GLASS AS A SUSTAINABLE MATERIAL TO DESIGN A MODERN OFFICE BUILDING IN SEISMIC AREA
A Case of : Banda Aceh, Indonesia

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Abstract : Glass as a material in building facades is rarely applied in a large scale, especially in design of office buildings, within Aceh province. Since Aceh is located in the area with dynamic earthquake activities, building design in this area required higher degree of concern in relation to better refrain from earthquake movements. Nowadays, glass technology that could withstand the seismic effects while sustaining seismic loads is available. To bring this new technology into design of office buildings in Aceh, the paper aims to measure the suitability and level of acceptance of the technology among Acehnese people by conducting some methods of cost comparison and cost savings. In this regard, a comparison in dead loads of a sample building with conventional cavity walls against that of high performance glazing system in a façade of the building was performed. The results indicated that the cost for glass technology are twice higher compared with cavity wall. But in the dead loads part, the glass material are 13.8 times more lighter than cavity wall.

Key words: Glass; Sustainable Design; Office building; Seismicity ; Aceh

1. Introduction

The using of glass materials for office building are important and giving a long term benefits to occupants both on psychologycal and sustainability aspects. Material selection and carefully designing facades to managing the interaction between the outdoors and the internal spaces can saves the energy for thermal and visual comfort. A 2006 California Energy commission study of electro chromic windows on the estimated lighting energy savings of about 44%, compared to a reference case with no delighting controls [1]. Glass can offer acoustic performance so that buildings meet the appropriate standards and significantly reduce noise, it is also be able to reduce the load on building foundation.

Fig.1 : Aceh situates on the Ring of Fire, it is the zone of earthquakes that has a very high intensity of seismic activity

Source : [2]

Aceh is a province on the tip of Sumatra Island in Indonesia with a rich of sunlight intensity every year. Integrating glass material into a building designs in Aceh required to allow the sunlight and fresh air penetrate into the building, but currently, it poses a major problem by applying glass as building facades. In this regard, not performance glass materials increased the overall temperature in the building, particularly when it exposed to the sunlight, and inducing the occupants to install Air Conditioner to stabilize the temperature in the building interiors. Hence, the people of Aceh prefer to use brick wall and avoided to use glass materials in a large-scale on the building facades.

For recent years the earthquake intensity increases significantly in this province, there are 15 cases of earthquakes activity in the magnitude more than 6 scale richter being recorded during 2002 until 2014. High intensity of earthquakes occuring because Aceh was situated in 'the ring of fire' or circum-pacific belt, it is the zone of earthquakes that has a very high intensity of seismic activity. Hence, the seismic loads required serious consideration through building designs in Aceh

The common material that had been used for building constructions in Aceh are brick wall facades, with a little combination of wood and glass. The current technology that been used in the application of glass material in Aceh has not been currently accommodated to consider of seismic load effects on glazing systems. If they want to make energy-efficient facade design using current materials, they should provide cavity wall. That is why in this research, the author enclose the calculation for cavity wall designs as a building facades.

Fig.2 : A little amount of glass materials being applied in the latest office building in Aceh, Syari'ah court Aceh (left), Prosecutor Aceh offices (right)

The followings are some of the reasons on why design of buildings in seismic prone areas must consider seismic events, and has a structural and non-structural elements with a proper and good design [3]:

- The failure of a non-structural element can be a direct danger for the immediate nearby, falling and striking someone;
- The failure and consequent non-functionality of a non-structural system can also effect the functionality of another non-structural, or even structural system;
- The building will be very probably unfit for use for a very long period, until it will be safe again for the utilization. If the building is the base of a business, this could be a very expensive period of inactivity and the cost can also be greater than the repairing cost.

The worst thing that can happen caused by earthquakes is totally collapse and destruction of the building because structural failure. In some cases, a moderate earthquakes will causes damage to the facade and also increase the risk of injury or death from things such as falling masonry, ceilings, cladding facades, curtain wall, and shards of broken glass.

