. The quantitative analyses of furniture and other elements of a building were conducted in addition to the scientific analyses of the human body and activities in the domestic environment. Measurements were the very foundation for innovations in interior and exterior design.

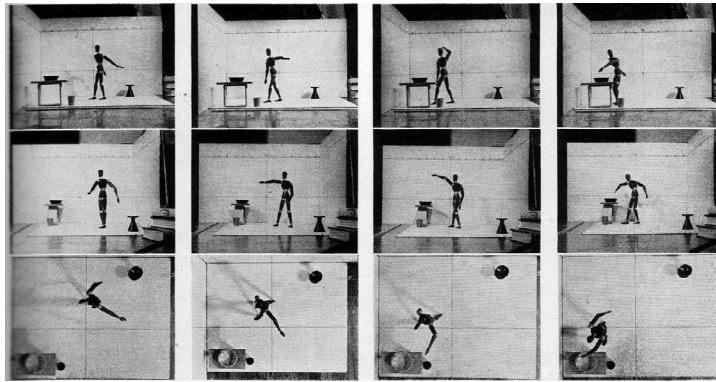
For the September 1942 issue of *Architectural Forum*, "The New House 194X," the journal invited thirty-three firms, including Edward Stone, William Wurster, Gilbert Rohde, and Richard Neutra, to present ideas on standardization and systemization of housing production. Many of these proposals were based on programmatic and practical design considerations. SOM's submission was titled "Flexible Space," with the intention of presenting a formula of spatial organization in which a building was conceived as a collection of disassembled parts and dividable functions⁷ (Figure 2). In essence, the architects of SOM theorized the flexibility of a spatial system. Using a crude linguistic model, SOM subdivided architectural production



△ Figure 3. A prefabricated house by SOM and the Pierce Foundation. (Credit: Orville K. Blake)

into three stages. The first stage, "Vocabulary," referred to the shell or enclosure of a space, its practical units, wall units, and mobile units. The second, "Grammar," or the "functional relation of vocabulary," was a process of combining the shell and utilities to create spaces that successfully met visual, acoustical, and atmospheric requirements. "Grammar" would satisfy the diverse demands of each occupant. The final stage was "Composition," which clarified the possible variations of the spatial system based on certain prototypes.⁸ Physical and spatial measurements were the essential bases of all three stages. Extensive measuring of physical objects such as tables, chairs, bathtubs, windows, doors, and structural frames accompanied physiological measuring of vision, acoustics, humidity, dust, and comforts. These measurements enabled SOM to compose domestic units efficiently. In "Flexible Space," the firm's proposal claims that "every family is different" and "every family changes," suggesting that the approach could meet the diverse demands of various households.⁹

▷ Figure 4. (left)
Testing a new
photographic
measuring method
with a puppet
(Credit: John. B.
Pierce Laboratory)



▷ Figure 5. (right)
Volumetric study of a
man changing clothes.
(Credit: John. B.
Pierce Laboratory)



SOM devised the idea of “Flexible Space” to justify and facilitate the mass production of standardized buildings.

SOM’s abstract and systematic concept of space was derived from its previous experience with the John B. Pierce Foundation, an institution that translated rigorous research on houses to become a pre-eminent research authority on prefabrication. The Foundation set up its Housing Research Division in 1931 with the aim of modernizing the housing industry, and in 1933, it established the Laboratory of Hygiene for public health and physiological research. These laboratories studied prefabricated housing, the use of space in the domestic environment, physiology, and psychology. SOM and the Foundation began to collaborate in 1939 on a small “Experimental House” (Figure 3). This house and succeeding projects allowed SOM to gain sufficient technical knowledge and on-site experience. This would later prove to be crucial to designing and developing concepts for postwar office buildings. However, this newfound understanding of prefabrication was not limited to the industrialization of construction.

