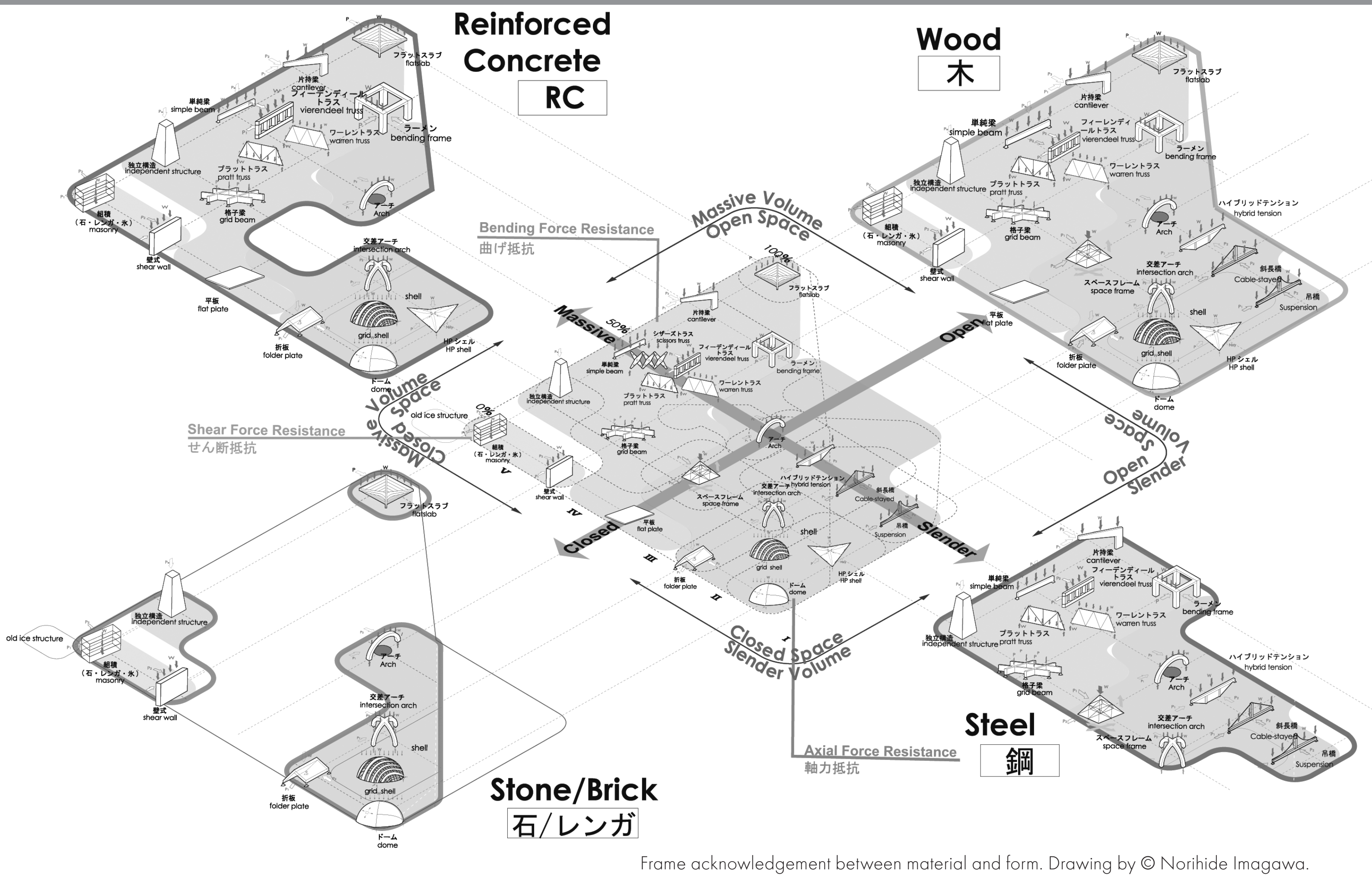
Finding Modern Japanese Bridges: Stone, Wood and Steel



Frame acknowledgement between material and form. Drawing by © Norihide Imagawa.

IN Japan where many earthquakes occur there is a certain standpoint about long-life architecture and bridges. The relation between material and form is important for this standpoint. The reason is not only that materials have their own character, for example, physical and chemical properties, but also that form has its own individual character as load-bearing system. Without the relation between material and form, long-life architecture and bridges can't be realized.

