# Study on Side Shading Optimization with Expanded Metal in Kitakyushu

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エキスパンドメタル，影，パッシブデザイン，庇

## 1. Background and purpose

In 2016, The University of Kitakyushu has been built Institute of Environmental Science and Technology building (figure 1). The function of this building is to improve the learning facilities for some experimental laboratories in this campus complex. The orientation of windows opening of the building are north and south direction. There are no windows facing east and west direction. This building will be operate on April 2017.

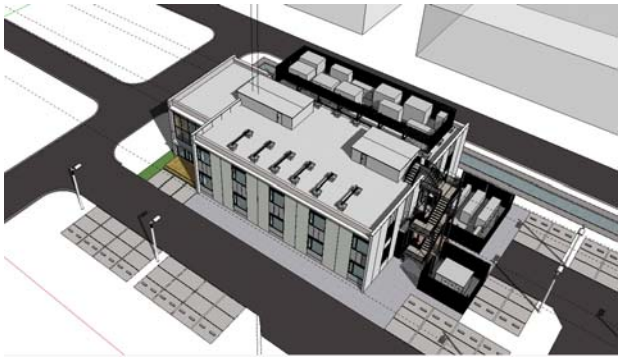


Fig 1. Design of Building

As part of the green building concept, the original building design need to be improve. One of the improvement that need to be done was optimizing the energy efficient of the building and increasing the visual comfort.

## 2. Method

In this research, the analysis was done by comparing each type of shading base on the number of shadow fall into the south windows area on peak summer time which is 22 August from 09:00 AM to 14:00PM.

### 2-1. Location of study

This building is located in the Kitakyushu city area with altitude 33.88 and longitude 130.71 (figure 2). The solar radiation that need to be block in summer are in the south orientation, while the north side doesn't need to be blocked. The building orientation is 19 degree from north direction.

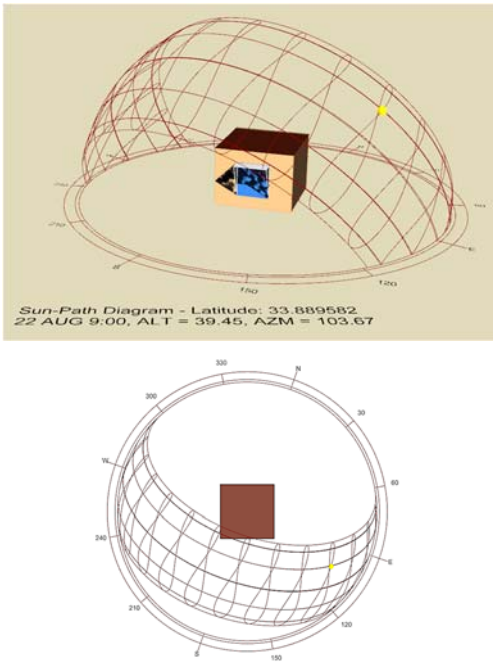



Fig 2. Site Location and Building Orientation

### 2-1. Design Improvement

The original building was designed without any shading device, but to improve the energy performance and visual comfort for this building, the architect introduce shading device (figure 3). Outside shading is one of passive design strategy that have the optimum effect on reducing direct solar radiation, because it will prevent direct radiation from entering the interior room or heating the window glass which will also cause heat load from conduction of glass material. In this design, the architect use not only horizontal shading (overhang) but also use side

shading to improve the performance. The economic aspect effect from this approach was additional budget for construction, although it's not much because of the material selection for the shading. Main concerns in this improvement of design were aesthetic and budget.

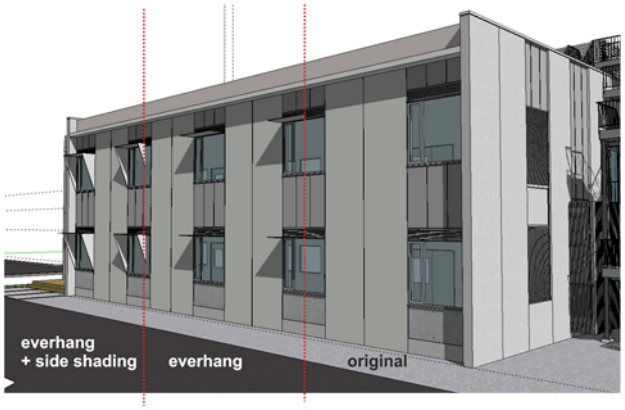



Fig 3. Shading device

### 2-3. Side Shading Material

In this study, the expanded metal were being used to find the maximum area of shadow casting in the window with minimum material. Expanded Metal is produced from solid sheets or plates of carbon, galvanized and stainless steel, as well as aluminum and a variety of alloys of copper, nickel, silver, titanium and other metals. Because expanded metal is made from a solid sheet of metal, and it is not woven or welded - it can never unravel.

