FE Analysis of High Pressure Laminate Panel for High Rise Building

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Abstract*: *In present study, numerical analysis carried out on Aluminium, Duralcan and their composite (HPL-High pressure laminate) Panels, implemented through a finite element model (FEM) as a unique quasi-static solution for adequacy of HPL as cladding for high rise buildings. The HPL panel is multi-stiffened material made by bonding stiff between high strength skins facing to low-density material. In current study, different sizes and different materials stiffened panels analyzed under lateral and wind response at high-rise building. The details study on materials (Aluminium, Duralcan and HPL) provide losses during the shear strength due to buckling. The model is implemented and calibrated with a numerical model developed in previous studies. High Pressure Laminates provides resistance to environmental effects, more durable and cheaper for decor surface. An achievement in overall performance under cyclic loading and high wind pressure of HPL is observed as an infill panel, later on also utilized as cladding. Furthermore, thermal insulation study should be carried out to check full occupancy of HPL for in situ practices.

***Keywords*: HPL, Pure Aluminium, Cladding, Duralcan, Abaqus, High-rise.**

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I. INTRODUCTION

Claddings are used in the exterior as well as interior of the buildings, however subjected to structural forces too these forces developed by Muhammad Tayyab Naqash [1].The structural function of cladding apart from architectural purposes like, reduce dead load of buildings, provide proper thermal insulation, suitable to resist high wind pressure and provided with sufficient shear strength during earthquake for thermal insulation, for bonding between HPL and structure various type of adhesive developed by Dimitar Angelski [2]. Nowadays claddings are available in many forms which are in different colours, different materials, and different sizes. It is a trend now, to utilize composite of traditional materials to enhance performance and resistance against affecting environmental factors obtained by Sandra Magina et al. [3]. For advanced in building technology, many alternatives of cladding materials are now available in the market like metal , stone, timber, fiber-cement, brick, vinyl these cladding comparison at high-rise building provide by Salih Ben-Nail Abu Sief [4]. Examples are studied in the current works, namely Aluminium (AW-1050), Duralcan (A380) and HPL (Composite of AW-1050 and A380). This material is commonly used for furniture and building industries [5]. HPL sheets are the nexus at high pressure which makes them highly durable provided by P. Vitulo [6]. Until now limited researcher research done on HPL panel to check its adequacy against shear resistance during earthquake and as a cladding subjected to high wind pressure for high-rise buildings. So, current research work is carried out to study behaviour of HPL under static uniform pressure as well seismic performance, with and without stiffeners. Experimental and numerical studies on shear panels with different material under static and dynamic load have been carried out to determine the feasibility [9-13].

The experimental study was conducted on aluminium panels with different six prototypes and experimented under shear cyclic loading. Two different materials were used for specimens, aluminium alloys AW5154A and AW1050A H24 [14-17]. In addition, few tests under diagonal cyclic loading on square braced-frame pure fitted with aluminium shear panels have been carried out [18,19]. Furthermore, tests have been performed to determine the lower-limit of the local slenderness. To explicate the experiments theoretically, numerical studies have been adopted [20], and parametric study has been carried out using virtual laboratory [21].

In present study, cyclic loading test of stiffened panels of pure Aluminium (AW-1050), Duralcan (A380) and HPL have been carried out to check feasibility of an application as cladding for tall buildings under excessive wind pressure, which are also suitable to provide sufficient thermal insulation. Wind pressure analysis has been carried out to check the intensity of pressure on cladding in tall structures. Total four models have been tested with different two materials and one with their composite. Stiffeners alignment is varies for model to model. Hysteresis loops were generated of load vs displacement results to conclude the effectiveness of materials and stiffened techniques.

Nomenclature

SPA1	Pure Aluminium (AW-1050) model 1
SPD1	Duralcan (A380) model 1
SPC1	Composite (HPL) model 1
SPA2	Pure Aluminium (AW-1050) model 2
SPD2	Duralcan (A380) model 2
SPC2	Composite (HPL) model 2
SPA3	Pure Aluminium (AW-1050) model 3
SPD3	Duralcan (A380) model 3
SPC3	Composite (HPL) model 3
SPA4	Pure Aluminium (AW-1050) model 4
SPD4	Duralcan (A380) model 4
SPC4	Composite (HPL) model 4

II. VERIFICATION

3D non-linear model is developed using ABAQUS as a quasi-static solution for validation. Modelling methodology like various interactions, constraints, boundary condition, loading and meshing size are assigned. Figure 1 shows comparison of load v/s displacement graph between analytical results and result obtained by Giuseppe Brando [7].