Around 1940, members of the Foundation, Jane Callaghan and Catherine Palmer developed measurement techniques to understand human activities in terms of volume, and created “space shapes,” which were documented in *Measuring Space and Motion*¹⁰ (Figure 4). Along these lines, John Hancock Callender, another key member of the foundation, argued that “housing design should be based on family needs. The problem was how to obtain the data on which to base a design for housing, not one, but several thousand, families.”¹¹ As illustrated in SOM’s concept of “Flexible Space,” Callender believed that the scientific and quantitative understanding of human bodies and their movements would help achieve flexibility in meeting varying household needs and would also inform prefabrication. The Pierce Foundation interpreted the issue of design as “a problem of conflicts in space and time,” hoping to envision scientific principles to guide dwelling design. This research proceeded from a study of 131 families in the New York area, which had a limited focus on “sleeping, dressing, washing, and bodily elimination.” Volumetric measurements of human motions, such as when a person changes clothes or washes their hair, were observed in the study¹² (Figure 5). The Foundation also conducted physiological and psychological research, such as on the effects of thermal changes in a domestic environment.¹³ A dwelling was divided into three categories: space, equipment, and environment. While space was measured by the physical occupation of a person and equipment was measured in relation to use, the environment was analyzed in terms of

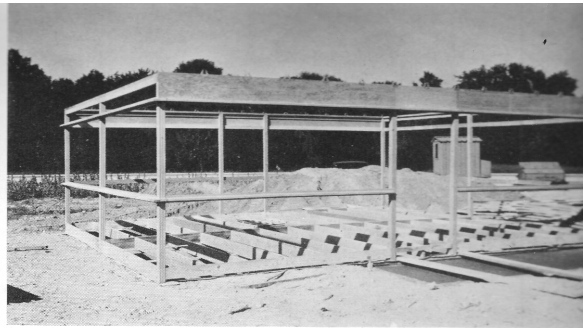
physiological and psychological measurements. The physiological environment included control of moisture, heat, ventilation, light, sound, and sanitation. The psychological environment incorporated control of privacy, consideration of the general appearance of the home, impression of the space and equipment, personal aesthetic preferences, and social standards. In this process, design did not begin with physical walls and their shapes, but with “a human and wrapping around him with the required space, equipment, and environment.”¹⁴ Thus, measurements incorporated not only objects, human activities, and various furnishings, but also the emotions and feelings of individuals. This way, the prefabricated house could become efficient, comfortable, and pleasing.

Prefabrication was generally understood as “the assembly, in varying degrees, of parts or sub-assemblies into sections to be assembled into a structure, as distinguished from the assembly of parts during erection of the building.”¹⁵ In the 1930s, the industrialization of the building industry appeared to be a potential solution to the devastated economy of the Great Depression. Thus, there were many different opportunities for the employment of prefabrication. SOM was commissioned by *Architectural Forum* for its November 1940 issue to create “a basic house design” that supposedly included all the benefits and excluded all the weaknesses of individual variations.¹⁶ SOM presented a prefabricated house and developed a feasible manual for large-scale housing development. In October 1941, the Glenn L. Martin Aircraft Company celebrated the completion of several hundred housing units near Baltimore, Maryland, for which SOM produced general plans and technical drawings and provided construction supervision. Based on the Experimental House, the firm produced drawings for 600 identical houses. All panels, ceiling boards, and structural members were cut to specific sizes by the manufacturers. With no need for paint, assembly work was quickly completed in a field shop. The project helped SOM participate in the planning and construction of the city of Oak Ridge, Tennessee, between 1943 and 1945 as part of the atomic bomb development, otherwise known as the Manhattan Project. This secret government project proved to be “the biggest job of quick town building ever attempted in the U.S.A.”¹⁷ In the spring of 1945, what had been empty land in 1942 was filled with a population of 75,000, complete with the necessary facilities for a traditional town.

