Journal of Agriculture and Technology Management (JATM)
25(1): 79-87 (January-June 2022)

Original article

Advancing an automated evaluation in the design of a curtain wall

Porferio M. Almerino, Jr.

Cebu Technology University, Cor. M.J. Cuenco R. Palma St., Cebu City, Philippines

ABSTRACT

Proprietors are generally conscious as to the cost implication of a project. This impels the industry to resourcefully seek ways and means to at least satisfy both owners and what the American Architectural Manufacturers Association (AAMA) standards have, in particular, spelled out as regards aluminum curtain wall (CW). In Cebu, Philippines, the prevailing approach in assessing the design of CW is through manual computation. However, experiences in the field saw likelihood for this method to trigger calculation deficiency or error during the technical appraisal. To mitigate probable risks in the computational process, the present study advances an automated evaluation that timely, conveniently and safely assesses a CW design and departs from the traditional way. Findings showed that a shift from manual computation using the identified formulas of mathematical science to an automated evaluation can indeed boost a swift, easier, and safer design of curtain wall. However, further investigation on such technological acceptance and utilization specifically among the small-scale players is recommended.

KEYWORDS: *aluminum curtain wall, American Architectural Manufacturers Association (AAMA), mathematical science, risks management, computing technology*

1 INTRODUCTION

Few decades ago, developed nations embraced an innovative wall system for their skyscrapers that subscribed to green technology. A recent study has pointed out that such utilization of curtain walls shows a decline in carbon emissions and energy costs in any high-rise edifices (Almerino, et al., 2021). Such application of green technologies has aided the construction industry attain sustainable development (Shukla et al., 2017). Instead of using concrete blocks as covering walls for buildings, a curtain wall (CW) was alternatively considered for such external enclosures. While the Philippines had adopted this wall system earlier, it was only in the 1990s when the CW had been recognized by yet few building owners, engineers and architects in Cebu. In this period also, some high-rise buildings have their façade and storefronts started to receive CW installations. Albeit the design of such a system, the manner how it is extruded and fabricated are essential aspects in construction; nonetheless, the initial interest of its utilization during those times is towards architectural elegance. The concerns on structural integrity were well-pronounced when the province of Cebu was hit by a strong typhoon Ruping in 1990 that exposed the critical parts in the design and construction of curtain wall, which caused its eventual destruction. Like the typhoon Nina which hit Bicol peninsula last 2016, severe damage has been recorded on the infrastructures particularly on the window openings and walls of edifices (Acosta et al., 2018).

As to the CW-related damages incurred from typhoon Ruping, basic evaluations on the case revealed that many aluminum profiles, which were sold in the market, did not meet the structural requirements established by the American Architectural Manufacturers Association (AAMA). Verily, this AAMA is a reliable reference in both international and local construction industries when it comes to fabrication adherence to standards (Lee et al., 2018). The circumstance here, where the CW installations were destroyed, is traced from the constraint of these local suppliers in Cebu to only sell to the contractors what the manufacturers could offer from their stocks. At their end, too, the manufacturers practically have to wrestle between compliance to AAMA-prescribed compositions of aluminum alloy for extrusions and the cost implication it shall have to the buyers. Earlier study scientifically expounded the difficulty which the construction industry has been experiencing in terms of addressing building-related issues and choosing a specialty contractor. Like the aluminum manufacturers, the raw materials, labor and production costs are matters of concern when it comes to bid price (Aboelmagd, 2018). Consequently, probable hazards could take place when the production, design or construction of the wall system deviates from the established standards.

To abhor these threats, it is imperative that

*corresponding author: porferiojr.almerino@ctu.edu.ph
p-ISSN: 2599-4875 e-ISSN: 2599-4980

technical evaluations of a CW wall must be critically carried out before manufacturing and assembly are done. An empirical investigation pointed out the crucial aspects in the performance assessment and selection of a CW with various boundary conditions (Memari et al., 2021). With the number of aluminum suppliers or specialty contractors in Cebu mushrooming up, it is worrisome to note that only a small number of them are into assessing the CW wall prior to its fabrications and installations. For these few industry players, they are still into manual computation while the rest are yet to engage in such necessitated appraisals on the design and construction of such wallsystems. The structural evaluations of CW, which were conventionally done by those fully-trained technical workers, have been noted to consume longer days. Likewise, observations and actual accounts on the field divulged that there are tendencies for inaccuracy to occur when calculation is done by hand. As a result, this shall negatively affect the structural integrity of the CW if no intervention is made. To manage possible errors to happen during the evaluative process, there is an exigency to depart from manual computation and pursue a technology-aided evaluation.

To this date, there is a meager inventory from the aluminum industry or none at all yet being heard from the engineering institutions in Cebu that introduced a simplified evaluation of a curtain wall. Hence, it is the intent of the present study to advance an automated evaluation in the design of a CW as opposed to a manual calculation. Accordingly, this paper would be significant to the current literature as it shall be the first to advance an automated assessment within such a locale. Through this study, the local suppliers, designers, and contractors may reflect on the advantages of shifting from a computation that is purely done by technical workers only. For the end-users or buyers, this research would provide them insights on the importance of a well-assessed and safer wall system over the specific concern on its procurement cost. Additionally, the study would help correct previous impressions and deepen the understanding of how a curtain wall must be viewed and procedurally appraised as an integrative system of any structures.