By Norihide Imagawa and Shinsuke Suematsu

WHEN we recognize construction space, we use the design acknowledgement diagram between space and framework. This diagram expresses with Cartesian coordinate the sense of openness and massiveness about more than 20 kinds of basic framework designed in past and present.

The load-bearing systems of form include three mechanical properties as follows; axial force resistance, bending force resistance and shear force resistance.

The materials of constructions and bridges include stone, wood, iron, and concrete. Each character of these materials is as follows;

Stone	Axial force resistance
Wood	Axial force resistance, bending and shear force resistance
Iron	Bending force resistance
RC	Axial force resistance and bending force resistance

The load-bearing systems of bridges are as follows;

Arch, Cable-stayed and Suspension	Axial force resistance
Girder, truss and bending-frame	Bending force resistance
Masonry	Shear force resistance

These relations between material and form are understood by the frame acknowledgement between material and form.

Some bridges represented by each material are to be handed on to the next generation and estimated according to five points as follows:

1. *Material resistance* corresponds exactly to *form resistance*.
   This means that it can be ensured consistency between resistance systems appropriated for material characters and form.
2. No disturbance of the environment.
   It matches its environment or not.
3. Beautiful proportion and form.
   It has the balance bridge's structure and beauty of form.
4. Continuity of function, connection of places between bridges.
   This means that the bridge has a role for its community and a continuity of space.
5. Characteristics of bridge and construction method.
   Is the bridge suitable for its location or not? Consideration of economic efficiency of bridges.

Some bridges as we shortly will discuss are still as Modern bridges in existence and selected as designated bridges and cultural heritage by government or prefecture.

Ryuzu-bashi Bridge
Kitsuki-shi, Oita.
Material: Stone. Stone Girder Bridge. L: 61.5m. W: 3.0m
Completion: 1912

© Photo from Japan society of civil engineers.

This oldest Japanese sinkable bridge in existence was awarded as civil engineering heritage in 2007 by Japan society of civil engineers. The material resistance system, stone, corresponds to the resistance structure of its form, a girder bridge. This bridge blends in with the surrounding nature and does not disturb the surrounding nature. Normally the bridge insists on its own structure, but this bridge accommodates itself to its environment. It shows its significant existence and situation. It is special worth to mention that this bridge excels frame acknowledgement in 3 points (1, 2 and 4).

Torii-bashi Bridge
Innai town, Usa-shi, Oita.
Material: Stone. Five Arch Stone Bridge. L: 55.2m. W: 4.4m
Completion: 1916
Design: Seiichiro Tsuru, Stonemason: Shinnosuke Matsuda

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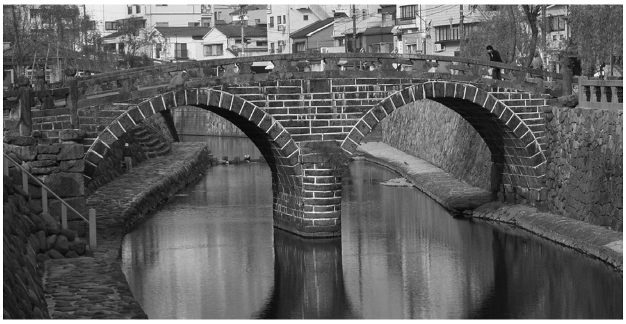
Innai town has the most number of stone bridges. The river which flows from south to north and its branch form a deep valley so villages are scattered along the river and wooden bridges are swept away by rapid flows. Shinnosuke Matsuda, called King of stone bridge, was a master builder that had learned the technique of arch bridges. He designed the Torii-bashi Bridge with various spans and different heights. The 1951 Ruth typhoon made the river overflow and the water level dropped 12 m. There was no damage to the bridge thanks to the good ground and bridge pier designed for the feature of water flow. The resistance system of its material, stone, corresponds with the resistance structure of its form, arch. This bridge has an indispensable presence of the stone bridge family and as a sightseeing resource. This bridge excels the frame acknowledgement in 5 points (1, 2, 3, 4 and 5).

Megane-bashi Bridge

Nagasaki-shi, Nagasaki.
Material: stone. Double Arch Stone Bridge. L: 23.2m. W: 4.70m
Completion: 1634. Collapse of the bridge by flood: 1647
Half collapse of bridge by Nagasaki heavy rain and mudflow: 1982



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This bridge is appointed national cultural asset and is famous as one of the oldest stone bridges in Japan utilizing a traditional Chinese construction technique. The bridge was severely damaged by Nagasaki heavy rain and mudflow 1982, therefore the rebuild bridge was located between tunnel waterways on both sides to protect it for the next flood. The resistance system of its material, stone, corresponds with the resistance structure of its form, arch. It is a pioneer of presence of stone bridge family and has an important role in this area. It is worthy of special mention that this bridge excels the frame acknowledgement in four points (1, 2, 3 and 4).