▷ Figure 6. Opposite page. Construction of Cemesto houses, 1941.
(Credit: John. B. Pierce Laboratory)



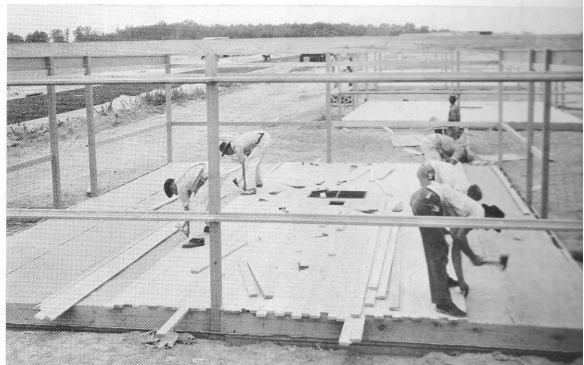
Tops of the columns are bound together with wood girders.



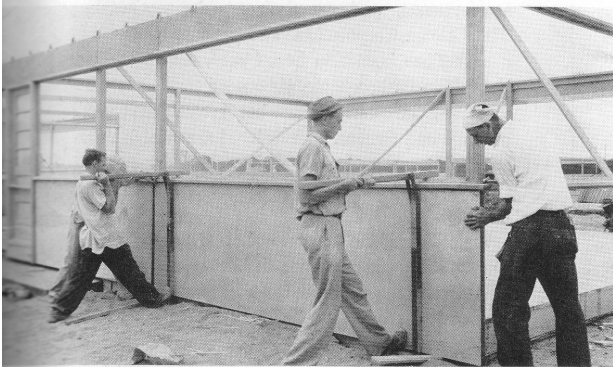
Here floor and wall framing has been completed.



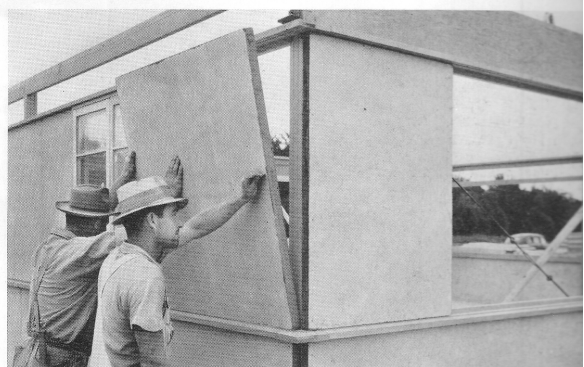
An oil burning floor furnace is put into each house before the flooring is laid.



The floors are laid with 1 1/4" thick T and G flooring.



A sheet of 1 1/2" Celotex Cemesto Board is being applied to the lower section of a wall. This Cemesto panel is 12 feet long and 4 feet wide.



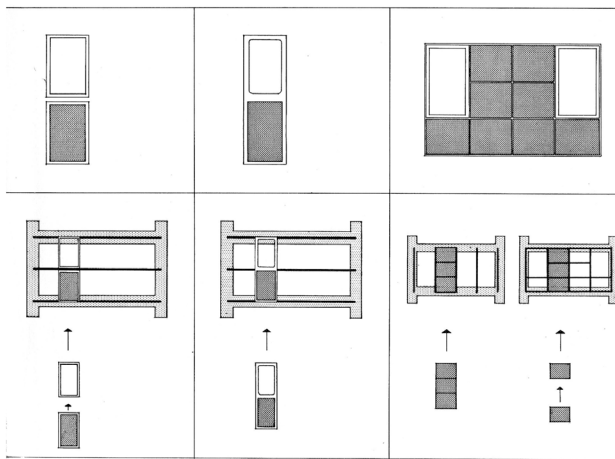
A short Cemesto Board panel is put into place at a corner of window course. The Cemesto is nailed to the wood columns.



A wood casement window, complete with frame, is slipped into place.