III. ANAYLTICAL STUDY

Various models are developed using pure Aluminium (AW-1050), Duralcan (A380) and HPL having in-plane dimension 640×640mm and 1500×1000mm. For the ease in application and adequacy check, the height of the building is taken as 300m and data calculated by IS:875, Part 3 [8].

A. Geometry

Models SPA1, SPD1, SPC1, SPA2, SPD2, SPC2, SPA3, SPD3 and SPC3 have been analysed under cyclic load and model SPA4, SPD4 and SPC4 have been analysed under wind pressure derived using IS:875 part-3 [8]. Therefore, model developed to check shear strength of each panel using support stiffeners and intermediate stiffeners as bracings with different materials pure Aluminium (AW-1050), Duralcan (A380) and HPL. For all models geometry for in plane dimensions are in figure 2.

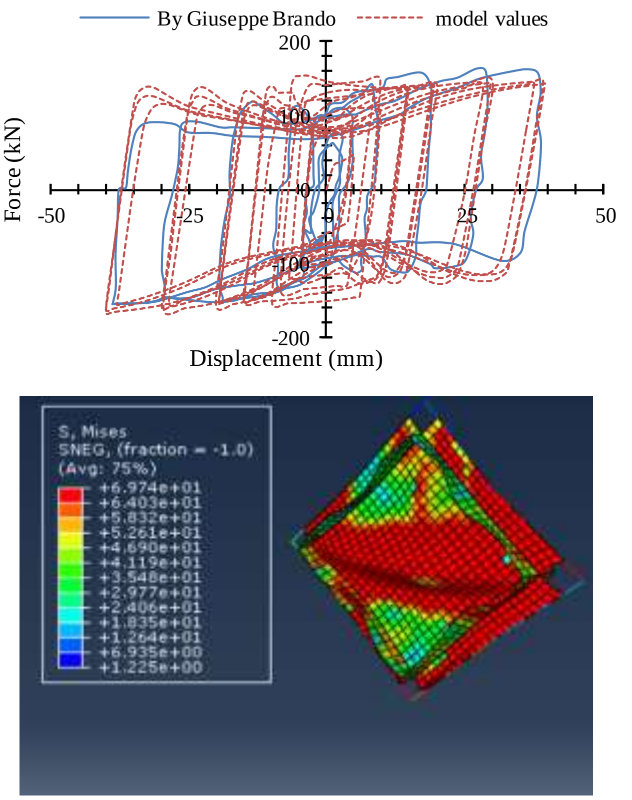
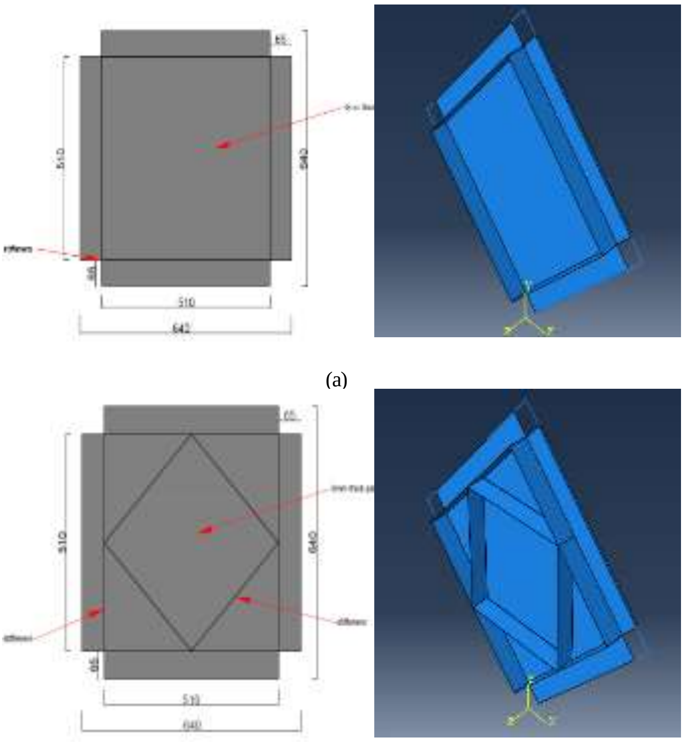
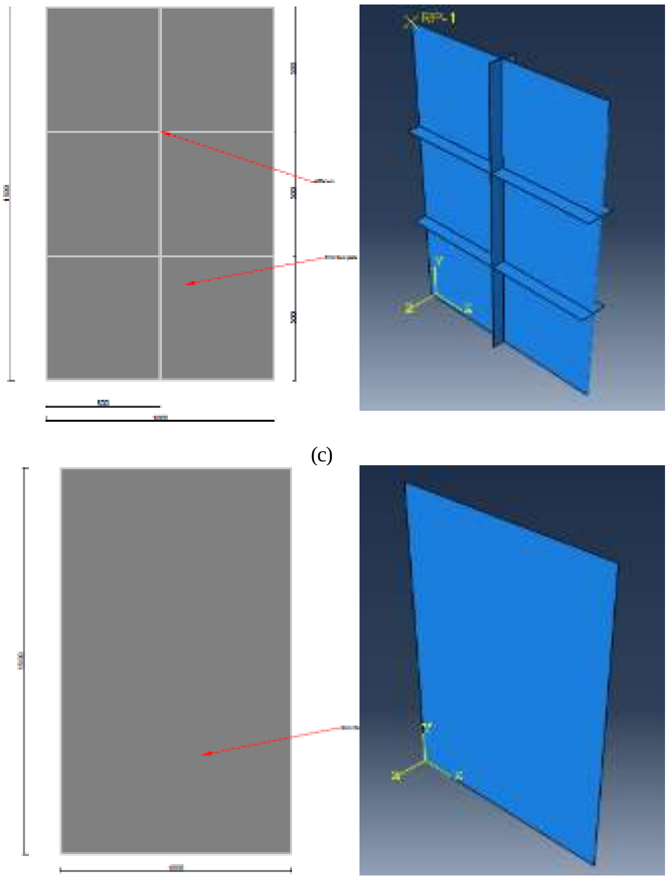