To allow ease of readings and reviews, this paper is organized as follows. Section 1 explains the rationale of the current study and particularly points out the research gap therein. Also, Section 2 provides the materials and methods being employed, where the computing technology and software-developer have both been described while the 10-simplified steps in utilizing the automated evaluation tool were procedurally laid out. Section 3 presents an overview of curtain walls, points out mathematical science as a design reference for CW, and discusses the threats and risks management involving the design of a curtain wall. On the other hand, Section 4 establishes the conclusion of such recent investigation and the future works.

2 MATERIALS AND METHODS

The material involved in the recent study is a computing technology that comes in the form of an application-software which evaluates the design of curtain walls. The programming language on MicrosoftC#.net was employed since it is a faster and more secure variant of C. Contents of such software were the complex engineering, science and mathematical formulas that were converted into a sophisticated programming language to simulate manual computations. Also, embedded in such application software are the technical requisites and established international standards in the design of curtain walls.

The expert-developer, who was hired and accordingly remunerated by the researcher for the services rendered, has a master's degree in Digital System Design from a Technological Center of a very well-known private university in Banilad, Cebu City, Philippines. Likewise, the developer is currently working as a software engineer from a leading developer, manufacturer and supplier of printing solutions and a former software developer of a premier web/mobile development firm specializing in scalable *e*Commerce. For several years, too, the developer had once worked as a college professor from aprivate Catholic research and coeducational basic and higher education institution in Cebu City and a private and non-sectarian university in Mandaue City, respectively. Hence, it is ascertained that the development of such computing technology is well-grounded on its optimal intent to purposely expedite, at least, an error-deterrent and ease of use.

Expressly, the computing technology will give the specialty contractors, engineers, and architects a fast and comfortable assessment on the design of said walling system as opposed to manual calculation. In this regard, the prior method would require a lot of time and extensive effort to ensure that any computational error or deficiency that could eventually pose risks or threats during actual construction is managed. On the contrary, utilization of this application software could be made by technically-trained employees and even by those non-technical people during technical evaluations if procedures are rightly followed. Thus, for prospective users, there are basically 10 simplified steps that expose them on this application software as exhibited below.

Referring now to the application software, the following are methods for its usage. To run the application software, the user(s) shall double-click on the shortcut icon labeled Curtain Wall located on the windows desktop for the display of Step 1 outlook. In

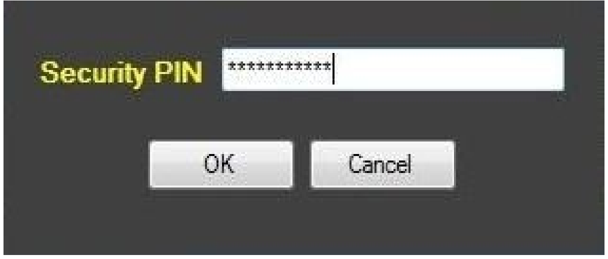
p-ISSN: 2599-4875 e-ISSN: 2599-4980

reference to Step 1, the application software will exhibit the perspective view of the two (2) ribbon tabs on "About" and "Main App". Once the application software is already active, a building with an alternative walling system, a brief narration of thecurtain wall, and the pictorial shots of the main proponent and the software-developer can be seen by the user(s) or viewers, respectively. There are two buttons assigned to view the profile of the proponent and developer by left-clicking the mouse on each button, respectively.

Curtain wall is commonly a glass-aluminum structure that covers the building façade and which does not carry any dead load from the edifice other than its own dead load. These loads are transferred through connections at beams, slabs or columns of the building. A curtain wall is designed to resist air, water infiltration, wind forces acting on the building, seismic forces, and its own dead load forces. Hence, engineering design and calculations are necessitated for any types of curtain wall to ascertain the structural soundness of the system itself.

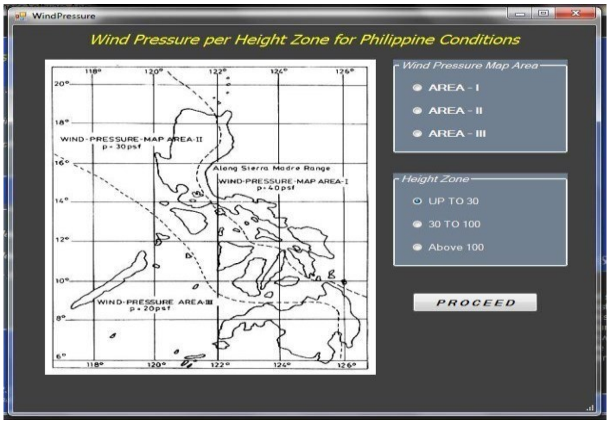
Step 1. In this display view, the two (2) ribbon tabs for "About the Proponent & Software Developer" and the "Main App" permit the user(s) to select and operate.