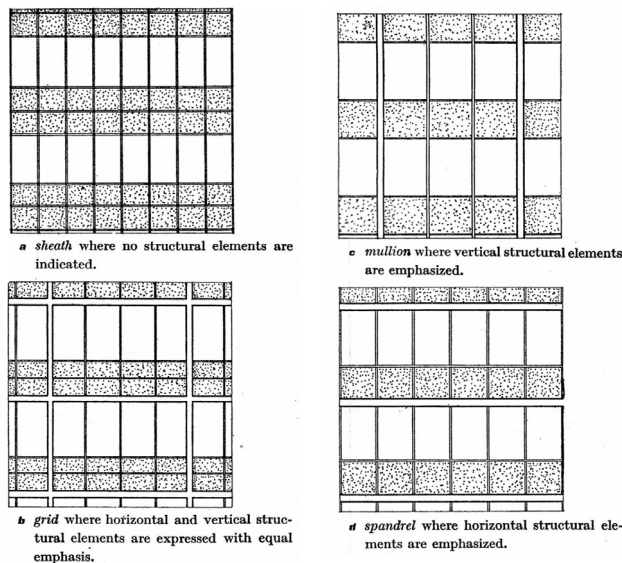


An end roof truss, equipped with ventilating louvres, is fitted into position.



△ Figure 7a. Basic Curtain Wall Units. (Credit: Princeton University, 1955)

▽ Figure 7b. Curtain wall classifications. (Credit: *Architectural Review* 121:724, 1955)



The standardization of building parts, processes, and the efficient management of personnel that it necessitated were crucial to SOM's rise as a large modern firm during the Second World War. The military's positive evaluation of SOM's work at Oak Ridge highlights these proficiencies. Captain Samuel Baxter, then the Contracting Officer's representative at the Manhattan Engineer District, wrote that "The Architect-Engineer [SOM] was required to maintain his complete staff, and conduct all his operations at Oak Ridge."¹⁸ After working with SOM during all stages of the contract, Baxter reported that "an adequate and competent organization was maintained throughout the period of the contract."¹⁹ The positive evaluation SOM received was, in part, the result of having imported personnel from other fields and managing them efficiently.¹⁹ All of this was made possible by standardizing architectural components and systemizing construction.

Modulating Curtain Walls

In both the Glenn Martin and Oak Ridge projects, SOM extensively employed the Pierce Foundation's prefabricated construction method with the new building material called Cemesto, a product of the Celotex Corporation.²⁰ The shape of the Cemesto House was largely identical to that of the Experimental House, and the major difference was the change of materials from plywood to Cemesto. It consisted of a cane fiber insulation board core sealed with a special compound sandwiched between two layers of weather-, fire-, and wear-resistant combinations of asbestos and cement.²¹ Exterior walls employed one and one-half inch thick board, interior partitions were one inch in thickness. Assembly work was executed mainly in a field shop on the construction site, and a second field shop was set up for the assembly of plumbing components. Erecting the walls and roof of one house required approximately only 35 hours of labor²² (Figure 6).

The house was composed of a living room with a dining alcove, two bedrooms, a kitchen, and a bathroom. It had three curtained closets and two storage spaces and demonstrated careful consideration in minimizing both traffic congestion and sound transmission. In addition, the Cemesto House had more considerations for normal family living. Significant additions included two large windows covered with Venetian metal blinds in the living/dining area, a covered porch, a linen closet, a coat closet, a shower fixture over a tile-trimmed bathtub, built-in shelves, and cabinets in the kitchen.²³ Each house was furnished with electric appliances, including a refrigerator, a water heater, a stove, and an oven. These detailed considerations were conceived to attract working families, encouraging them to remain at the plant in the middle of the war when the labor supply was limited and most-needed.

When this prefabricated construction procedure replaced traditional craftsmanship, it also changed the traditional concept of housing design: the house became a product. Swift construction with the help of standardization of parts was crucial to the process. Accordingly, construction was reorganized into specialized groups concentrating solely on singular tasks without any idea of how the whole house was completed. The construction workers of each team completed their tasks in a similar fashion to assembly line workers at a factory.²⁴

