A Form Analysis of "Seamless Architecture"

– A Study of "Seamless Architecture" (1) –

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"Seamless Architecture" refers to a global architectural trend that has been emerging since around the year 2000.
It describes architecture in which the walls and roof (and in some cases, the floors) are covered with a single material, with the seams made as inconspicuous as possible—just as our bodies are covered with seamless skin made of a single material.
The purpose of this study is to make the characteristics of "Seamless Architecture" clear by the classification on the viewpoint of the form and the surface finish as the first research of "Seamless Architecture".
The main study results are as follows:
1. "Seamless Architecture" is a concept which does *not* depend on the particular form.
2. We proposed "Ridge Number" and "Curved Architecture Degree" to classify the forms quantitatively.
3. A way of the surface finish of "Seamless Architecture" is classified into 3 kinds which are monolithic, tiling, and division.

Keywords : *Seamless Architecture, Form Analysis, Surface Finish, Number of Ridges, Curved Architecture Degree, Architectural Morphology, Topology, Contemporary Architecture*

1. Introduction

In recent years, architecturally unique buildings have been emerging in rapid succession, particularly in international projects (Fig. 1). A notable characteristic of these structures is that their roofs and exterior walls are finished with identical materials, designed to make structural seams as imperceptible as possible. They are increased rapidly since about A.D. 2000. The purpose of this study is to conceptualize buildings with these distinctive features as "Seamless Architecture" [Note 1] and to conduct a detailed analysis of them.

1-1. What Is "Seamless Architecture"?

For the purpose of this study, "seamless architecture" is provisionally defined as follows: "An architectural structure whose exterior surfaces are finished with a single identical material—specifically, a building where the roof and exterior walls (and in some cases, the floor) consist of the same material."

In short, it can be described as architecture enclosed within a single, continuous envelope. Just as our bodies are covered with seamless skin made of a single material. Although still in the hypothesis stage, we believe that this is 21st-century architecture modeled after "life-form," as opposed to 20th-century architecture modeled after "machines."

Since seamless architecture blurs the boundary between the roof and exterior walls, it is hypothesized that an ideal, fully realized seamless architecture would be one in which the distinction between roof, wall, and floor becomes faint, both internally and externally.

2. Methodology

2-1. Case Study Collection

Based on the provisional definition outlined above, this study conducts a comprehensive survey of both domestic and international (with an emphasis on international) case studies, followed by an analysis.

First, as many potential examples of seamless architecture as possible are selected from projects featured in daily updated international web magazines, specifically *ArchDaily* and *Archello*. Following this initial screening, more detailed documentation and materials are gathered for projects that have also been published in architectural journals. In addition, further case studies are compiled from the *world-architects.com* newsletter (eMagazine) and books containing a broad collection of contemporary architecture, such as *Sky is The Limit*.

2-2. Analytical Framework

The collected case studies will be examined through the following :

- A. Form (Overall Geometry and Surface Finish)
- B. Function (Program and Spatial Plan)
- C. Structure (Typology and Construction Method)
- D. Environment (Sustainability and Environmental Control)
- E. Relationship Between Parts and the Whole

To fully articulate the characteristics of seamless architecture, elucidating E (Relationship between parts and the whole) is considered particularly vital. However, as an initial phase, this paper focuses its analysis and reporting specifically on A (Form: Overall Geometry and Surface Finish).

※This paper is an English translation of an unpublished Japanese manuscript completed in June 2017, which was recently featured in the author's portfolio book, *Seamless Architecture of Fujiki Studio + F.A.D.S 2010–2026* (published in 2026), but remains unpublished in any academic journal.

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2-3. Research Goals

The ultimate goal of this series of studies is to elucidate the distinct characteristics of "seamless architecture" and, based on the findings, to subsequently establish a refined redefinition of the concept.

2-4. Objective and Scope of This Paper

The specific objectives of this paper are twofold:

1. To clarify the characteristics and trends of seamless architecture from an external perspective by analyzing projects through the lenses of "form" and "surface finish."
2. To devise an analytical methodology (specifically, indicators for quantifying form) to achieve this purpose.

The scope of this study consists of a total of 100 selected architectural works (Table 1). These cases were compiled from projects published up to September 2015 [Note 2] in *ArchDaily* and *Archello*, works featured in the book *The Sky is the Limit*, projects documented in Japanese architectural journals such as *Shinkenchiku*, *Shinkenchiku Jutakutokushu* (Residential Architecture), and *a+u* (Architecture and Urbanism), as well as structures visited firsthand by the author.

2-5. Reserved Matters and Limitations

At present, how to classify buildings where only the *interior* surfaces (ceilings, walls, and floors) are finished with an identical material remains a reserved matter; thus, they are excluded from the analysis in this paper.