To produce expanded metal, a sheet or plate is simultaneously slit and stretched. This process expands the cuts into diamond shaped holes of uniform size and shape. Because no metal is lost in the expanding process, expanded metal is cost effective and saves energy by conserving material and allowing the fabrication to go further and do more. Another consideration when ordering expanded metal mesh panels is the actual metal strand width and metal strand thickness. These are important because they contribute the actual opening size of the diamond and the % open area or visibility through the expanded metal sheet.

The physical characteristic of expanded metal can be seen in figure 4. The use of expanded metal were because of the fact that the design need light and functional material but still have aesthetic factor. Compare to the plate metal, the weight of expanded metal are lower than solid plate, it`s about 20% - 80% depend on the type of the expanded metal.

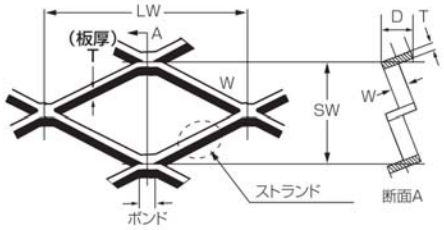



Fig 4. Expanded Metal

SW: Distance between centers in direction of short mesh

LW: Distance between centers in direction of long mesh

T: Plate thickness

W: Step width

### 2-4. Shadow Simulation

In this research, expanded metal models were built parametrically based on different SW, LW, W and Bond in a Grasshopper 3D software inside Rhinoceros 3D. There were many variation that can be built with Grasshopper software, but in this research, the geometry were limited to standard and grating type of expanded metal. The position of sun was determine by inputting location from climate data using Ladybug plugin inside Grasshopper 3D. The shadow simulation from expanded metals geometries were projected to the window area and wall area using mesh shadow component from grasshopper 3D. It works based on the vector location of the sun at certain date and time, and the orientation of windows where in this case the orientation of windows were already decided.

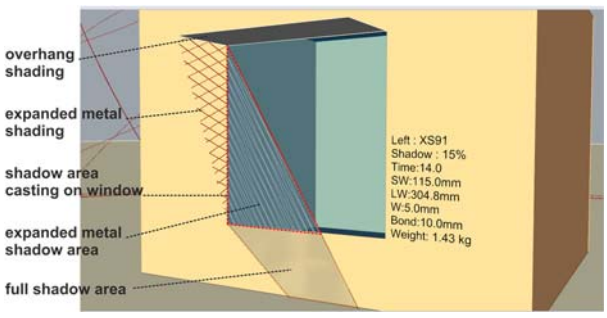



Fig 5. Shadow simulation method

The percentage shadow casting in window area for each expanded metal shading can be utilize from the ratio between shadows area that casting on glass using expanded metal with the glass area that should be fill with shadows when using solid flat metal.

### 3. Data and Analysis

Data of shadow casting in the windows from simulation were compared to get the best possible type of expanded metal (figure 6-7). There are 27 types of expanded metal that available on the market based on JIS G3351 (standard type and grating type).

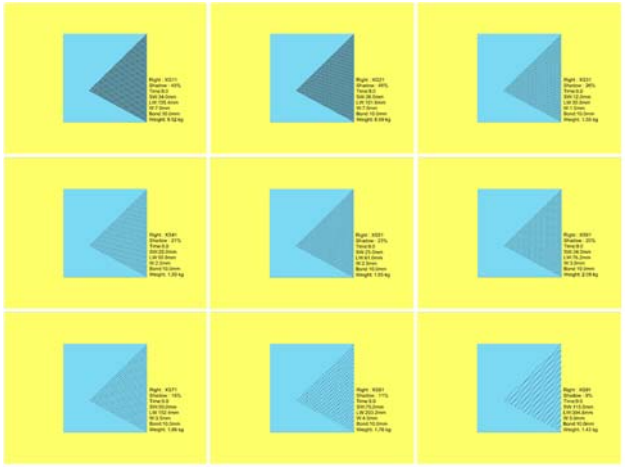


Fig 6. Shadow casting in right side

The right side were simulated using August 22, at 09:00 AM sun position due to the minimum condition of solar radiation that should be reduced.