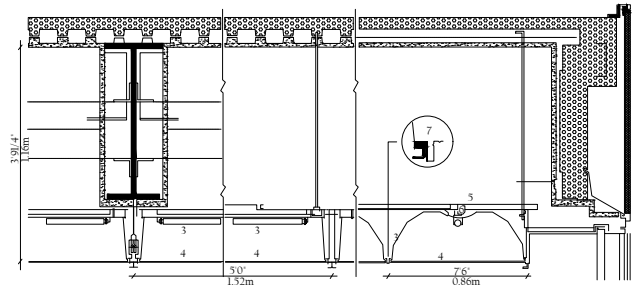
According to the research published by the Pierce Foundation in 1947, *Evaluation of A Steel-Frame Construction System*, from an engineering point of view, there were two types of structures: load-bearing and non-load-bearing. Continuous loading-bearing walls and partitions characterized the former, and this construction method accounted for nearly all existing dwelling construction, including conventional wood frame (balloon or platform) and masonry construction. The latter could be described by non-load-bearing (curtain) walls on a skeleton of columns and girders. While the first type had height limits, the second could be employed irrespective of the height of the structure as long as the strength of the frame allowed it.²⁵ "The Pierce system of horizontal construction employed a lightweight steel (or wood) framework of widely-spaced columns which support lintel girders and roof trusses. This open framework was enclosed by curtain walls of stressed-skin box girder plywood panels."²⁶ In the Pierce prefabrication method, the columns were anchored to foundation piers. Spandrel girder panels were fastened to the columns and acted as deep-web girders to carry floor joists.



△ Figure 8. Office interior of the Union Carbide Building, by Skidmore, Owings and Merrill, New York, 1960. (Credit: Ezra Stoller/Esto)

Lintel girder panels were fastened to columns to support the roof trusses. The central portion was composed of panels and window units.²⁷ The wall and roof assemblies were factory made and delivered to the construction site. Through these lessons learned from innovations in construction, the researchers and architects of the prefabricated house at the Pierce Foundation became pioneers of glass-and-metal curtain wall research.²⁸ SOM designers actively employed and explored the potential of the construction system they collaborated on with the Pierce Foundation. Soon after the war, the designers of the firm combined the Pierce System with modern forms. Schools in Oak Ridge, Tennessee, and office buildings in New York City between the late 1940s and the early 1950s demonstrate the firm's efforts to advance the glass-and-metal curtain wall technology.

In 1955, the Princeton University School of Architecture published a research report, *Curtain Walls of Stainless Steel: A Study Prepared for the Committee of Stainless Steel Producers, American Iron and Steel Institute*. This report, led by Callender, was one of the first studies on glass-and-metal curtain walls in the country. His theoretical and technical expertise and experience on prefabrication contributed significantly to the research on glass-and-metal curtain wall systems.²⁹ According to the report, the wall would evolve to be more active, able to "perform a number of rather intricate operations" such as excluding moisture, dirt, insects, animals, and people, as well as allowing easy control of the indoor environment. The wall would play "so important a part in the control of the environment that it can almost be considered as mechanical equipment."³⁰ Callender understood the thin layer of a wall as an active component of a building, gradually and sufficiently incorporating various other environmental controls. The main idea of this report about an active curtain wall was an extension of the more elemental logic outlined in Owings's earlier text. A more technologically "active," multifunctional glass wall was made possible by first understanding the curtain wall as part of a technological system that encompasses a variety of functions. The close resemblance of Owings's and Callender's ideas is a clear indication of their intense and fertile experiences with the Pierce Foundation's prefabricated house before and during the Second World War.



- | | |
|-------------------------|---|
| 1 Runner A | 5 Wireway |
| 2 Adjustable suspension | 6 Ballard |
| 3 Metal Deflector | 7 Detail, joint to T-runner of plastic diffuser |
| 4 Plastic Diffuser | |

△ Figure 9. Cross and longitudinal section through integrated ceiling of the Union Carbide Building by Skidmore, Owings and Merrill, New York, 1960. (Credit: Christelle Salloom)

In addition, the Princeton report introduces a more advanced understanding of the modern wall, contending that "the wall of a building is analogous to the skin of the body which is not just a covering but is an active and important organ of the body."³¹ While the traditional load-bearing wall was heavy, hardened, and immobile, the modern wall of the Pierce Foundation's Experimental House was non-load-bearing, lightweight, and easy to assemble. It became important for the glass-and-metal curtain wall to perform in terms of environmental control, and at the same time, to generate new formal expressions. This lightweight enclosure, "the skin of the body," allowed flexibility inside and outside since it could be independent of previously inseparable relationships with structure.