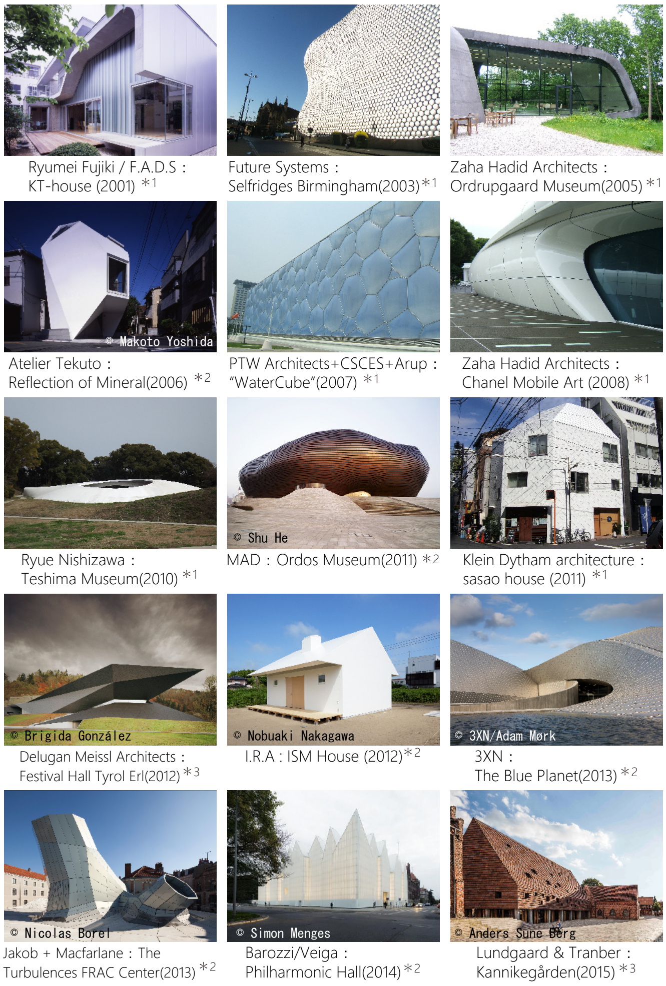

Fig.1 Examples of *Seamless Architecture*

3. Analysis of Form

At present, "seamless architecture" can be considered a concept independent of any specific form. This is because examples of seamless architecture can be identified across a wide variety of architectural geometries rather than being confined to a single typical shape.

3-1. Classification of Form

3-1-1. Classification by Formal Characteristics

The 100 collected case studies of seamless architecture were categorized into the following six types based on their architectural geometry and formal characteristics:

[I] Box Type (Gabled/Rectilinear) : This category comprises forms composed of cubes or rectangular parallelepipeds, including configurations where multiple boxes are combined. Generally, in a standard box model, the roof finish is difficult to visually perceive from the ground level. Consequently, its character as seamless architecture—in the sense that the exterior walls and roof are covered with the same material—tends to be less pronounced.

[II] House Type (Vernacular/Archetypal) : This architectural form features distinct roof shapes such as gables or shed roofs (monopitch roofs). When a house model manifests as seamless architecture, it typically lacks eaves, resulting in a form where the roof and walls connect without a visible boundary. This category also includes cluster configurations where multiple house forms are grouped together.

[III] Polyhedral Type : The overall geometry in this model is configured through a combination of regular or irregular polygons (flat planes).

[IV] Dome Type : The dome model represents the historically oldest form of seamless architecture, inherently characterized by an ambiguous boundary between the roof and the exterior walls.

[V] 2D Curved Surface Type (Folding Model) : Mathematically speaking, all surfaces (including planes) are two-dimensional. However, for the purpose of morphological classification, forms created by folding flat planes are designated here as the "2D curved surface model." Since buildings utilizing the design methodology known as "folding" fall into this category, it is also referred to as the folding model.

[VI] 3D Curved Surface Type : This model encompasses forms composed of surfaces that cannot be generated simply by folding flat planes, such as egg-shaped (ovoid) geometries or organic, fluid forms.

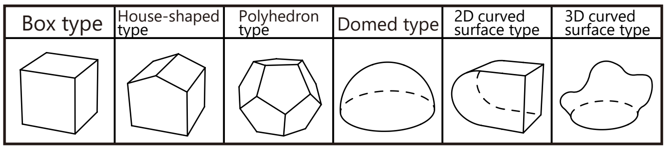

Fig.2 Classification by the feature of architectural form

3-1-2. Discussion: Formal Trends in Seamless Architecture

The Type [III] polyhedral model is the most prevalent, accounting for 37% of the total case studies. However, curved surface models also constitute a significant portion; when the 2D and 3D curved surface models are combined, they represent 36% of the cases, which is nearly equal to the Type [III].