Step 2. After pressing the "Main App" from that preceding step, the user must now choose a design mode and that particular task(s) to be performed by this application-software.

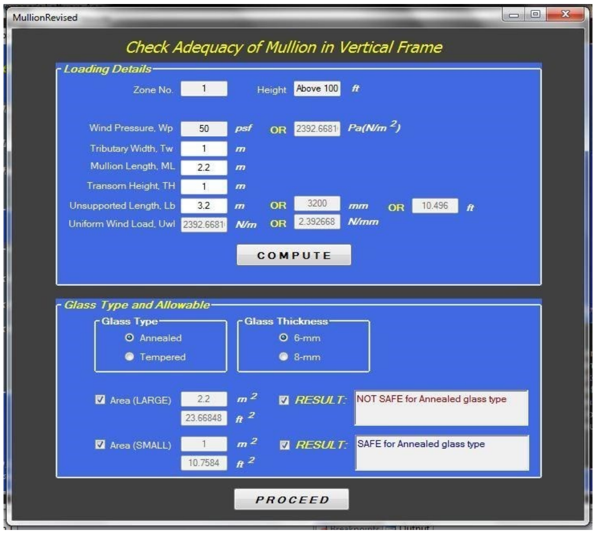


Security PIN ************

Step 3. After Step 2, the textbox on "Security PIN" shall automatically display and demands the user(s) to key in the pass code.



Step 4. Once access is confirmed from such a successful entry of PIN, a map of the wind pressure per height zone for Philippine condition (WPHZP) is displayed.



MullionRevised

Check Adequacy of Mullion in Vertical Frame

Loading Details

Zone No. 1 Height Above 100 ft

Wind Pressure, Wp 50 psf OR 2392.6681 Pa(N/m ^{2})

Tributary Width, Tw 1 m

Mullion Length, ML 2.2 m

Transom Height, TH 1 m

Unsupported Length, Lb 3.2 m OR 3200 mm OR 10.496 ft

Uniform Wind Load, Uwl 2392.6681 N/m OR 2.392668 N/mm

Glass Type and Allowable

Glass Type: ● Annealed ○ Tempered

Glass Thickness: ● 6-mm ○ 8-mm

☑ Area (LARGE) 2.2 m ^{2} 23.66848 ft ^{2} ☑ RESULT: NOT SAFE for Annealed glass type

☑ Area (SMALL) 1 m ^{2} 10.7584 ft ^{2} ☑ RESULT: SAFE for Annealed glass type

Step 5. After accomplishing the previous step, the application-software shall permit the data generation and computation on mullion (on the option for WPHZP).

MullionRevised

Check Adequacy of Mullion in Vertical Frame

Loading Details

No. of Level 3 Total Height 9.6 m

Wind Pressure, Wp 30 psf OR 1435.6009 Pa(N/m ^{2})

Tributary Width, Tw 1 m

Mullion Length, ML 2.2 m

Transom Height, TH 1 m

Unsupported Length, Lb 3.2 m OR 3200 mm OR 10.496 ft

Uniform Wind Load, Uwl 1435.6009 N/m OR 1.435601 N/mm

Glass Type and Allowable

Glass Type: ● Annealed ○ Tempered

Glass Thickness: ● 6-mm ○ 8-mm

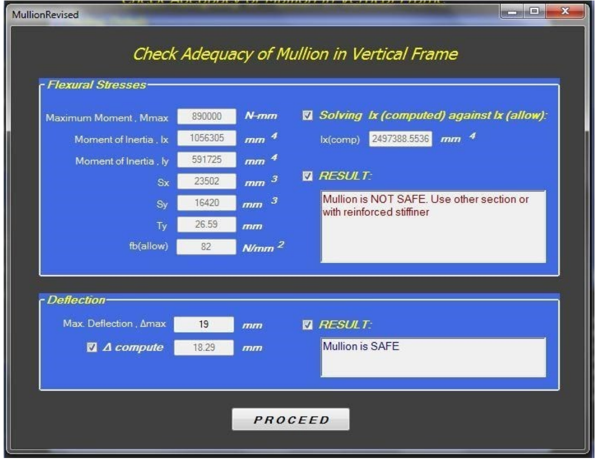
☑ Area (LARGE) 2.2 m ^{2} 23.66848 ft ^{2} ☑ RESULT: SAFE for Annealed glass type

☑ Area (SMALL) 1 m ^{2} 10.7584 ft ^{2} ☑ RESULT: SAFE for Annealed glass type

Step 6. The software application in this part shall further

p-ISSN: 2599-4875 e-ISSN: 2599-4980

allow the data generation and computation on mullion (on the option for architect's preference).



Check Adequacy of Mullion in Vertical Frame

Flexural Stresses

Maximum Moment, Mmax: 890000 N-mm
Moment of Inertia, Ix: 1056305 mm^4
Moment of Inertia, Iy: 591725 mm^4
Sx: 23502 mm^3
Sy: 16420 mm^3
Ty: 26.59 mm
fb(allow): 82 N/mm^2
☑ Solving Ix (computed) against Ix (allow):
Ix(comp): 2497388.5536 mm^4
☑ RESULT: Mullion is NOT SAFE. Use other section or with reinforced stiffiner

Deflection

Max. Deflection, Δmax: 19 mm
☑ Δ compute: 18.29 mm
☑ RESULT: Mullion is SAFE

Step 7. Here, the application software shall grant the data generation and computation for the two (2) moments of inertia and the maximum deflection for the mullion.