The Princeton report classified curtain wall systems into six categories based on "the construction of the wall and not on its finished appearance," because it was "often impossible to tell by looking at a finished building which type of curtain wall unit was used"³² (Figure 7a). A year after the report, the American Building Research Institute (ABRI) organized a conference and further developed the definition of the curtain wall proposed by the Princeton report. This time, the focus greatly shifted: the importance of expressing the construction on the surface was diminished, and it was decided that the first classification of curtain walls "should be based on appearance," and further, "almost any system of construction can be used to achieve any one of the common curtain wall appearances." Accordingly, ABRI proposed four basic visual characteristics: sheath, grid, mullion, and spandrel³³ (Figure 7b). These four characteristics proved to be sufficient for all classifications of the existing glass-and-metal curtain walls. The façade was now believed to create more variations since it was not limited to the representation of the building structure. Therefore, "If curtain wall buildings do begin to look alike, it will be from the architect's choice, not from technical necessity."³⁴ The rectilinear wall panel and frame could be used to create various distinctive expressions while allowing maximum flexibility in the spaces behind the skin. The research on measurement of building components and potential occupants manifested as constructible, aesthetically versatile façade systems.

Case Study in Measurement and Modularity: The Union Carbide Headquarters

Initially conceived as part of the modernization and industrialization of the housing industry, the curtain wall resurfaced as an essential consideration for the design of glass and metal office buildings. In the postwar period, SOM's glass-and-metal curtain wall provided a mechanism for inherent formal and spatial flexibility; it reconfigured the relationships among interior space and exterior surface, volume and mass, and opaqueness and transparency. Its office buildings were the epitome of the institutional, the dramatic, and the utilitarian. The firm generated a new corporate identity while creating spectacular modern workplaces. The buildings encompassed the efficient and systematic application of problem-solving processes for circulation, program clarification, and spatial organization.

The Union Carbide building, designed by SOM's Natalie de Blois, was among the most conspicuous examples of corporate advertising through architecture, particularly with the appearance of its gleaming, modulated skin. Stretching from 47th to 48th Street and from Park to Madison Avenue, the building occupies a two-acre, full-block site. Housing the administrative offices of the Union Carbide Corporation, the 1.2 million-square-foot complex consists of a fifty-two-story tower and a twelve-story annex connected by a short link. Like many other examples by SOM during the period, this building heavily relied on a module repeated throughout the entire building. The module is both a measurement and an abstraction in that it is physical and, simultaneously, does not require any physical object to exist.³⁵ As a code for ordering separate pieces into a holistic body, this fundamental unit of measurement facilitates efficient, systemic, and flexible organization of the physical and spatial components of a building. The modularity of the skin system and the interior organization of office space go far beyond constructability to define the spatial distribution, relationships among objects and humans, and the flow of the workers in the building. In other words, modularity synthesizes the workers and the architecture into a single holistic system. The module no longer solely indexes a construction process, but also produces a synthesis of procedural form and flexible space for modern office workers. The curtain wall serves as the crucial apparatus in securing the space and its inhabitants.