Fig.3 : The falling of alumunium frame because disconnection of cladding (left), The damage of Spider glass after earthquakes in New zealand buildings (right)
Source : [3]

The case of glazing system failures during seismic events were occuring in New Zealand on the 22nd February 2011 afternoon, the magnitude 6.3 SR earthquake took the lives of 182 people and causing damage to facades, ceilings, partitions, and contents.

Cracked or broken glass is usually the most obvious indicator of damage to light-medium weight cladding system, older systems normally provide less movement allowance for the glass and consequently were more likely to exhibit glazing damage. The picture above showing, that the entire alumunium frame and glazing along one side of the building at the second floor fell to the ground. Closer inspection indicated that the alumunium frame was screwed into a wooden sub-frame and the failure was a result of the screws both shearing off and tearing out of wood.

The main objective of this study is to bring the sustainable glass technology that can withstand earthquake loads for Aceh provinces that are able to solve the classic problem of rising temperatures in the room due to exposure to sunlight on the surface of the glass. The other objectives are :

- To identify the advantages and disadvantages of glass material compare with a conventional materials used as facade of public building in Aceh

- To explore proper glazing system for modern building facades which could be available, acceptable, and applicable in seismic areas, and
- To enhance the knowledge of sustainability among Acehnese people, especially the stakeholders, developers, and key decision makers, about the importance of using glass materials for the facade of buildings.

Scope of Study on this research is only focus on the using of glass material as a facade at goverment office building in Aceh.

2. Literature Review

The types of facade systems for using glass material can be classified by three main types ; such as claddings , double skin facades and infills. The simplest way to differentiate between the three type is that infills are constructed within the frame of the stucture, while claddings are attached externally to the primary structure. And there are one more methods of building facades that used glass material which usually used for passive solar system purpose called Double skin facades (DSF), the using of DSF are related with sustainable issue/energy using on the building.

In the sustainable designs, the building material should have a minimal effect to the environment by reduce the pollution, reduce the energy consumption, reduce construction waste, use of natural/ local sources, provide healthy and safety for the occupants [4].

Fig. 4 : Light-medium weight cladding (left), Double skin facades (centre), and heavy cladding (right) [3]

The ground motion caused by an earthquake consists of random vibrations. If ground acceleration is small, the building will simply go along with this motion as one unit and the earthquake load will be small. Otherwise if the sudden and swift earthquake motion was occuring, the lower part of the building moves horizontally whereas the upper part remains in its original position, and the earthquake load will be large. Further more, this vibrations cause deformation to buildings.

The other factor that affects the magnitude of the earthquake load is the weight of the building, ligther buildings attract a smaller earthquake load than heavier buildings[5]. The earthquake vibrations will affects all components of the building. The following factors must be considered in determining earthquake loads on buildings:

- Ground motion
- Building's mass and ductility of the structural frame
- The type of soil

The underlying design phylosophy is the building should be remain in intact condition in an intense earthquakes, to provide security and safety.

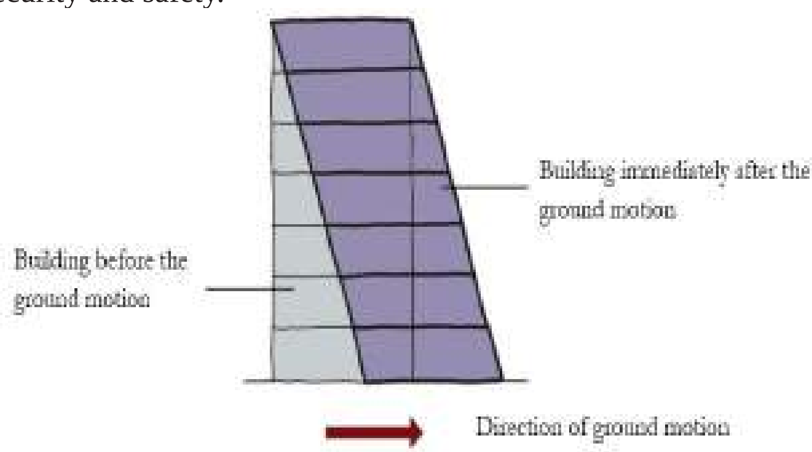

Fig. 5 : Deformation of a building resulting from ground movement. [5]