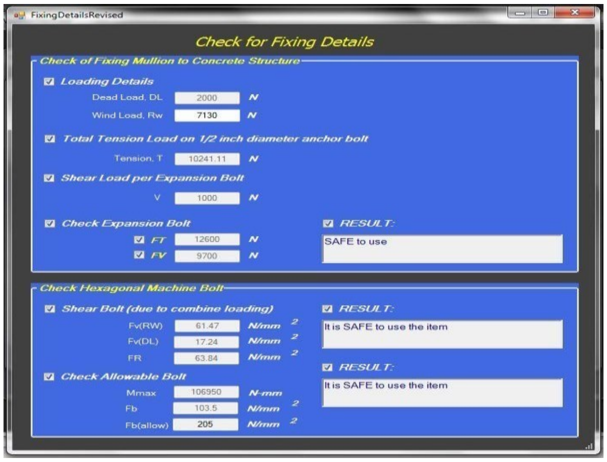
Check Adequacy of Transom in Horizontal Frame

Transom in Horizontal Frame

☑ Solving Ix (computed) against Ix (allow):
Ix(comp): 23781 mm^4
☑ RESULT: Transom is SAFE

☑ Check for Deflection:
Max. Deflect, Δmax: 19 mm
Max. Deflect, Δcomp: 5.71 mm
☑ RESULT: Transom is SAFE

Step 8. Data generation & computation for the area moment of inertia & maximum deflection for the transom are made in this part here.



Check for Fixing Details

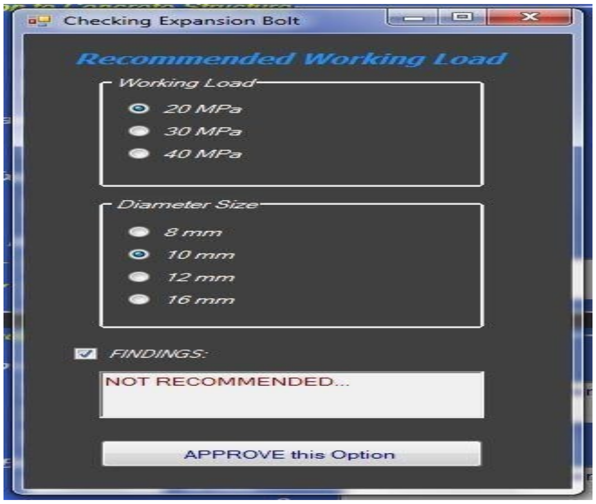
Check of Fixing Mullion to Concrete Structure

☑ Loading Details
Dead Load, DL: 2000 N
Wind Load, Rw: 7130 N
☑ Total Tension Load on 1/2 inch diameter anchor bolt
Tension, T: 10241.11 N
☑ Shear Load per Expansion Bolt
V: 1000 N
☑ Check Expansion Bolt
☑ FT: 12600 N
☑ FV: 9700 N
☑ RESULT: SAFE to use

Check Hexagonal Machine Bolt

☑ Shear Bolt (due to combine loading)
Fv(RW): 61.47 N/mm^2
Fv(DL): 17.24 N/mm^2
FR: 63.84 N/mm^2
☑ RESULT: It is SAFE to use the item
☑ Check Allowable Bolt
Mmax: 106950 N-mm
Fb: 103.5 N/mm^2
Fb(allow): 205 N/mm^2
☑ RESULT: It is SAFE to use the item

Step 9. In this part, the data generation and computation are carried out to theoretically verify the tensile and shear stresses of the structural anchors.



Recommended Working Load

Working Load
● 20 MPa
○ 30 MPa
○ 40 MPa

Diameter Size
○ 8 mm
● 10 mm
○ 12 mm
○ 16 mm

☑ FINDINGS: NOT RECOMMENDED...

Step 10. Working load for the anchors of mullion and overall "Findings" of such automated evaluation is offered for the user's appropriate action to take.

From there, the user is given the full capability in the utilization of such application software by switching the tab strip to the "Main App" panel as shown on Step 2. In this panel,users can see and choose among the two design modes (Philippine Standard Wind Pressure per Zone and the Architect's Preference) before the application software can perform the automated tasks. After an option is chosen, the user clicks the perform button as shown on the Step 2 perspective view. After the clicking of the button, the "Security PIN" window pop-ups based in Step 3 and will require a correct pin code to access the full feature of the software app.