For the Union Carbide building, the architects employed a module of 5 ft. by 2 ft. and 6 inches. This module was applied throughout the exterior and interior design. This dimension was partly chosen by the architects as a practical, cost-saving solution in response to the railroad tracks beneath the site. The structural columns of the tower were thus designed to transmit the loads to the walls and piers of the underground railroad. The exterior columns on 47th and 48th Street were positioned to make bays divisible by 5 feet. Furthermore, the module was regarded ideal by the architects for the coordinated ceiling lighting and air conditioning installations and for maximum flexibility of office arrangement and corridor partitions.³⁶

Adequate equipment was a precondition of maximum flexibility, which was demanded by Union Carbide for its office layout. To house the diverse programs and activities in a single building, the architects extended the use of the module beyond the curtain walls to meticulously design the space behind it and the

mechanical and environmental facilities. The interior most clearly illustrates their technical ingenuity. The client wanted "to be able to change office layouts overnight, without requiring maintenance men to climb up into the ceiling to make adjustments in the services or sound barriers."³⁷ For this, SOM developed a highly refined integrated partition and ceiling system that also incorporated lighting, air conditioning, and sound control for privacy "in a manner that allows unusual flexibility for location of office partitioning."³⁸ Therefore, it was not a merely luminous ceiling as conventionally known, but rather a "'fixture' ceiling, since it is composed of a series of contiguous fixture units (about 70,000)."³⁹ The ceiling runners support the plastic ceiling, lock the modular partitions in place, and act as continuous strip-diffusers for the air conditioning. The ceiling is divided into modular cells, each enclosing light fixtures. (Figure 9) Initially, almost all of the partitions had clear glass at the top to create the image of an unhindered plane. However, in some rooms, glass was darkened, or mirror was utilized as a replacement for the clear glass for privacy.⁴⁰ As a whole, the ceiling created an endless, uninterrupted surface (Figure 8). The architects also implemented an extensive level of modular design in furniture, filing, and storage systems. They introduced clustered workstations with low dividers.⁴¹ All furniture was either custom designed or carefully adapted from existing projects. Ashtrays, desk sets, and all other objects in the office were carefully selected or redesigned to integrate into the modular system of the space.

The flexible modern office space of the Union Carbide building was an evolution of the modernization and industrialization of building made possible through the scientific and systematic measuring of office and domestic life before and during the Second World War. SOM's earlier research and investment in measurement led to innovations in prefabrication and modularity, impacting design, constructability, and occupants' experiences.

Conclusion

SOM's measurement research with the John B. Pierce Foundation laid the foundation and set the stage for the advancement of prefabrication and modulation in architecture. From conducting the extensive measurement of human activities and domestic objects to examining physiological and psychological investigations in the domestic environment, SOM assimilated what it learned from the Foundation into its architectural practice. The research into and measurements of human activities, both domestic and workplace, and the scientific analysis of the impacts of interior environmental conditions allowed SOM to methodically approach design and construction while solidifying its reputation as a flagship corporate firm.

SOM's efficient organization and business operation after the Second World War would not have been possible without the quantification and classification of human activities, domestic objects, and physiological and psychological responses. Based on the initial contributions on measurement and modularity by the Pierce Foundation and the firm itself, SOM continued to produce iconic buildings of the twentieth century. The contributions by the Pierce Foundation and SOM significantly influenced the development of modern American architecture.

Acknowledgments

The author would like to thank Reinhold Martin for helping to see the connection between seemingly disjointed pieces. The author presented a related paper at the international symposium, "Standard Architecture from Jean-Nicolas-Louis Durand to BIM," organized by the Department of Architectural Theory and Design at the University of Kassel in cooperation with ARCH+, Deutsches Architekturmuseum, and Project Bauhaus in Frankfurt, Germany, Oct. 20–22, 2017.