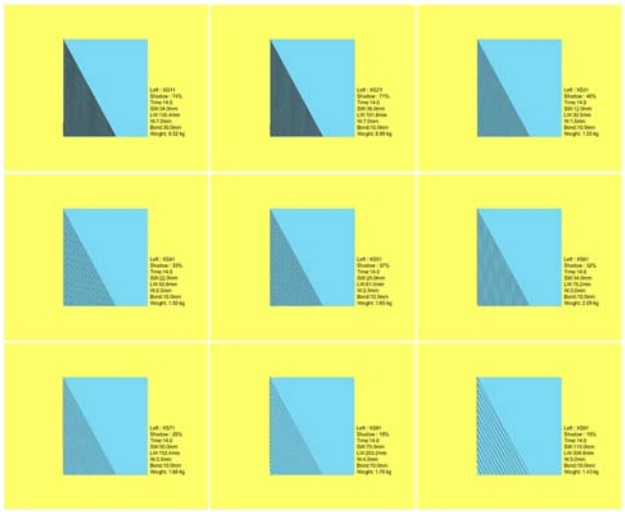


Fig 7. Shadow casting in left side

In the left side, the simulation were done on August 22, at 02:00 PM sun position due to the maximum condition of solar radiation in one day.

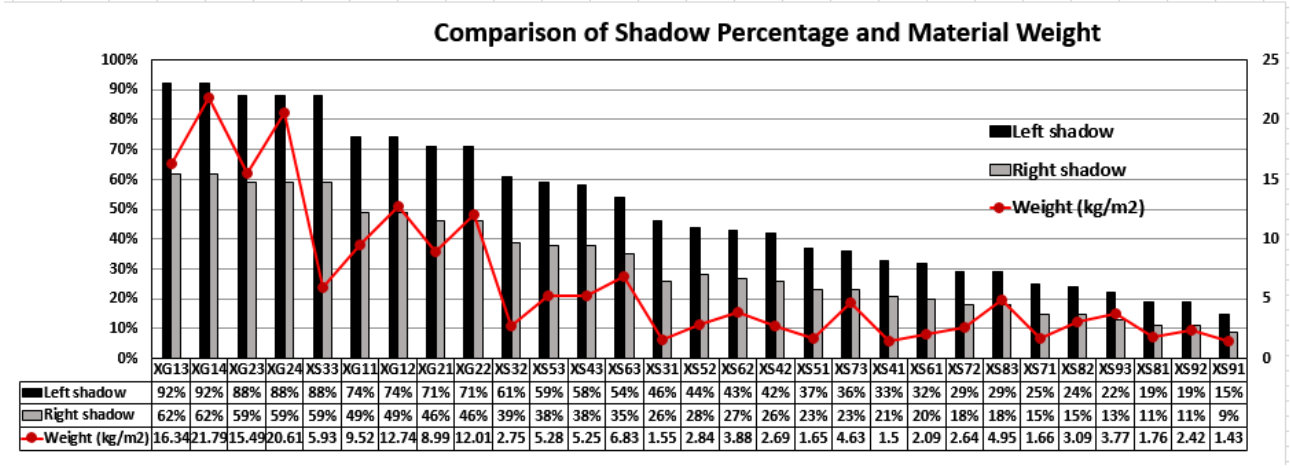
Table 1 shows the amount of shadow percentage in each simulation and the weight of each shading. It also showed the dimension of SW, LW, W (strand), and bond.

Table 1. Shadow and Weight Result

| No | Type | SW mm | LW mm | W mm | bond mm | weight kg | Left | Right |
|---|---|---|---|---|---|---|---|---|
| 1 | XG11 | 34 | 135.4 | 7 | 30 | 9.52 | 74% | 49% |
| **2** | **XG13** | 34 | 135.4 | 9 | 30 | 16.34 | **92%** | **62%** |
| **3** | **XG14** | 34 | 135.4 | 9 | 30 | 21.79 | **92%** | **62%** |
| 4 | XG21 | 36 | 101.6 | 7 | 10 | 8.99 | 71% | 46% |
| **5** | **XG23** | 36 | 101.6 | 9 | 10 | 15.49 | **88%** | **59%** |
| **6** | **XG24** | 36 | 101.6 | 9 | 10 | 20.61 | **88%** | **59%** |
| 7 | XS31 | 12 | 30.5 | 1.5 | 10 | 1.55 | 46% | 26% |
| 8 | XS32 | 12 | 30.5 | 2 | 10 | 2.75 | 61% | 39% |
| **9** | **XS33** | 12 | 30.5 | 3 | 10 | 5.93 | **88%** | **59%** |
| 10 | XS41 | 22 | 50.8 | 2 | 10 | 1.5 | 33% | 21% |
| 11 | XS42 | 22 | 50.8 | 2.5 | 10 | 2.69 | 42% | 26% |
| 12 | XS43 | 22 | 50.8 | 3.5 | 10 | 5.25 | 58% | 38% |
| 13 | XS51 | 25 | 61 | 2.5 | 10 | 1.65 | 37% | 23% |
| 14 | XS52 | 25 | 61 | 3 | 10 | 2.84 | 44% | 28% |
| 15 | XS53 | 25 | 61 | 4 | 10 | 5.28 | 59% | 38% |
| 16 | XS61 | 34 | 76.2 | 3 | 10 | 2.09 | 32% | 20% |
| 17 | XS62 | 34 | 76.2 | 4 | 10 | 3.88 | 43% | 27% |
| 18 | XS63 | 34 | 76.2 | 5 | 10 | 6.83 | 54% | 35% |
| 19 | XS71 | 50 | 152.4 | 3.5 | 10 | 1.66 | 25% | 15% |
| 20 | XS72 | 50 | 152.4 | 4 | 10 | 2.64 | 29% | 18% |
| 21 | XS73 | 50 | 152.4 | 5 | 10 | 4.63 | 36% | 23% |
| 22 | XS81 | 75 | 203.2 | 4 | 10 | 1.76 | 19% | 11% |
| 23 | XS82 | 75 | 203.2 | 5 | 10 | 3.09 | 24% | 15% |
| 24 | XS83 | 75 | 203.2 | 6 | 10 | 4.95 | 29% | 18% |
| 25 | XS91 | 115 | 304.8 | 5 | 10 | 1.43 | 15% | 9% |
| 26 | XS92 | 115 | 304.8 | 6 | 10 | 2.42 | 19% | 11% |
| 27 | XS93 | 115 | 304.8 | 7 | 10 | 3.77 | 22% | 13% |