Using the option on Philippine Standard Wind Pressure per Zone (PSWPZ) as shown on Step 4, the user pursues to choose the Philippine map with the corresponding area and height based on the design of the building and thereafter maps in on the appropriate map area and equivalent height, respectively. Referring to Step 5 with the user's choice to consider the PSWPZ option, the zone number and height are provided automatically but on the remaining parameters namely: Wind Pressure, Tributary Width, Mullion Length, Transom Height, Unsupported Length must be filled-up. The user then clicks the compute button. To compute the Area "Large" and Area "Small", the user should click on each checkbox adjacent to it. Before clicking each result for Area "Large" and Area "Small", an appropriate glass type and thickness must be chosen as shown on Step 5 still to derive the findings. By clicking the "Proceed" button on "glass type and allowable" sub-part in Step 5, another window will eventually pop-up.

Alternatively, an option to consider Architect's preference as shown on Step 2 is displayed where the user is offered to input the number of floor level together with the rest of the important parameters (e.g. tributary width, length of mullion, height of transom, and unsupported length). Then the user may pursue to click the "Compute" button to derive the results on uniform wind load. Just the same for the Area "Large" and Area "Small", the user should click on each checkbox adjacent to it. Before clicking each, the findings on the appropriateness of the glass type and thickness is divulged as shown on Step 5 still. Again, by clicking the "Proceed" button, a window pops-up for the second phase checking Mullion adequacy as shown Step 6.

Hence, in reference to Step 7, the user is enjoined to plainly click the corresponding textboxes on "Solving I_x (computed) against I_x (allowed)" and on the "result", respectively. In such doing, the window automatically displayed the values on the maximum moment, the two (2) moments of Inertia (I_y and I_x) and maximum deflection that the mullion must be designed as well as the partial findings. Hereafter, after clicking the "Proceed" button at Step 7, another window pops-up again for checking Transom adequacy as displayed on Step 8 insuch a manner.

Referring to Step 8, the user is enjoined to click the corresponding textboxes on "Solving I_x (computed) against I_x (allowed)" and on the "Check for deflection" as well as the checking of another set of textboxes for the two (2) categorical "Results" to arrive and for the eventual display of the findings in such part. By clicking the "Proceed" button, another window will pop-up to look into the "Fixing details" in checking the adequacy of Transom as exhibited on Step 9.

On the other hand, Step 9, when viewed, shall task the user to check all the textboxes that point to the various parameters such as "Loading details", "Tension and shear loads" on anchor and pursue in checking the boxes on "Check expansion bolt" and "Result", respectively. Before computing the Total Tension and the rest of the solution, it is important to provide the Wind Load, Wp parameter. Furthermore, the next part in Step 9 gives the user another task in checking again the textboxes on shear load (due to combined loading), "check allowable bolt" as well as the "Result" in that order. By clicking the "Check Expansion Bolt", an option window will pop-up for the designer's approval as shown on Step 10 –where the recommended working load is offered. It is in this phase that the user(s) shall either consider the findings or perform another set of technical evaluation.

3 RESULTS AND DISCUSSION

Overview of curtain wall

Curtain walls are nonstructural and weathertight external enclosures of a building. They are normally fabricated from the combined materials of glasses and aluminum alloy (Lee et al., 2017). Designers have adopted this wall system as it provides operational advantages aside from its interesting architectural view. Electrical consumption could drop to an acceptable level as the system will allow the sun rays to penetrate the glass panels and illuminate the interior parts of an office (Nazi et al., 2017; Chen and Lu, 2018). Being nonstructural, the stress experienced by a curtain wall, while mounted at the exterior part of an edifice, is comparably lesser than the stress imposed by the concrete blocks on the building. Peripheral spaces are maximized as the wall system is usually built along the beam surfaces, thus, leaving the perimeter flooring free from possible obstructions (Huang et al., 2017). Verily, the foregoing narratives are just few of those known advantages that this curtain wall could offer to designers and end-users particularly when cost-benefit analysis is employed.

Mathematical science as design reference for CW

Reference on both mathematics and science is central in the conceptualization, analyses and validation of any CW end products. Subscription to mathematical science in the design of CW is logical as it potentially offers technical inputs for practical applications. Analytically, there are several influencing factors that trigger an intricate interaction in the design of curtain walls such as durability, static stability, and many more (Leśniak&Górka, 2018). To equally address the concerns on quality and cost implication on CW usage, it is practical that the design criteria of such a wall system shall focus basically on the wind pressure and loading, glass specifications, area moment of inertia, deflection, tensile and shear stresses. Other nonstructural-related criteria in the design and assessment of a curtain wall may be considered as the need calls for their incorporation. As to the current study, some salient concepts from mathematical science have been the reference in preliminary drawing out the simplified criteria to assess a CW that is safe and conformance to standards.

Theoretically, the shape and surface texture of the exterior walls, geometric bearing of each exterior wall, building height above ground level, and its geographic location some factors that have been found to influence the magnitude and distribution of wind forces on a building structure include wind speed and direction. A study pointed out that the lifetime performance of a stick or panel type curtain wall has to deal with the specific local conditions (Yalaz et al., 2018). In the case of the Philippines, the wind loading of the curtain wall system is anchored on the Wind Pressure per Height Zone (WPHZ). For example, building elevation above 100-feet at Area-1 has to consider a 50-psf as reference for the maximum tributary area that a glass panel must be sized while Area-2 requires 40-psf. With the same structural height to refer, the design requisite at Area-3 warrants a 30-psf wind pressure in the choice of the glass size and type. As to this WPHZ's specification, the 2.5 safety factor and the 0.001 failure probability are both the recommended values in the design and selection of the glass items. Based on this condition, the Federal Specification DD-G-451c, which is in accordance to the AAMA procedural guide, has outlined the glass table that variedly laid down the required nominal thickness of regular plate float and sheet glass according to their distinctive types (Aiello et al., 2018). In fact, the allowable and required maximum area factor as well as the design pressure posed different standards for tempered safety glass, sealed insulating glass, heat-strengthened glass, sand blasted annealed glass, laminated glass and even wired glass with respect to the aluminum frame ratio and glass types (Bae et al., 2015).