Tamaru-bashi Bridge

Uchiko town, Kita-gun, Ehime.
Material: Wood. Wood Girder Bridge roofing with cedar bark reinforced by using angle brace. L: 15m. W: 2m
Completion: 1943

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This bridge was awarded as heritage of civil engineering 2002 by Japan society of civil engineers. The resistance system of its material, wood, corresponds with the resistance structure of form, girder reinforced by the use of angle brace. Every wood bridge roofing except for this bridge across the Fumoto river has been swept away. The inhabitants of the district has refurbished this bridge and has controlled it carefully. This wooden bridge has an indispensable presence of existence that doesn't disturb the landscape. This bridge excels the frame acknowledgement in 2 points (1 and 2).

Hourai-bashi Bridge

Shimada-shi, Shizuoka.
Material: Wood. Wood Girder Bridge. L: 897.4m. W: 2.7m
Completion: 1897. Modification of concrete pier: 1965
Post-disaster construction and damage repair: 2005

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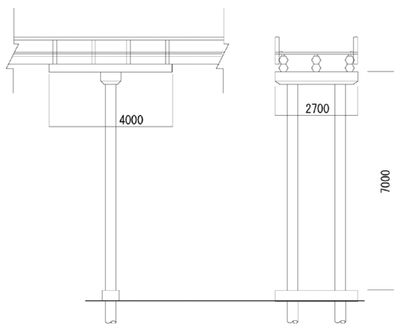

This bridge has been recorded in the Guinness Book of World Records as the longest wooden footbridge. The resistance system of its material, wood, corresponds with the resistance structure of its form, girder. Although this bridge has passed away by rise of water level, it has been restored every time. Its piers were replaced with concrete piles after the overflow of river in 1965. For the harmony with the landscape, the concrete piles were covered with wooden panels. This wood bridge fits exactly into the landscape. This bridge excels the frame of acknowledgement in 3 points (1, 2 and 4).

Hachiman-bashi Bridge (Dansei-bashi Bridge)

Koutou-ku.
Material: Wrought iron, Cast iron. Single Span Bowstring Truss Bridge.
L: 15.2m. W: 2m
Completion: 1878 Momiji-gawa. Relocation: 1929, Fuka-gawa
Design: Souichirou Matsumoto

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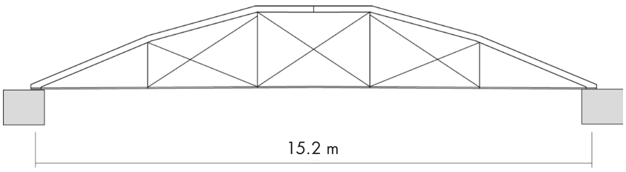
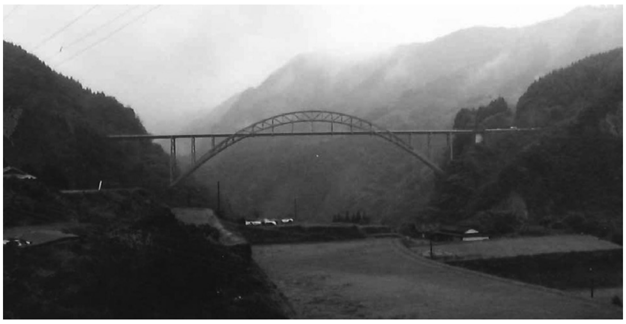


This bridge has been appointed a national cultural asset and a Japan historic civil engineering landmark by American society of civil engineers. Akabane factory, ministry of land infrastructure, manufactured originally this bridge on the basis of American engineering patent. It bridges across Momiji River as a symbol of cultural enlightenment. The new Dansei Bridge was constructed on the north of the old Dansei Bridge according to revised city development in 1912. The old Dansei Bridge was laid in ruins according to the earthquake disaster reconstruction for the great Kanto earthquake in 1923 and was relocated in Fuka-gawa. The arch members of this bridge are manufactured with wrought iron and tension members are of cast iron. At transition period from wrought iron to cast iron, to put the right material in the right member, the resistance system of the material corresponds to the resistance structure of its form, bowstring truss bridge. This bridge excels the frame acknowledgement in 1 point (1).