Some of laboratory studies were conducted by Behr (2001), that investigated the cracking resistance and fallout resistance of different types of architectural glass installed in the strorefronts and mid-rise wall systems. Along with qualitative observations regarding the various failure modes exhibited by architectural glass under simulated seismic loadings. This laboratory results revealed that distinct magnitudes of differential horizontal movements between adjacent floors in a building frame (drift), cause glass cracking and glass fallout in each glass type tested.

The basic performance and design characteristics of common glass configurations for buildings in seismic-prone regions.

Seismic Effects on Architectural Glazing	
Seismic Intensity	**Effects on Architectural Glazing**
Light	Glass moves in opening; Gaskets may be loosened. May require repositioning of glass and gasket replacement.
Moderate	Glass may move laterally and fall off of setting blocks; gaskets fall from glazing rabbet; glass edges may be damaged; and glazing systems that have not been seismically engineered may experience glass fracture and fallout.
Severe	Nonengineered systems could experience extensive glass breakage and fallout; seismically engineered systems will experience systemic damage (edge damage to glass, setting block failure, gasket fallout) ; glass breakage and fallout may occur in monolithic glazing systems.

Source: [6]

Seismic Glazing design consideration :

- Flexible frame to accommodate racking without damage or serviceability failure
- Adequate glass to frame clearances
- Laminated glass with minimum 0.030 inch (0.76mm) architectural interlayers

Solutia Inc. Commissioned studies and participated in cooperative efforts with universities and the U.S. Natinoal Science Foundation to investigate glazing system performance in seismic events. These kind of glazing system use of glass that laminated with polyvinyl butyral-based interlayers by *Soultia Inc* (the Glazing system company which have cooperated with Dr. Richard A. Behr and Dr. Joseph Minor from Univeristy of Missouri and The Pennsylvania State University to develop the brochure of glazing product). Laminated glass can contribute to the building envelope surviving a seismic event essentially intact and allows the building to be available to resume routine functions and operations quickly.

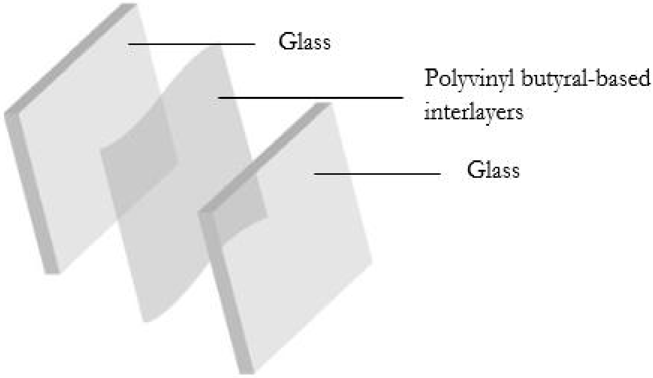

Fig.6 : Laminated glass schematic developed by Soultia Inc. cooperated with Behr and Minor [6]

This glass technology (ex: the product by Soultia Inc. called *DuraSafe* in the market), offering:

- *Security*, this glass technology tends to resist impatc. In multi-ply configurations, it can even resist bullets, heavy objects, and small explosions.
- *Safety,* this technology adheres to the interlayer when broken, hence reducing the risk of dangerous glass shards in injuring people and damaging properties. In horizontal or sloped applications, this materials prevents glass from falling out.
- *Acoustic barrier*, the dampening performance of the interlayer giving this glass technology sound-proofing properties and is thus used in acoustic glazing. It helps to absorb unwanted noise from traffic, lawnmowers, and power tools outside for internal peace and tranquility.
- *Heat insulation,* the PVB in this glass technology can reduce solar energy transmittance , it saving energy by reduce cooling loads.
- *Disaster protection (earthquake & hurricanes),* the glass tend to remains in the frame following impact.
- *Ultraviolet screening,* this technology screens out over 99% of the damaging UV rays (wavelengths 380 nm and below), protecting interior furnishings, displays or merchandise from

the fading effect of UV radiation. However, it allows the transmittance of visible light that is required for photosynthesis in plant.

Fig.7 : Buildings that use glass technology for seismic loads, Kobe Marui Building in Japan (left), Changi airport in Singapore (centre), AUTB in New Zealand (right) [7]

- U-Factor of *DuraSafe* Product by safflex

  The U-factor will expressed of insulation value from this Annealed Laminated glass materials as a facades.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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Fig.8 : UV screening defined as the ability of the configuration to screen greater than 99% of UV radiationto 380 nm wave lenght[9]

- Energy Efficient Rate of *DuraSafe* Product by safflex

  This product can contribute significantly to solar heat gain reduction in structural glazing applications, it allows to use more glazing in the overall building design without increasing loads on the building's heating ventilation and Cooling (HVAC) systems.

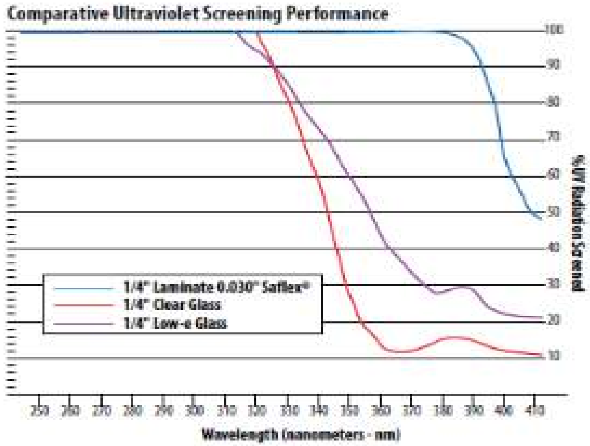

Fig.9 : UV screening defined as the ability of the configuration to screen greater than 99% of UV radiation to 380 nm wave lenght[9]

3. Research Methodology

There are three methods that been used to achieve the objectives of this study, the methodology are:

a. The Building Load Comparison between normal facades / brick wall, cavity wall, and glass material

The Calculation the weight of building (normal material), glass material, and cavity wall. It shows the different of loads that been providing of this 3 different materials to the structure.

Brick / Normal wall as the building facades in weight is 250 kg/m2 [8] , the area for two storey building 10.5 m (Height) x 435.6 m (Length) = 4573.8 m2. The weight of the building facades that using brick material for two storey building will reach 250 kg/m2 (weight) x 4573.8 m2 (Area) = 1143450 kg. The area for four storey building 19.5 m (Height) x 435.6 m (Length) = 8494.2 m2. The weight of the building facades that using brick material for two storey building will reach 250 kg/ m2 (weight) x 8494.2 m2 (Area) = 2123550 kg.

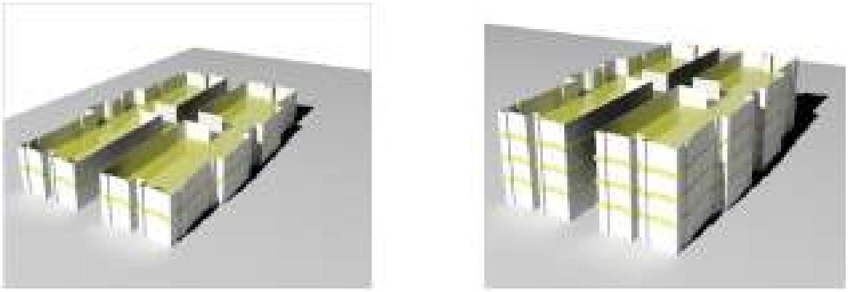

Fig.10 : Two storeys (left), and four storeys (right) of Prosecutor Aceh office buildings using brick materials as a facades