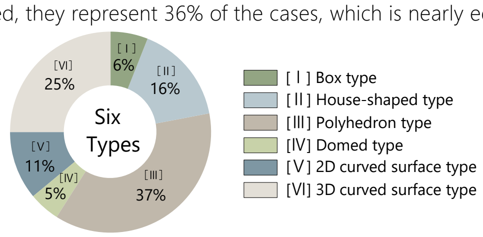

Fig.3 Percentage classified by the types of architectural form

3-2. Quantification of Form

In the previous section, the forms of seamless architecture were categorized into six models based on their morphological characteristics. To enable a more quantitative analysis, this section explores methods for the quantification of form. First, a brief overview of the quantification of form in mathematics is provided below.

3-2-1. Quantification of Form in Elementary Geometry

In elementary geometry, metrics for quantifying form include the number of vertices, edges, and faces. While these can be applied to box, house, and polyhedral models that possess distinct edges and flat surfaces, they cannot be applied to architectural forms with curved surfaces.

3-2-2. Topology

Topology is a branch of geometry that developed rapidly in the 20th century [2, 3, 4]. To avoid unnecessary complexity, the following discussion excludes non-orientable surfaces, such as the projective plane and the Klein bottle, as they are considered irrelevant to standard architectural spaces addressed in this study.

a. Genus [4]

In topology, when considering two distinct forms, if they are imagined as being made of a rubber-like material and can be stretched or contracted into the same shape without tearing or gluing, the two figures are considered identical (homeomorphic). Conversely, a sphere and a doughnut shape (referred to as a torus, which has a single hole in the center) cannot be transformed into the same shape no matter how they are deformed; thus, they are not topologically identical.

In this context, the number of holes in a figure serves as a key clue for classification. A sphere has 0 holes, a torus has 1 hole, and so on. This number of holes corresponds to a topological invariant known as the "genus" [Note 3]. According to the classification of closed surfaces in topology, every surface is homeomorphic to either a sphere or a torus of genus n. A surface with a genus of 2 or more—meaning it has two or more holes—is sometimes referred to as a "biscuit surface" [3] to distinguish it from a standard doughnut shape.

b. Connectivity [1]

Let F be a continuously connected 3D solid object. If F can be divided into two separate parts by making a single cut at an arbitrary location, the connectivity of F is defined as 0 (also referred to as simply connected). If a solid can be rendered simply connected by making $n+1$ cuts, the connectivity of that solid is defined as n.

For example, the connectivity of an apple is 0, whereas the connectivity of a doughnut (torus) with one hole is 1, as it requires two cuts to be completely divided into two separate pieces. For the standard 3D solid objects dealt with in architectural design, the aforementioned "genus" and "connectivity" are equivalent.

c. Euler Characteristic [1]

When a 3D solid F is a polyhedron, let S, E, and V denote the number of faces, edges, and vertices, respectively. If the connectivity of F is n, the following equation holds:

$$\chi = S - E + V = 2(1 - n) \tag{3-1}$$

χ is referred to as the Euler characteristic, or simply the Euler number.

The Euler characteristic can also be determined for figures that do not possess distinct vertices, edges, or faces (unlike polyhedrons) by appropriately applying simplicial decomposition [3]. The Euler characteristic of a sphere is 2, that of a torus with a single central hole is 0, and that of a biscuit surface with two holes is -2. While topologically identical figures share the same Euler characteristic, having the same Euler characteristic does not necessarily guarantee that the figures are topologically homeomorphic.

d. Betti Numbers [2]

When a closed surface K is decomposed into several connected closed surfaces, each separated component is called a connected component. The number of connected components of K, denoted as r, is defined as the 0-dimensional Betti number of the closed surface K and is written as $p_0(K)$. Next, the number of non-torsional principal cutting lines (essential cycles) on a closed surface K is defined as the 1-dimensional Betti number of K and is written as $p_1(K)$. The p_1 of a sphere is 0, whereas the p_1 of a torus of genus n is $2n$. Furthermore, the 2-dimensional Betti number p_2 for both a sphere and a torus of genus n is 1. Regarding the relationship between Betti numbers and the Euler characteristic, the following Euler-Poincaré formula holds:

$$\chi = p_0 - p_1 + p_2 \tag{3-2}$$

3-2-3. Proposal of the "Ridge Number"

Although the aforementioned Betti numbers are reportedly "applied to the analysis of complex curved surfaces such as biological tissues" [1], topology is fundamentally a branch of geometry that abstracts away fine morphological differences to "study figures based solely on the connectivity between points" [3]. Therefore, while it is useful for exploring the structure of the universe, it is inherently ill-suited for the analysis of architectural forms, where minute formal variations are of critical importance.