Naidaijin-kyo Bridge

Misato town, Shimomashiki-gun.
Material: Steel. Truss Arch Bridge. L: 199.5m. W: 5.5m
Completion: 1963. Design: Kumamoto regional forestry office



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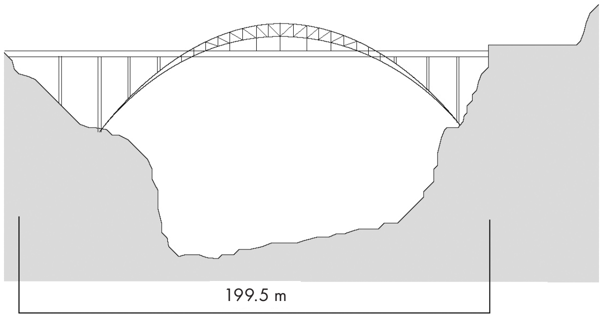
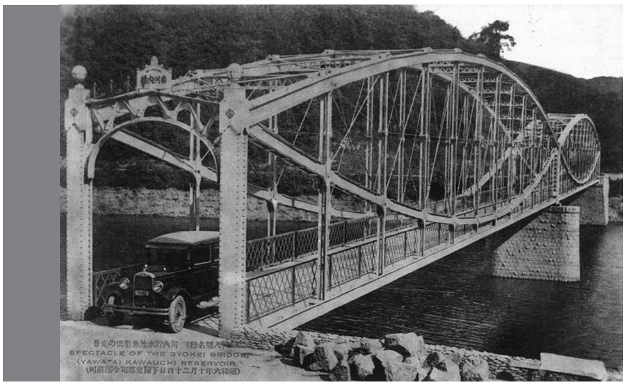


This bridge was constructed across the Naidaijin valley to support the development of local forest resources. At the time it was the longest arch bridge in the East, later renewed in railing and paint. Crossing the Midori River is also the Ayunose Bridge which has Y-formed piers and cable-stayed form and the Tsujyun Bridge, famous as a stone navigable aqueduct and a sightseeing resource. The resistance system of the material, steel, corresponds with the resistance structure of its form, truss arch bridge. The design and the fine form like floating on air display various looks in response to seasons change of surroundings. This bridge excels the frame acknowledgement in 3 points (1, 2 and 3).

Minamikouchi-bashi Bridge

Kitakyusyu-shi, Fukuoka.
Material: Steel. Lenticular Truss Steel Bridge. L: 133m. W: 3.1m
Completion: 1926. Design: Hisanori Numata, Motojiro Adachi, Saburo Nishijima(Yahata steel plant)



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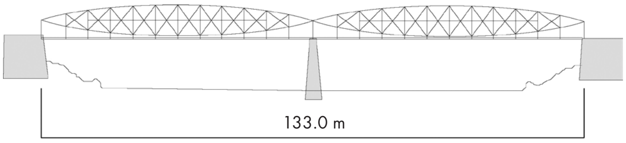

This bridge is the only one across the reservoir that ensures stable water supplies for Yahata factory. It is appointed national cultural asset and the heritage of civil engineering 2000 by Japan society of civil engineers. The form of the structure is composed of two curved-chord trusses turning up and down and the vertical members from which the deck is hung. The resistance system of its material, steel, corresponds with the resistance structure of its form, truss arch bridge with rational components. It is red colored as symbol and contrast favorably to the blue sky and the green forest. This bridge excels the frame acknowledgement in 3 points (1, 3 and 5).

Eitai-bashi Bridge
Cyuou-ku, Tokyo.
Material: Steel. Tied Arch Steel Bridge. L: 184.7m. W: 25m
Completion: 1926. Design: Yutaka Tanaka (original), Yoshitada Takenaka, (Mamoru Yamada, Bunzo Yamaguchi), Tokyo reconstruction bureau.
Manufacture: Kobe Kawasaki dockyard.
Construction: Futomarugumi, Hazamagumi