Fig. 1. Comparison of Force vs. Displacement graph to validate the models



(a)

(b)



(c)

(d)

Fig. 2. Configuration of model, (a) SPA1, SPD1, SPC1 (b) SPA2, SPD2, SPC2 (c) SPA3, SPD3, SPC3 (d) SPA4, SPD4, SPC4

B. *Material properties*

For a simulation, material properties plays vital role in accuracy of results. All models developed using different properties as defined in Table 2, using from EUROCODE [5]. Here, HPL is developed using a tie constrain of AW-1050 and Duralcan A380. The strain-stress relationship of Aluminium (AW-1050), and Duralcan (A380) material shown in fig. 3. For economical and structural point of view this system is suitable and represents a valid solution.

C. *Loading protocol*

a) Cyclic load: The time history shown in Fig. 4 is applied to all models as shown in Fig. 6. The cycles are progressievely increasing with three repetitions with range of 10mm to 40mm displacement.

b) Plate pressure: Determination of wind pressure for SPA4, SPD4 and SPC4 as per IS:875 part 3 [8] as shown in table 3.

- Data
  Length – 70m
  Width – 40m
  Total height – 300m

- Materials
  Pure Aluminium (AW-1050)
  Duralcan (A380)
  HPL (composite of AW-1050 and A380)

TABLE 1. WIND DESIGN CALCULATION [8]

Description	**IS:875-part 3**
Wind Design factors	
Wind zone = Zone IV, V_b = 47 m/s	Section 5.2
Risk coefficient (k_1) = 1.00	Section 5.3.1
Terrain & Height (k_2) (Table [3])	Section 5.3.2.2
Topography (k_3) = 1.00	Section 5.3.3.1
Importance factor (k_4) = 1.00	Section 5.3.4
Wind directionally (k_d) = 0.90	Section 6.1.1