To address this limitation, this paper proposes the "Ridge Number"($\mathcal{R}$) as a metric applicable to both polyhedral and curved-surface architectural forms. The Ridge Number is defined as the total count of "ridges," where a "ridge" refers to a line formed by a collection of non-differentiable points on a three-dimensional solid object. In polyhedral architecture, this corresponds directly to the number of edges. Generally, in curved-surface architecture, a ridge represents sections that lack smoothness and are folded or sharp—akin to the ridgelines or crests of a mountain—as well as the boundaries (edges) of the form. The method for identifying and counting ridges and determining the Ridge Number on a curved surface is illustrated in the figure below.

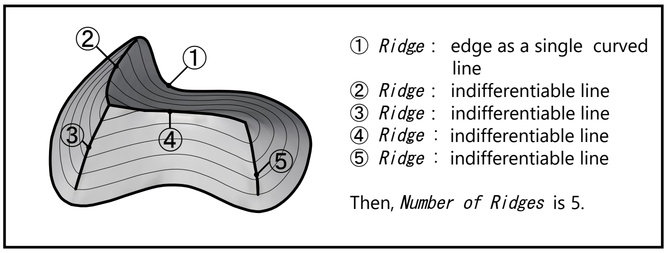

Fig.4 How to count *Number of Ridges* ($\mathcal{R}$)

The term "ridge" originates from the "Active Contour Theory (AC Theory)" [5, 6, 7] developed by Hara, Ashikawa, Fujii, et al. However, the concept of the "Ridge Number" ($\mathcal{R}$) has been newly devised by the authors. Furthermore, this study extends the conventional definition of a ridge so that it can be applied not only to curved surfaces but also to polyhedral geometries. (For a detailed definition of a ridge (R*) within the context of the Active Contour Theory, see Note 4). Although the Ridge Number of a building resembling a sphere suspended in mid-air would be 0, such a morphology is practically non-existent in actual architecture. Therefore, the *Ridge Number* is defined as a natural number greater than or equal to 1:

$$1 \leqq \mathcal{R} \quad (\text{where } \mathcal{R} \text{ is a natural number}) \qquad (3\text{-}3)$$

The *Ridge Numbers* (R) corresponding to the six morphological classifications based on formal characteristics are illustrated in Fig. 5.

Box type	House-shaped type	Polyhedron type	Domed type	2D curved surface type	3D curved surface type
R =12	R =15	R =n	R =1	R =6	R =1

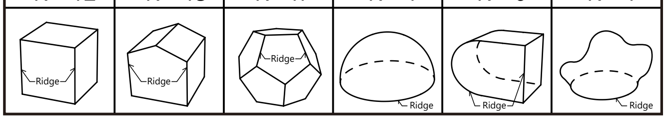

Fig.5 Examples of the *Ridge Number* ($\mathcal{R}$)

3-2-4. Treatment of Openings in the Calculation of the $\mathcal{R}$ [Note 5]

How openings are designed within seamless architecture is a significant research theme in its own right. However, this section focuses exclusively on how openings are treated when calculating the *Ridge Number*.

- (1) In calculating the *Ridge Number*, ridges around openings that can be considered as holes punctured within the same continu ous surface (including flat planes) are disregarded (Fig. 6).
- (2) Exceptionally, protruding elements such as the skylights of the Kunsthaus Graz exert a significant impact on the overall architec tural geometry; thus, the ridges of such protrusions are included in the *Ridge Number* count (Fig. 7).
- (3) Furthermore, fixed glass screens are morphologically more appropriate to treat as walls rather than conventional openings. Therefore, the ridges along the perimeter of fixed glass screens are included in the *Ridge Number* count (Fig. 7).

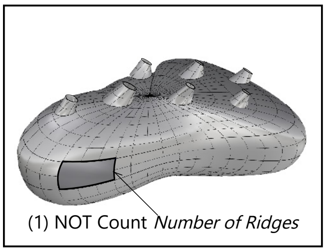

Fig.6 NOT Count *Ridges*

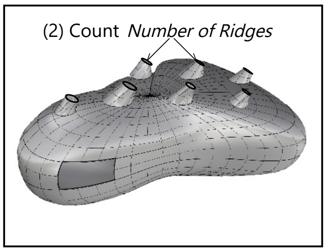

Fig.7 Count *Ridges*

3-2-5. Proposal of the "Curved Architecture Degree"

While an architectural form with a larger *Ridge Number* can be described as more polyhedral, this paper proposes the **"Curved Architecture Degree"** ($\mathcal{C}$) as an inverse indicator to determine how curved a form is. The *Curved Architecture Degree* ($\mathcal{C}$) is defined as the reciprocal of the *Ridge Number* ($\mathcal{R}$):

$$\mathcal{C} = \frac{1}{\mathcal{R}} \quad (\text{where } 0 < \mathcal{C} \leqq 1) \qquad (3\text{-}4)$$

Because the minimum value of the *Ridge Number* is 1, the maximum value of the *Curved Architecture Degree* is 1. Conversely, as the configuration becomes increasingly polyhedral, the *Ridge Number* approaches infinity ($\mathcal{R}\to\infty$), which causes the *Curved Architecture Degree* to approach 0 ($\mathcal{C}\to 0$). Therefore, the range is established as $0 < \mathcal{C} \leqq 1$.