Glass material weight for 10 mm [9] of thickness is 25 kg/m2 , and steel frames 5 kg/m2 so the total weight is 30 kg ,the area for two storey building 10.5 m (Height) x 435.6 m (Length) = 4573.8 m2. The weight of the building facades that using brick material for two storey building will reach 30 kg/m2 (weight) x 4573.8 m2 (Area) = 137214 kg. The area for four storey building 19.5 m (Height) x 435.6 m (Length) = 8494.2 m2. The weight of the building facades that using glass material for four storey building will reach 30 kg/m2 (weight) x 8494.2 m2 (Area) = 254826 kg.

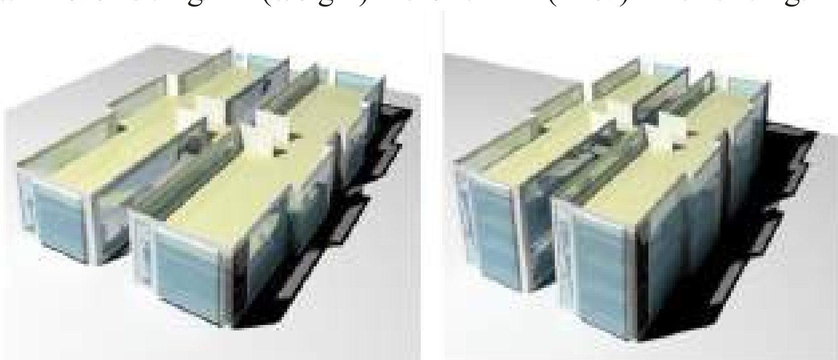

Fig.11 : Two storeys (left), and four storeys (right) of Prosecutor Aceh office buildings using glass materials as a facades

Cavity wall normal weight is 415 kg/m2 [10] , the area for two storey building 10.5 m (Height) x 435.6 m (Length) = 4573.8 m2. The weight of the building facades that using brick material for two storey building will reach 415 kg/m2 (weight) x 4573.8 m2 (Area) = 1898127 kg. The area for four storey building 19.5 m (Height) x 435.6 m (Length) = 8494.2 m2. The weight of the building facades that using brick material for two storey building will reach 415 kg/m2 (weight) x 8494.2 m2 (Area) = 3525093 kg.

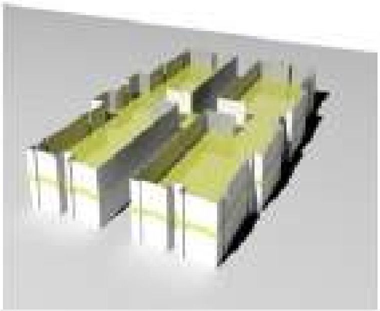
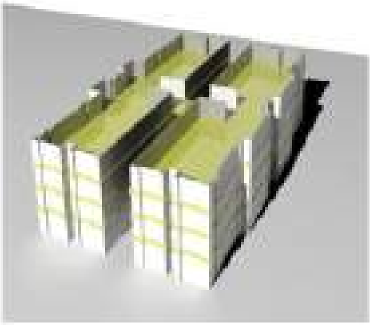

Fig.12 : Two storeys (left), and four storeys (right) of Prosecutor Aceh office buildings using cavity wall as a facades

b. Cost Comparison between normal facades in Aceh & glass facades using glass earthquake resistants technology

The cost comparison and cost analysis will be carried out between the previous existing building with the new-design of this office buildings that using earthquake resistant glass technology based on Indonesia price, and particularly Aceh. Hence, in this research the author taking one case of government office buildings as a study case.