Another significant criterion to mull over in the assessment of the curtain wall is grounded on the deflection state of the structural members. With this, it is a complex mathematical quest to determine the optimal extrusion profile to address these integrative design components (Lee et al., 2017). However, one of the serious concerns that the owners, architects and engineers must carefully look into of using aluminum for mullions is its modulus of elasticity which is about one-third that of steel. This translates to three times more deflection in an aluminum mullion compared to the same steel section under a given load. An axial rotation and the lateral torsional buckling are few of the matters that must be looked into during the design stage and extrusion of aluminum mullion (Lee et al., 2019). It is an informed protocol in construction that building specifications set deflection limits for perpendicular (wind-induced) and in-plane (dead load-induced) deflections. A deflection limit of L/175 is common in CW specifications, when not critically observed, are likely to inflict damage to those glass panels held by mullion that restrict a torque-like movement (Larkin, 2018). Vital it is to note that these deflection limits are not imposed due to strength capacities of the mullions; rather they are designed to limit deflection of the glass (which may break under excessive deflection), and to ensure that the glass does not come out of its pocket in the mullion.

Moreover, the area moment of inertia controls the allowable depth of a given curtain wall system to deliberately keep deflection limits under the specification. The general principle here discussed the disparity among sectional profiles of any frame such that an increased area moment of inertia can contribute to higher buckling resistance (Huang et al., 2017). In the actual construction practices, too, stiffeners are embedded within the aluminum section or profile to limit deflections. An empirical investigation which resolved the structural issue concerning area moment of inertia is the reinforcement of steel stiffeners to improve the durability of open and hollow mullion sections (Kesawan& Mahendran, 2019). Since steel (galvanized in form) deflects at 1/3 the rate of aluminum, the steel will resist much of the load at a lower cost or smaller depth when made as a stiffener for aluminum mullion. By such usage, this will permit a rigid and stable mullion to hold the entire system. Results from a related study revealed that a concrete-filled aluminum profile enhanced the bearing and buckling deformation capacity (Chen et al., 2018). In a curtain wall, the choice of an aluminum profile to be utilized in a particular structure is normally based on one of the computing standards which include the area moment of inertia. Thus, the performance of CW under any condition may be reinforced using stiffeners to address cost implication and technical demand of area moment of inertia during design and construction phases.

The design of the aluminum curtain wall, in principle, is crucial and demanding. Thus, a computing technology is suitably needed to narrow down, if not eliminate, possible lapses within the design itself. This includes the structural evaluation of anchors and/or fasteners – like the brackets, expansion bolts, rivets and the like. In the assessment of bolts for example, the inference of their holding limits should take reference on the established specification which suggests that most fastener applications are designed to support or transmit some form of externally applied load. As to the specification table for tensile and shear, the determination of their respective strengths are central in the proper selection of a bolt which shall be utilized to hold the structure and withstand prevailing threats of its soundness.

To scholastically recall, the most widely-linked mechanical property associated with standard threaded fasteners is tensile strength. Previous research pointed out that the tensile strength of stainless-steel bolts as possible anchors of CW is retained attemperatures lower than 650°C (Hu et al., 2018). Tensile strength is the maximum tension-applied load the fastener can support prior to or coinciding with its fracture. When a standard threaded fastener fails in pure tension, it typically fractures through the threaded portion leaving the projected working loads in jeopardy. For this reason, the tensile stress area is calculated through an empirical formula involving the nominal diameter of the fastener and the thread pitch. Another matter to be concerned of during evaluation is shear forces. In one scientific study, structural deformation is primarily attributed from any lateral sway due to shear forces (Casagrande et al., 2019). This is a matter of concern with respect to the shear stress that the CW anchors have to deal with. Shear strength, on the other hand, is the maximum load

p-ISSN: 2599-4875 e-ISSN: 2599-4980

that can be supported prior to fracture, when applied at a right angle to the fastener's axis. Just like tensile, the recommended working load or structural limit of the bolt under shear during installation must take reference from those established standards.

With such complexity of interactions of these factors on the wall system, scholars have emphasized on the vitality to review their effects (Tovarović et al., 2017). Agreeably, it is imperative that the impact of wind load on the curtain wall panels must be analyzed to determine the permissible tributary area of glass. There is a need also to look into how the type and size of glass influence the static stability or the buckling tendency of the aluminum transoms and mullions when wind forces subject the materials. With the building elevation as a basis, too, the area moment of inertia of an aluminum profile must be derived to ensure that excessive deflection shall not take place within the unsupported length of a mullion. Corollary to this, the durability of anchor bolt that carries the total dead load requires critical analyses to avoid possible collapse of the curtain wall. All of these articulated matters demand technical expertise in evaluating the system to at least manage the possible threats.