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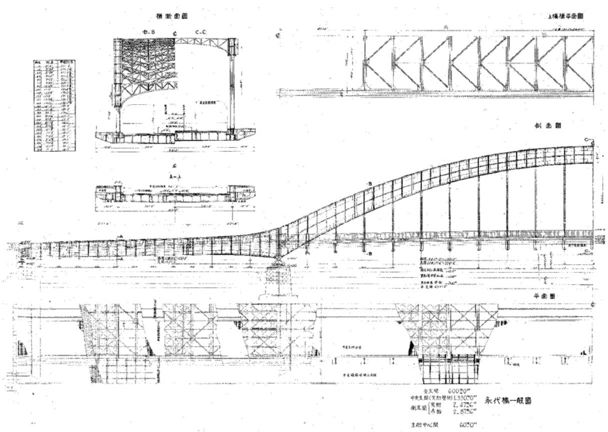

Kiyosu-bashi Bridge
Cyuou-ku, Tokyo.
Material: Steel. Suspension Steel Bridge. L: 186.3m. W: 22m
Completion: 1928. Design: Seiichi Suzuki (Mamoru Yamada, Bunzo Yamaguchi), Tokyo reconstruction bureau. Manufacture: Kobe Kawasaki dockyard

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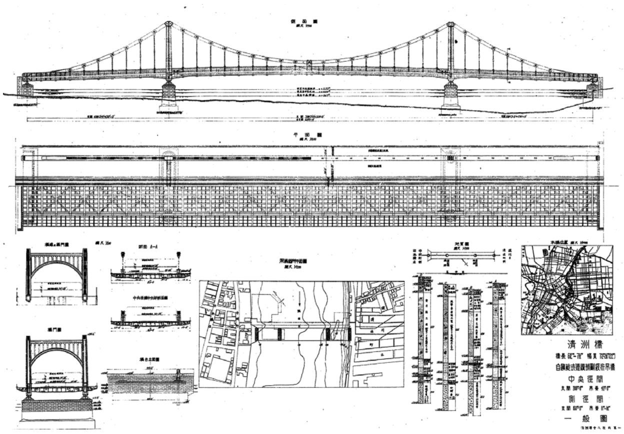

These two bridges are appointed national cultural asset and heritage of civil engineering 2000 by Japan society of civil engineers. Eïtai Bridge has been called the gate of Teito Tokyo and Kiyosu Bridge was called the flower of earthquake disaster reconstruction. These bridges took the central role in Tokyo reconstruction as the Twin Gates. The design introduced new technologies, for example to use high-strength steel like the German bridges. The resistance system of the materials of the bridges, steel and high-strength steel, corresponds with the resistance structure of its forms, tied arch and suspension. These are not only the main bridges across the Sumida River, but also symbols of Tokyo city. This bridge excels the frame acknowledgement in 5 points (1, 2, 3, 4 and 5).

Hijiri-bashi Bridge
Chiyoda-ku, Tokyo.
Material: R. Concrete. Arch Bridge. L: 92.5m. W: 22.0m
Completion: 1927. Design: Mamoru Yamada, Katsutake Naruse

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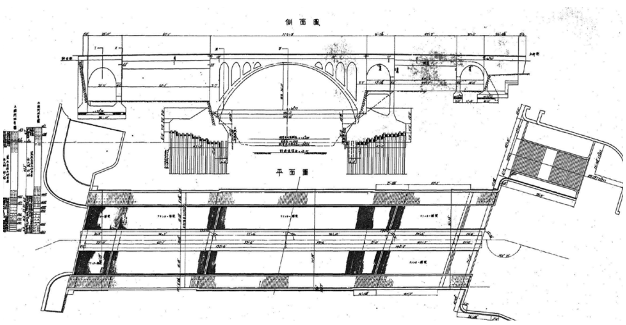

A Teito reconstruction after the Great Kanto earthquake by Mamoru Yamada, a Japanese Modern architect. The design, modelled with bold parabola, is in large part thanks to him. The resistance system of the reinforced concrete corresponds to the resistance structure of its form, arch. This bridge is not only an image of the site, but also a part of the arterial roadway. It excels the frame acknowledgement in 3 points (1, 3 and 4).

Bandai–bashi Bridge
Niigata–shi, Nigata.
Material: R. Concrete. Six Arch Bridge. L: 306.9m. W: 21.9m
Completion: 1886. Wooden bridge:1909, 1929
Design: Takeo Fukuda, Mamoru Yamada, Yutaka Tanaka (supervisor), Reconstruction bureau, Ministry of interior

Appointed national cultural asset and well–established as symbol of Niigata, the reinforced concrete resistance system corresponds with the resistance of its form, arch. In addition, this design is made with consideration to strength and aesthetic form by rolling back at the center of arch drawn loose parabola. The foundations were built with the pneumatic caisson method for the first time with only Japanese people. The Niigata Earthquake in 1964 made part of the bridge sink only 10 cm. The original illuminating lamp was restored by local citizens with zeal. The importance of this bridge is rediscovered by the local area. This bridge excels the frame acknowledgement in 5 points (1, 2, 3, 4 and 5).