The building used as a case study is the prosecutor office buildings in Banda Aceh, was completed and inaugurated in 2009. Located on jalan T.Mohd.Hasan, this goverment office buildings using brick wall for facades. This building has the advantage of having a courtyard inside the building, which is a potential to let breeze and daylight coming into the building.

Fig.13 : The Prosecutor Aceh Office buildings from the out side

Re-Design of Prosecutors Aceh Office by using glass technology for seismic area on the building facades, the facades will requires about 4573,8 m^2 of glass materials.

Fig.14 : The new-design of Prosecutors Aceh Office by using earthquake resistant glass technology

Cost Comparison between normal facades in Aceh/brick wall & glass facades using Durasafe glass earthquakes resistant technology (include transport cost from Singapore).

Cavity wall cost per m^2	**Cost for 4573.8 m^2 of Cavity wall**	**Glass Facades cost per m^2**	**Cost for 4573.8 m^2 of Glass Facades**
-Masonry/brick wall 1:2 Rp. 154,512 -Plastering 1 pc : 2 s Rp. 31,033.52 -Painting Rp. 21,664.72 **Total cots per m^2** **Rp. 207,210.24**	Rp. 947,738,195.7	Rp. 400.000	Rp. 1.829.520.000

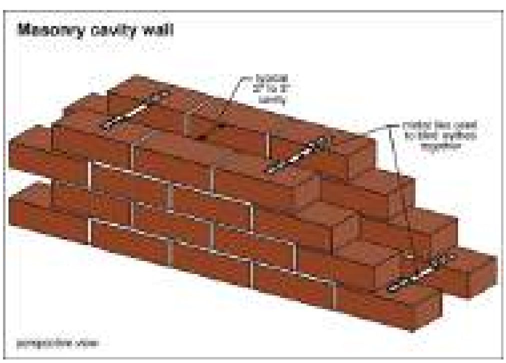

Fig.15 : Detail Of Cavity wall [11]

4. Discussions and Recommendations

The cost comparison was conducted between glass material and cavity walls for the area of 4573.8 m^2 in a sample office building in Aceh. Accordingly, the cavity walls cost about Rp. 947,738,195.7 , while the glass materials will ask about Rp. 1.829.520.000, it shows that the cost for glass material is almost twice higher that with those of cavity walls.

Building load comparison was also conducted between glass material and cavity walls for the total area of 4573.8 m2 in the sample designed building. The results show that a different of building loads for facades in two storeys building, indicated on the lighter weight of glass material for facades within which is glass materials (137214 kg) are almost 13.8 times lighter than cavity wall (1898127 kg).

5. Conclusion

There are so many advantages of using this glass materials as a building facades in the office buildings, because it can provide good environmental quality for the workers. Although the cost to bring the technology of glass for office buildings in Aceh could be more expensive and almost two time more higher be compared with cavity wall. But to construct with glass material will require less time and less labour compare with brick wall constructions. From the building load comparison and load calculation the using of glass material as a facades will reduce dead loads almost fourteenth times compare with cavity wall. The reducing of a dead loads on the building facades will reduce the size of the structural element in the building such as the column, beams, and also the foundations.

For a long-term benefits, using of glass material as a facades the will provide a tangible benefit such as the reducing energy use and energy consumption in office buildings, and intangible benefits such as sustainability, and security in the seismic events.

4. Limitation and Future Study

The limitation of time is the main limitation in the carried out of research about glass as sustainable materials to design a modern office buildings in seismic area, there are so many aspect that we have to consider to bring a new technology material in the new region. For the future study, the researcher can includes about earthquake load calculations that can be affected of the structural design by using glass material as a building facades, cost calculation of building structures using glass material, and building design simulations related with the size of building structures using glass material as a facades. It also can include the strategy of how to make this technology can be more cheaper to buy, and easy to get in Aceh.

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