A value of $\mathcal{C}$=1 represents a form with the highest degree of curvature.

3-3. Distribution of Works Based on $\mathcal{R}$ and $\mathcal{C}$

3-3-1. Distribution of $\mathcal{R}$ and Number of Works in *Seamless Architecture*

We shows the distribution in Fig. 8.

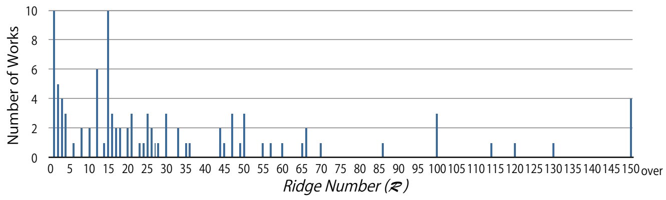

Fig.8 Number of works corresponding to the *Ridge Number* ($\mathcal{R}$)

3-3-2. Relationship Between Six Morphological Typologies and $\mathcal{R}$

While the forms were previously categorized into six models based on their formal characteristics, this section investigates how the *Ridge Number* and the number of works are distributed with in each typology.

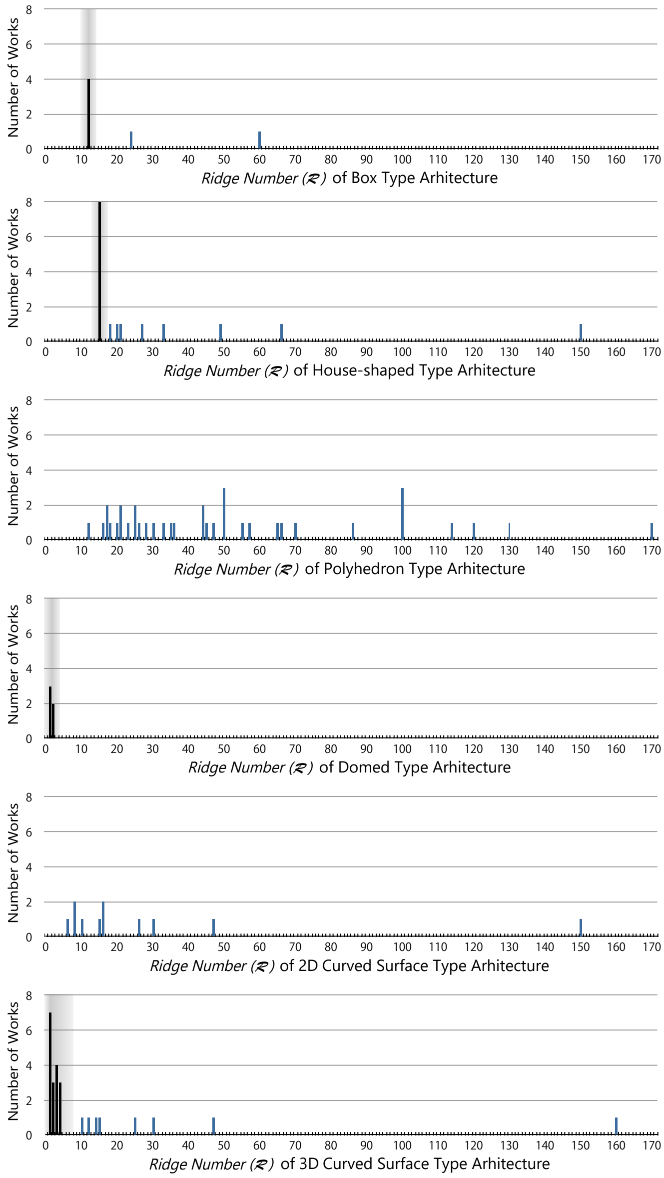

Fig.9 Number of works corresponding to the *Ridge Number* ($\mathcal{R}$) classified by the types of architectural form

For the house model, dome model, and 3D curved surface model, a clear correspondence with specific *Ridge Number* ranges was identified. Conversely, the polyhedral model exhibited a wide distribution of *Ridge Numbers* spanning a broad range.