TABLE 2. MECHANICAL PROPERTIES

Material	**Density (tonne/mm^3)**	**Modulus of elasticity (MPa)**	**µ**
Aluminium (AW-1050A)	2.68e-9	68300	0.34
Duralcan (A380)	2.98e-9	73800	0.33

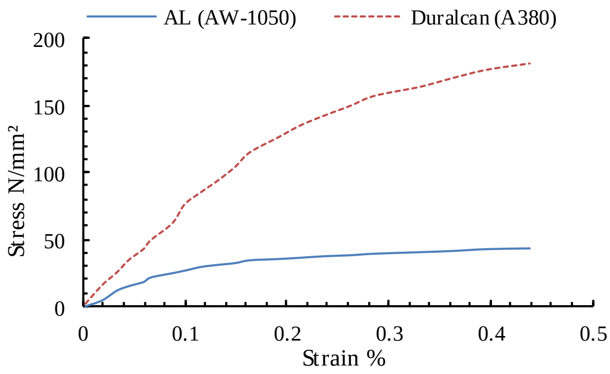


Fig. 3. Strain stress relationship for low strength materials

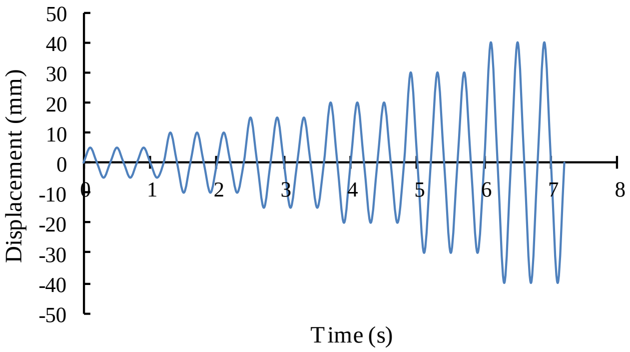


Fig. 4. Time history of cyclic loading

TABLE 3. CALCULATION OF DEVIATION IN PRESSURE WITH HEIGHT & PROJECT WIND SPEED [8]

Height of the building from ground (m)	k_2	V_z (m/s)	P_z (kN/m²)
Up to 10	1.05	49.35	1.461
15	1.09	51.23	1.574
20	1.12	52.64	1.662
30	1.15	54.05	1.752
50	1.20	56.4	1.908
100	1.26	59.22	2.104
150	1.30	61.1	2.239
200	1.32	62.04	2.309
250	1.34	62.98	2.379
300	1.35	63.45	2.115

D. Assembly

The finite element software Abaqus/CAE is used to developed models of shear panels. 3D Nonlinear shell element called (S4R) is used for modelling of 5mm thick shitting and stiffeners. While the two-node linear beam element (B31) has been used in modelling of beam and column of the external frame [22]. The planer geometry has been considered as shown in Fig. 2 for all parts and assembled using global coordinates in assembly module as described by Soni et al. [23]. Reference point is provided at top of the frame. Panel is arranged diagonally in frame and stiffeners are arranged at the inside boundaries of cross arms fig. 5.

E. Interaction

From the using Abaqus constraint library panel and external frame connection have been assigned at the panel side and corresponding frame members [22]. For stiffeners and plate as well as plate to plate connection (HPL – composite panel) have been using same constrained command used from Abaqus library as applied by Desai et al. [24]. The external frame to panel connection Each end node of external frame is constrained trough the MPC pin joint as depicted in Fig. 5(a & b).

F. Boundary conditions

The External frame (beam element) has been adopted additional degree of freedom and restrained to translate along global Z-axis and bottom most node is fixed as shown in Fig.6 for all models, which are subjected to cyclic loading. Moreover, external frame is fixed for models, which are subjected to wind pressure, Fig.8 (a). The external transverse displacement has been applied with an amplitude as shown in Fig.4 to the reference point assigned on external frame, depicted in Fig.6. In detail, the static general method used for displacement-based loading. For cyclic analysis, isotropic strain hardening has been used for all elements.