The maximum shadow percentage that can be achieved are 92% for left side shading and 62% for right side shading. In this condition, the weight of the side shading are too heavy, 21.79 kg (XG14) and 16.34 kg (XG13).

The second best are 88% (left side) and 59% (right side) which have weight of 20.61 kg (XG24), 15.49 (XG23) and 5.93 kg (XS33), can be seen in figure 8. Comparing to the two other types, XS33 have the lightest weight, 29% from type XG23 and 38% from XG24. When comparing with XG13 and XG14 which have 92% shadow, it become 36% and 27%. The main difference between above types is thickness of metal plat and also the ratio between SW, LW and W.




| | XG13 | XG14 | XG23 | XG24 | XS33 | XG11 | XG12 | XG21 | XG22 | XS32 | XS53 | XS43 | XS63 | XS31 | XS52 | XS62 | XS42 | XS51 | XS73 | XS41 | XS61 | XS72 | XS83 | XS71 | XS82 | XS93 | XS81 | XS92 | XS91 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Left shadow | 92% | 92% | 88% | 88% | 88% | 74% | 74% | 71% | 71% | 61% | 59% | 58% | 54% | 46% | 44% | 43% | 42% | 37% | 36% | 33% | 32% | 29% | 29% | 25% | 24% | 22% | 19% | 19% | 15% |
| Right shadow | 62% | 62% | 59% | 59% | 59% | 49% | 49% | 46% | 46% | 39% | 38% | 38% | 35% | 26% | 28% | 27% | 26% | 23% | 23% | 21% | 20% | 18% | 18% | 15% | 15% | 13% | 11% | 11% | 9% |
| Weight (kg/m2) | 16.34 | 21.79 | 15.49 | 20.61 | 5.93 | 9.52 | 12.74 | 8.99 | 12.01 | 2.75 | 5.28 | 5.25 | 6.83 | 1.55 | 2.84 | 3.88 | 2.69 | 1.65 | 4.63 | 1.5 | 2.09 | 2.64 | 4.95 | 1.66 | 3.09 | 3.77 | 1.76 | 2.42 | 1.43 |

Fig 8. Comparison Result of Shadow and Weight

The opening ratio of XS33 (47%) is smaller compare to the other two types (51%) which mean the opening ratio have negative correlation with the amount of shadow percentage. In the visual aspect, XS33 have better view because of the smaller scale of solid void ratio compare to the XG series. While the others types only produced less than 75% of shadow percentage with heavier or lighter weight of shading material. The lowest shadow percentage is XS91 with 15% in the left side and 9% in the right side although the weight of the shading also lowest (1.43 kg).

Base on the scenario and due to the limitation of the types available the expanded metal type XS33 has the optimum result for the side shading.

## 4. Conclusion

Shadow percentage that casting on the windows can be used as an indicator of shading performance which show the amount of solar radiation that can be blocked by shading devices. The higher shadow percentage means less direct solar radiation that fall into the glass.

Based on the analysis of shadow percentage with the weight of each type, it can be conclude that:

1. Type XG13 and XG14 have the highest shadow percentage but not ideal choice due to the weight of the material.
2. TypeXG23, XG24 and XS33 have the same value of shadow percentage with different weight of material.
3. Type XS33 is the most optimum choice due to the shadow percentage performance with lightest weight compare to other type with the same result.
4. Others types of expanded metal produces less than 75% shadow percentage which mean cannot be better choice for the shading material.

This result can be improve using parametric design with custom profile to get more shadow area with less materials. Type XS33 can be used for starting point on improving the side shading.

## 5. Reference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