3-3-3. Distribution of $\mathcal{C}$ and Number of Works in *Seamless Architecture*

The distribution of the *Curved Architecture Degree* ($\mathcal{C}$) and its corresponding number of projects is illustrated in Fig. 10. Note that the horizontal axis is plotted on a logarithmic scale. Additionally, the range representing a high degree of curvature is indicated by a gradient in the figure. (This range was back-calculated from the *Ridge Numbers* where projects are densely concentrated within the 3D curved surface model shown in Fig. 9. Furthermore, since a *Ridge Number* of 12 or greater increases the likelihood of a project falling into the box, house, or polyhedral models, a *Curved Architecture Degree* of approximately 0.1 or higher was deemed to be predominantly Curved Surface Type.)

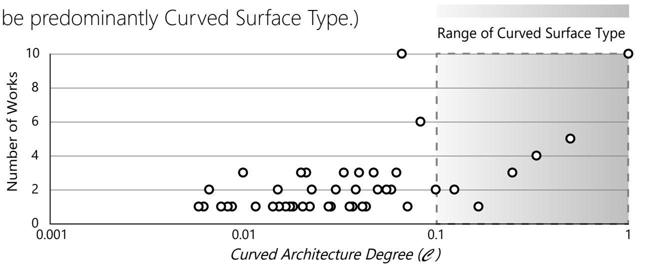

Fig.10 Number of works corresponding to *Curved Architecture Degree*

4. Surface Finish

4-1. Constraints on Materials and Construction Methods

As the surface finish requires the roof and exterior walls to be finished using the identical material and construction method, the selection of materials is strictly limited to those possessing waterproofing capabilities.

4-2. Classification of Overall Enclosure Methods

- [1] Monolithic Integration : This category comprises finishes, such as seamless coatings or plasters, that deliberately eliminate joints as much as possible to present the entire structure as a single, unified mass.
- [2] Tiling : This approach configures the entire surface by tightly laying components of the identical shape and material without any gaps.
- [3] Division : The overall form is segmented into finely divided components that conform to the geometry of the building. Here, the joints themselves play a crucial role in the architectural design. Generally, these segments do not retain a uniform shape and are often curved, though they may occasionally be approximated using flat, planar components.

Fig.11 A way of the surface finish of *Seamless Architecture*

5. Conclusion

5-1. Compilation of the Summary Table

Table 1 [Right Figure] presents a comprehensive summary table compiling the 100 examined case studies, categorized according to the following metrics:

No.	Name of Work	Complete	Form Type	$\mathcal{R}$	$\mathcal{C}$	Covering Way
1	KT-house	2001	2D	8	0.125	Tiling
2	Natural Ellipse	2002	3D	2	0.500	Monolithic
3	Dragspelhuset	2002	3D	1	1.000	Monolithic
4	Kupla the Bubble	2002	3D	2	0.500	Division
5	Palais de l' Equilibre	2002	Dome	1	1.000	Division
6	Selfridges Birmingham	2003	3D	3	0.333	Tiling
7	Graz Art Museum	2003	3D	25	0.040	Division
8	ARCAM	2003	2D	10	0.100	Division
9	TiFS ingegneria	2004	2D	8	0.125	Division
10	Casa da Musica	2005	Polyhedron	47	0.021	Tiling
11	Barn House	2005	House-shaped	15	0.067	Tiling
12	Allianz Arena	2005	Dome	2	0.500	Division
13	Booster Pump Station East	2005	Polyhedron	35	0.029	Monolithic
14	Ordrupgaard Museum Extension	2005	2D	30	0.033	Monolithic
15	Winter Bathing Ship	2005	2D	26	0.038	Monolithic
16	Reflection Mineral	2006	Polyhedron	25	0.040	Monolithic
17	Haus W	2006	Polyhedron	21	0.048	Tiling
18	Leonardo Glass Cube	2007	Box	12	0.083	Monolithic
19	Theatre Agora	2007	Polyhedron	55	0.018	Tiling
20	Watercube Beijing	2007	Box	12	0.083	Division
21	Pabellón Cultural	2008	Polyhedron	86	0.012	Tiling
22	Shenzen Grand Theatre	2008	3D	1	1.000	Tiling
23	Alpine Capsule	2008	3D	1	1.000	Monolithic
24	Barnhouse Dental Bovensmilde	2008	House-shaped	15	0.067	Tiling
25	House in Leiria	2008	House-shaped	15	0.067	Monolithic
26	GAB Maison Ternat	2008	House-shaped	15	0.067	Tiling
27	Shell / Kotaro Ide	2008	2D	15	0.067	Monolithic
28	Seashore Shell House	2008	Polyhedron	57	0.018	Tiling
29	Chanel Mobile Art	2008	3D	3	0.333	Division
30	Blob vB3	2009	3D	1	1.000	Monolithic
31	AU Hothouse	2009	Dome	1	1.000	Division
32	Autonomous Alpine shelter	2009	Polyhedron	25	0.040	Tiling
33	Hoto Fudo	2009	3D	3	0.333	Monolithic
34	Shiv Temple	2010	House-shaped	27	0.037	Monolithic
35	Tsubomi House	2010	Polyhedron	18	0.056	Tiling
36	Art Warehouse	2010	2D	6	0.167	Monolithic
37	Die Besorger Agency	2010	Polyhedron	28	0.036	Monolithic
38	Mirrorcube	2010	Box	12	0.083	Monolithic
39	Winnipeg Skating Shelters	2010	3D	30	0.033	Monolithic
40	Guangdong Museum	2010	Box	24	0.042	Tiling
41	The Finnish Pavilion	2010	3D	4	0.250	Tiling
42	Lleida Airport	2010	2D	16	0.063	Tiling
43	Teshima Art Museum	2010	Dome	2	0.500	Monolithic
44	27 Dwelling	2011	House-shaped	15	0.067	Monolithic
45	DC 2 Residence	2011	House-shaped	15	0.067	Tiling
46	Shanghai Sports Center	2011	Polyhedron	170	0.006	Division
47	Starhill Gallery	2011	Polyhedron	130	0.008	Tiling
48	Tel Aviv Museum of Art	2011	Polyhedron	45	0.022	Division
49	Tianmen Mount.Restaurant	2011	Polyhedron	50	0.020	Division
50	Vanke Triple V Gallery	2011	Polyhedron	33	0.030	Tiling
51	The Lemon and Triplings	2011	3D	47	0.021	Monolithic
52	Two Single Houses	2011	Polyhedron	44	0.023	Monolithic
53	The POD Exhibition Hall	2011	2D	150	0.007	Division
54	Ordos Museum	2011	3D	3	0.333	Tiling
55	K House	2011	Polyhedron	21	0.048	Tiling
56	Museum of Liverpool	2011	Polyhedron	17	0.059	Tiling
57	Ark Nova	2011	3D	1	1.000	Monolithic
58	Chiyoda Dental Clinic	2011	Polyhedron	16	0.063	Monolithic
59	La Ville Intelligente	2011	3D	1	1.000	Division
60	Standing Knights	2011	Polyhedron	50	0.020	Monolithic
61	Trollwall Restaurant	2011	Polyhedron	23	0.043	Tiling
62	sasao-house	2011	House-shaped	20	0.050	Tiling
63	OCT Design Museum	2011	3D	2	0.500	Tiling
64	Jean Cocteau Museum	2011	Box	12	0.083	Monolithic
65	Biodiversity Center	2011	Polyhedron	114	0.009	Monolithic
66	Riverside Museum	2011	House-shaped/3D	66	0.015	Tiling
67	Chongqing Clubhouse	2012	Polyhedron	17	0.059	Tiling
68	House in Isumi	2012	House-shaped	21	0.048	Monolithic
69	Umwelt Arena	2012	Polyhedron	66	0.015	Tiling
70	House Husarö	2012	House-shaped	18	0.056	Tiling
71	Peoples Meeting Dome	2012	Polyhedron	100	0.010	Tiling
72	Porsche Pavilion	2012	3D	4	0.250	Monolithic
73	The North Rhine	2012	Polyhedron	100	0.010	Tiling
74	Stadtvillen	2012	Polyhedron	12	0.083	Tiling
75	Eye	2012	Polyhedron	70	0.014	Tiling
76	Heydar Aliyev Center	2012	3D	15	0.067	Division
77	Kaap Skil	2012	House-shaped	33	0.030	Division
78	Festival Hall in Erl	2012	Polyhedron	30	0.033	Tiling
79	House B in B	2013	House-shaped	15	0.067	Tiling
80	Crossed House	2013	2D	16	0.063	Monolithic
81	Wood Sculpture Museum	2013	3D	12	0.083	Division
82	Rock Gym for Polur	2013	Polyhedron	120	0.008	Tiling
83	Autobahnkirche	2013	Polyhedron	50	0.020	Monolithic
84	Dome of Visions	2013	Dome	1	1.000	Division
85	FRAC Center	2013	3D	160	0.006	Division
86	Portable House ÁPH80	2013	House-shaped	15	0.067	Monolithic
87	The Exbury Egg	2013	3D	1	1.000	Monolithic
88	Socio Cultural Center	2013	Polyhedron	36	0.028	Tiling
89	The Blue Planet	2013	3D	10	0.100	Tiling
90	Dapeng Geology Museum	2014	Polyhedron	65	0.015	Tiling
91	House VDV	2014	House-shaped	49	0.020	Tiling
92	Tagus Gás Headquarters	2014	Polyhedron	44	0.023	Monolithic
93	Serpentine Galleries Pav.	2014	3D	14	0.071	Monolithic
94	Zhonghe Sports Center	2014	Polyhedron	26	0.038	Tiling
95	House for Contemporary Art	2014	Box	60	0.017	Monolithic
96	Hwa Hun	2014	Polyhedron	100	0.010	Tiling
97	New Civic Centre	2014	2D	47	0.021	Tiling
98	Philharmonic Hall	2014	House-shaped	150	0.007	Tiling
99	Algard Church	2015	Polyhedron	20	0.050	Tiling
100	Vanke Pavilion	2015	3D	4	0.250	Tiling