Threats and Risks Management

The overriding consideration in pursuit or revision of a design especially in the construction industry is generally based on monetary aspect. Engineers and architects take into account the financial perspective of their clients during project negotiation and planning stages. It is vital that the threats should be squarely given utmost concerns during conceptualization to attain a safer curtain wall. However, the evaluative approach from most of these local suppliers and contractors in Cebu is still through manual computations. Colleagues from the field shared the extent of risks that they are into every time an assessment ofsuch a wall system is done by hand. Hence, to manage the possible threats, precision is an important criterion to dig into for such related undertakings.

In the preparation of a project, the clients play a crucial role. Sadly, it is where some issues or problems in the design and construction start as a result of them pushing their personal thoughts. Experiences spoke well of the usual case where building owners control major decisions during conceptualizations specifically on materials and cost. For some owners who unheeded the expert opinions of the designers involving the articulated matters could usher the risks to feasibly occur. Conversely, the clients' indispensable part is to ensure that adequate resources are available to draw out a well-designed curtain wall to manage those threats. It is an acknowledged viewpoint that design and planning are essential components in every construction work to deal with risks. To address the probable vulnerabilities within these mentioned components, it is important to identify the source of such threats/risks.

Risks should be thoroughly scrutinized in the design of curtain walls as there are imitations rooting out in the market which may cause danger and eventual death in the process of fabrications and installations. Technical investigation, by some industrial players, as to whether the material composition or its structural condition is durable has not been seriously looked into in some parts of the product design. In fact, personal exposures lead to note that the standards in the design of aluminum profiles and extrusion procedures were, in some way, given less attention. Engineers and architects must then make conservative estimates of the conditions that would cause the resulting design to be on the safe side. There is no doubt that the risk and/or threat of doing evaluations manually on the CW design is imminent. Having both mathematics and science as primary references in the technical assessment of a curtain wall, there is exigency to depart from manual computation to avert evaluative errors during designing and pursue the utilization of an automated evaluation.

The design of an aluminum curtain wall of varying types that is aided with appropriate computing technology could guarantee that an accurate, timely-produced and threat-free output are equally feasible. Hence, the simplified criteria on wind load/pressure, glass specification, area moment of inertia, tensile or shear strengths of the bolts and the deflection of a mullion and transom could be better assessed using the application software. As aimed by this recent study, the shift from manual computation to an automated evaluation is imperative and can indeed boost a safer design of curtain wall.

4 CONCLUSIONS

Weighing the prospective threats between manual computations against the use of an automated evaluation in the design of curtain wall, it is, therefore, safer to depart from the former approach and subscribe on the latter form as explicitly discussed in this paper. As pointed out earlier, owners are usually mindful with regards to the project cost such that the same may influence the manner how the industry and its key players will work on a CW design to deliberately reduce the expected expenses on materials in particular. With the geographical location that a project has to consider as to the permissible tributary area and unsupported length of a CW member-frame, there is no room for such technical assessment to tolerate computational errors or deficiencies to happen. Thus, it is indeed better that the evaluation must be made towards a risk-managed process, which can only be actualized if a computing technology is adopted. If this contemporary investigation attracts future research, it is proposed that a post-subscription of such automated evaluation shall be empirically studied to further its deliberate intent specifically on other CW-integrated criteria. Future works may consider a migration of this automated evaluation from a computer-based installation towards a cellular phone-based application to advance an empirical scrutiny of its efficacy and efficiency of utilization.

ACKNOWLEDGEMENT

This is to acknowledge the kind gesture of our SUC President, Dr. Rosein A. Ancheta, Jr. and the Vice President for Research and Development, Dr. Adrian P. Ybanez, in bestowing all concerned faculty-researchers within the university such opportunity to publish their scientific papers in this institutional journal. Due credits are also given to Engr. Jimmy D. Maribong, who skillfully assisted the researcher in converting the formula translations into sophisticated application software. Profound gratitude is likewise expressed to Dr. Celbert Himang, as a dissertation adviser, whose expertise and good advice had helped this empirical undertaking forges forward. Lastly, appreciation is accorded to all personnel from the college where the researcher belonged.

REFERENCES

Aboelmagd, Y. M. (2018). Decision support system for selecting optimal construction bid price. A*lexandria Engineering Journal, 57*(4), 4189-4205.

Acosta, T. J. S., Galisim, J. J., Tan, L. R., & Hernandez Jr, J. Y. (2018). Development of empirical wind vulnerability curves of school buildings damaged by the 2016 Typhoon Nina. *Procedia Engineering, 212*(2), 395-402.

Aiello, C., Caterino, N., Maddaloni, G., Bonati, A., Franco, A., &Occhiuzzi, A. (2018). Experimental and numerical investigation of cyclic response of a glass curtain wall for seismic performance assessment. *Construction and Building Materials, 187*(3), 596-609.