In conclusion, the bridges with each material which should be handed on to the next generation can be realized as long–life constructions because they have the balance of material and form: stone for axial resistance; wood for axial and bending resistance; steel for bending resistance; concrete for axial and bending resistance. Through maintenance of steel and concrete and with wood replacement, bridges can gain long–life authenticity. We can plot these 13 bridges on the frame acknowledgement between material and form.

References

Imagawa, Norihide, "Design Epistemology to recognize the performance", docomomo Japan NSC Technology Conference, May 10-11 2008, Kyoto, 197-202.

Futagami, Kenji, "Stone bridges in Innai-cho of Oita-ken", Scent of Civil Engineering Inheritance, Consultant, Japan Civil Engineering Consultant Association, April 2003, vol. 219, 56-57.

Yasunori, Arai, "The roots of stone bridges", Heritages of Civil Engineering, Consultant, Japan Civil Engineering Consultant Association, January 2007, vol. 234, 24-27.

Japan Bunri Univ. Kono Lab. Sinkable bridges http://www.nbu.ac.jp/~kono/5.htm

Flow bridge http://www1.harenet.ne.jp/~wawa/B/EnglishNagarebashi.htm

Japan society of civil engineers http://www.jsce.or.jp/

Planning Office M http://www.kinomise.com/

JSCE Library, Japan Society of Civil Engineers http://www.jsce.or.jp/library/index.html

Ministry of Land, Infrastructure and Transport http://www.mlit.go.jp/

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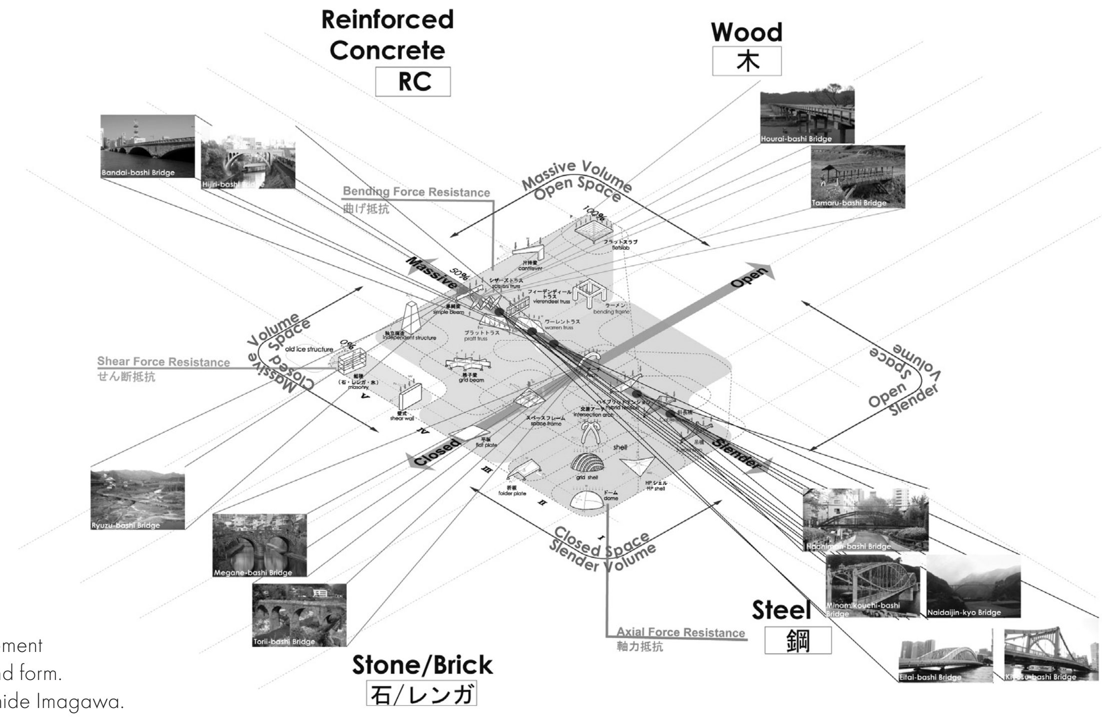

Frame acknowledgement
between material and form.
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