Table 1 A list of 100 examined of *Seamless Architecture*

1. Morphological classification of the overall form based on formal characteristics
2. Ridge Number ($\mathcal{R}$)
3. Curved Architecture Degree ($\mathcal{C}$)
4. Classification of the overall enclosure method regarding the surface finish

5-2. Future Research Directions (Regarding the Calculation of $\mathcal{R}$)

Based on the research findings obtained thus far, the following points are identified as key issues for future investigation, focusing primarily on the refinement of the *Ridge Number* calculation:

- (1) Treatment of Multi-Structure Ensembles: How to systematically address architectural projects that consist of a cluster or complex of multiple distinct buildings.
- (2) Handling of Appendages and Connected Volumes: Determining the appropriate methodological approach for handling architectural appendages such as bridges (e.g., Selfridges Birmingham) or cases where separate volumes with entirely different geometries are interconnected (e.g., Kunsthaus Graz).
- (3) Structural Variations within Curved Models: Addressing cases where certain "curved models" inherently yield a large *Ridge Number* depending on their specific geometric configuration (e.g., Heydar Aliyev Center).
- (4) Hybrid Geometries: Investigating complex architectural forms that simultaneously exhibit both curved and polyhedral characteristics (e.g., FRAC Centre).
- (5) Limitations of a Single Metric for Highly Complex Forms: Acknowledging that as architectural geometry increases in complexity, it becomes increasingly difficult to accurately discern and characterize specific formal features using the *Ridge Number* alone.

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Notes

[Note 1]
In this paper, concepts, indicators, and terms newly discovered or devised by the authors are enclosed in double quotation marks in the English version (and indicated with angled brackets "〈 〉" in the Japanese text). However, in the English captions of figures, tables, and photographs, italics are used without double quotation marks to avoid unnecessary complexity.

[Note 2]
The reason for setting a specific time limit for the architectural works to be collected was that, because new examples of seamless architecture are emerging daily, it was necessary to temporarily halt the collection process to proceed with the analysis. In recent years, the number of seamless architectural works among major award-winning projects has been increasing. For instance, the Philharmonic Hall Szczecin by Barozzi/Veiga, which won the 2015 Mies van der Rohe Award (EU Prize for Contemporary Architecture), as well as one of the five finalist projects for the same award in 2016, are classified as seamless architecture (the bottom-center and rightmost works in Fig. 1).

[Note 3]
For non-orientable surfaces whose true forms can only be visualized in a four-dimensional space, such as a projective plane or a Klein bottle, the meaning of the genus differs from the "number of holes."

> "In general, let us consider n distinct circular disks on a sphere, discard the interiors of these disks (thereby creating holes), and attach one Möbius strip to the boundary circumference of each disk (resulting in a total of n strips). The non-orientable surface thus constructed is called a non-orientable surface of genus ***n***. [...] A non-orientable surface of genus ***n*** has an Euler number of $\chi=2-n$." (Reference [3], pp. 128–129)

[Note 4]
In general, except for cases where a geometric figure can be explicitly represented by an equation, a vast amount of information contained within a shape can only be demonstrated in a simplified manner by replacing it with another figure. The ridge (R^*) in Active Contour Theory can be understood as an extraction of the essence (central concept) of a potential surface—which should originally be represented in a 3D display—by transforming it into a 2D contour geometry and subsequently condensing it into 1D linear information.
Because this paper proposes the ridge and the Ridge Number as clues for classifying the diverse morphologies of seamless architecture, it shares a commonality with Active Contour Theory in that a ridge represents a set of non-differentiable singular points on a curved surface. However, its intended architectural meaning differs somewhat from the ridge (R^*) defined above in Active Contour Theory.

[Note 5]
In calculating the *Ridge Number*, the architectural morphology is evaluated macroscopically to determine whether an element constitutes a "ridge." Evaluating macroscopically means, for example, that if there is an overhanging roof or floor slab, the slab actually possesses thickness, making the physical shape of its leading edge rectangular. Evaluating this purely from a microscopic perspective would increase the *Ridge Number* by 4 at the edge alone. Therefore, when calculating the *Ridge Number*, the thickness of the slab is disregarded, and it is treated as a single thicknessless plate, counting the tip as only one ridge. This is because a microscopic calculation would cause the *Ridge Number* to increase infinitely, thereby failing to fulfill its original purpose as a morphological classification indicator.

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