Almerino, P.M. Jr., Himang, C., Capuno, R.G., Capuyan, D.L., Espina, R.C., Mangubat, R.C., Villarin, E.R., Manguilimotan, R.P., Calasang, V.O., Marsan, A.L., Capuno, J.F.C., Bellete, J.B., Abellana, D. P., Ocampo, L.A. (in press). The roles of demographic attributes on technical design practices: a case of curtain wall systems. *International Journal of Process Management and Benchmarking*. DOI: 10.1504/IJPMB.2021.10039880

Bae, M. J., Oh, J. H., & Kim, S. S. (2015). The effects of the frame ratio and glass on the thermal performance of a curtain wall system. *Energy Procedia, 78*(3), 2488-2493.

Casagrande, L., Bonati, A., Occhiuzzi, A., Caterino, N., &Auricchio, F. (2019). Numerical investigation on the seismic dissipation of glazed curtain wall equipped on high-rise buildings. *Engineering Structures, 179*(1), 225-245.

Chen, K. and Lu, W. (2018) 'Design for manufacture and assembly-oriented design approach to a curtain wall system: a case study of a commercial building in Wuhan, China', *Sustainability, 10*(7), 2201-2211.

Chen, Y., Feng, R., & Gong, W. (2018). Flexural behavior of concrete-filled aluminum alloy circular hollow section tubes. *Construction and Building Materials, 165(*6), 173-186.

Hong, M., Feng, C., Xu, Z., Zhang, L., Zheng, H., & Wu, G. (2019). Performance study of a new type of transmissive concentrating system for solar photovoltaic glass curtain wall. *Energy Conversion and Management, 201*(6), 112167.

Hu, Y., Yang, C. B., Teh, L. H., & Yang, Y. B. (2018). Reduction factors for stainless steel bolts at elevated temperatures. *Journal of Constructional Steel Research, 148*(2), 198-205.

Huang, B., Chen, S., Lu, W., &Mosalam, K. M. (2017). Seismic demand and experimental evaluation of the nonstructural building curtain wall: A review. *Soil Dynamics and Earthquake Engineering, 100*(2), 16-33.

Huang, Y., Xue, Y., Wang, X., & Han, F. (2017). Effect of cross-sectional shape of struts on the mechanical properties of aluminum based pyramidal lattice structures. M*aterials Letters, 202(*1), 55-58.

Kesawan, S., & Mahendran, M. (2019). Member moment capacity of complex-shaped aluminium mullions under wind suction loading. *Thin-Walled Structures, 144*(6), 106258.

Larkin, J. H. (2018, April). Deflection analysis of high performance, exterior wall systems. In Structures Congress 2018: Bridges, Transportation Structures, and Nonbuilding Structures, 6(1), 455-461.

Lee, A. D., Alimanza, J. A., Shepherd, P., &Evernden, M. C. (2019, August). Axial rotation and lateral torsional buckling of extruded aluminium mullions in curtain wall facades. *In Structures, 20*(1), 658-675.

Lee, A. D., Shepherd, P., Evernden, M. C., & Metcalfe,

p-ISSN: 2599-4875 e-ISSN: 2599-4980

D. (2017, May). Optimizing the cross-sectional shapes of extruded aluminium structural members for unitized curtain wall facades. *In Structures 10(*1), 147-156.

Lee, A. D., Shepherd, P., Evernden, M. C., & Metcalfe, D. (2018). Measuring the effective young's modulus of structural silicone sealant in moment-resisting glazing joints. *Construction and Building Materials, 181*(2), 510-526.

Lee, A. D., Shepherd, P., Evernden, M. C., & Metcalfe, D. (2018, February). Optimizing the architectural layouts and technical specifications of curtain walls to minimize use of aluminium. *In Structures, 13*(2), 8-25.

Leśniak, A., &Górka, M. (2018, July). Evaluation of selected lightweight curtain wall solutions using multi criteria analysis. *In AIP Conference Proceedings, 1*(2), 24-300.

Memari, A. M., Simmons, N., &Solnosky, R. L. (2021). Unitized curtain wall systems joint performance with re-entrant corners under seismic racking testing. *Journal of Building Engineering, 40*(1), 102610-102715.

Nazi, W. I. W. M., Royapoor, M., Wang, Y., &Roskilly, A. P. (2017). Office building cooling load reduction using thermal analysis method–A case study. *Applied Energy, 185*(2), 1574-1584.

Shukla, A. K., Sudhakar, K., Baredar, P., &Mamat, R. (2017). BIPV in Southeast Asian countries–opportunities and challenges. *Renewable Energy Focus, 21*(1), 25-32.

Tovarović, J. Č., Šekularac, N., &Ivanović-Šekularac, J. (2017). Problems associated with curtain walls. *Structural engineering international, 27*(3), 413-417.

Yalaz, E. T., Tavil, A. U., &Celik, O. C. (2018). Lifetime performance evaluation of stick and panel curtain wall systems by full-scale testing. *Construction and Building Materials, 170*(1), 254-271.

p-ISSN: 2599-4875 e-ISSN: 2599-4980