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12. J. Callender, "The Scientific Approach to Design," *Prefabricated Homes* 1, no. 1 (May 1943): 6. Also see Callender, *Introduction to Studies of Family Living*. For more comprehensive research on family living as the basis for dwelling design, refer to Milton Blum and Beatrice Candee, *Family Behavior, Attitudes and Possessions* (New York: John B. Pierce Foundation, 1944).
13. For examples of physiological research of the Foundation, refer to C.O. Mackey and L.T. Wright, *Summer Comfort Factors as Influenced by Thermal Properties of Building Materials* (New York: John B. Pierce Foundation, 1943), C. O. Mackey, *Thermal Properties of a Floor in Contact with the Ground* (New York: John B. Pierce Foundation, 1944), and Lewis Gregory Cole, *Pneumoconiosis: The Story of Dusty Lungs* (New York: John B. Pierce Foundation, 1944).
14. Callender, *Introduction to Studies of Family Living*, 12–13.
15. Davison, Robert L. *The Engineered Dwelling*. (New York: John B. Pierce Foundation, 1944), 2. Reprinted from the April 1943 issue of *Prefabricated Homes*.
16. "The Architectural Forum Defense House by Skidmore, Owings & Merrill, Architects," *Architectural Forum* 73, no. 5 (November 1940): 444.
17. "Atom City," *Architectural Forum* 83, no. 4 (October 1945): 103.
18. Captain Samuel S. Baxter, "Completion Report of Skidmore, Owings and Merrill, Contract No. W-7401-eng.69," October 9, 1944, File MD-600.914, "Skidmore, Owings & Merrill, Completion Report," Box 51, RG 4nn-326-85005, National Archives and Records Administration..
19. He similarly indicated that the business administration of SOM was "well organized and functioned efficiently and that accounts, files and property records kept up to date and in good order with the result that final accounting and auditing of the contract should be completed in a minimum time after the completion of technical services." Ibid. For more details about SOM's activities in Oak Ridge, TN, refer to Hyun-Tae Jung, "'Technologically' Modern: The Prefabricated House and the Wartime Experience of Skidmore, Owings & Merrill," in *Sanctioning Modernism: Architecture and the Making of Postwar Identities*, edited by Vladimir Kulic, Timothy Parker, and Monica Penick (Austin: The University of Texas Press, 2014), 186–218.
20. *A Vital Contribution* (Chicago: The Celotex Corporation, 1941).7.
21. Ibid., 10.
22. Ibid., 8.
23. Ibid., 13.
24. "Six Houses a Day," *Business Week*, (September 13, 1941): 65. The magazine reports, "This Lebanon house is the spiritual father of homes for airplane workers which are going up at the rate of six a day at the Glenn L. Martin Co. Plant, Middle River, Md."
25. *Evaluation of A Steel-Frame Construction System* (Raritan, NJ: John B. Pierce Foundation, 1947), 3.
26. Ibid.
27. Ibid.
28. For example, R. Davison, "Thin, Lightweight Curtain Walls," *Architectural Forum* 92, no. 3 (March 1950): 81–96.
29. *Curtain Walls of Stainless Steel: A Study Prepared for the Committee of Stainless Steel Producers, American Iron and Steel Institute* (Princeton, NJ: School of Architecture, Princeton University, 1955).
30. Ibid., 11–12.
31. Ibid., 12.
32. Ibid.
33. Quotation from the article about the 1956 ABRI conference, "Syntax: The Contribution of the Curtain Wall to the New Vernacular," published in *Machine Made America*, edited by Ian McCallum, special issue of *Architecture Review* 121, no.724 (May 1957): 299–300.
34. Ibid.
35. The acclaimed architectural engineer Konrad Wachsmann defined the module as "the abstract fundamental unit of measurement." Konrad Wachsmann. *The Turning Point of Building*. trans. Thomas E. Burton (New York: Reinhold, 1961), 54.
36. "Union Carbide Corp., N.Y.C.," *Architectural Record* 128, no. 5 (November. 1960): 159.
37. "Toward Greater Ceiling Flexibility," *Architectural Record* 127, no. 2 (February 1960): 220.
38. Ibid.
39. Ibid.
40. "Union Carbide Corp., N.Y.C.," 160.
41. Robert A. M. Stern, Thomas Mellins, and David Fishman. *New York 1960: Architecture and Urbanism between the Second World War and the Bicentennial* (New York: Monacelli, 1995), 353.

Hyun-Tae Jung is a Visiting Assistant Professor of Architecture at Louisiana State University. Jung was trained as an architect at the University of Seoul, South Korea, and received a doctorate in History and Theory of Architecture from Columbia University. He specializes in technological and organizational developments in modern architecture.