G. Meshing

The meshing provides offers the best possible balance between the accuracy & performance of analysis. In Fig.7, the mesh size for the all models by keeping global size 25. Furthermore, plate and stiffeners modelled by using shell element (S4R) and external frame is assigned beam elements (B31) as shown in Fig.7 & Fig.8 (b). For models SPA4, SPD4 and SPC4, shell element (S4R) having global mesh size 25 is assigned, depicted in Fig.8 (b). Structured controlled mesh is opted described by Patel et al. [25].

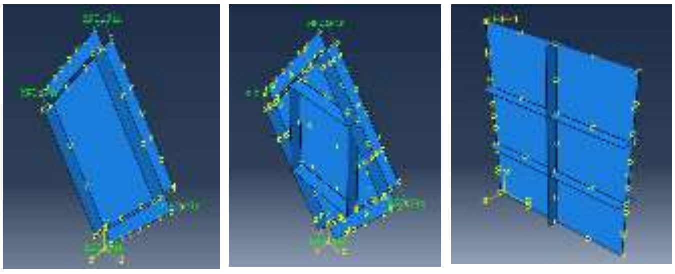

(a) (b) (c)

Fig. 5. Interaction - (a) SPA1, SPD1, SPC1 (b) SPA2, SPD2, SPC2 (c) SPA3, SPD3, SPC3

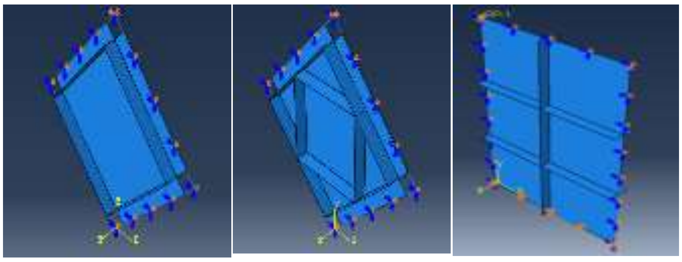

(a) (b) (c)

Fig. 6. Boundary Condition, (a) SPA1, SPD1, SPC1; (b) SPA2, SPD2, SPC2; (c) SPA3, SPD3, SPC3

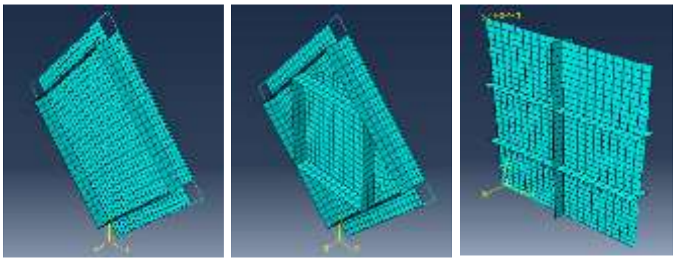

(a) (b) (c)

Fig. 7. Meshing, (a) SPA1, SPD1, SPC1; (b) SPA2, SPD2, SPC2; (c) SPA3, SPD3, SPC3

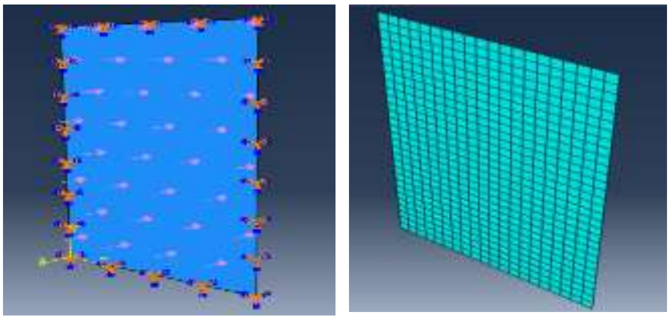

(a) (b)

Figure 8. Models SPA4, SPD4, SPC4 – (a) Boundary Condition & Loading; (b) Meshing

IV. RESULTS

In the current research work, detailed numerical analysis of various models assigned with different materials like, pure Aluminium, Duralcan and their composite (HPL) have been discussed. For all models width to thickness ratio is fixed as 100. Resisting mechanism and behavioural phenomena have been verified first. Comparison of HPL panels with Aluminium and Duralcan panels with respect to stresses, obtained through numerical analysis are observed as shown in Fig. 9.

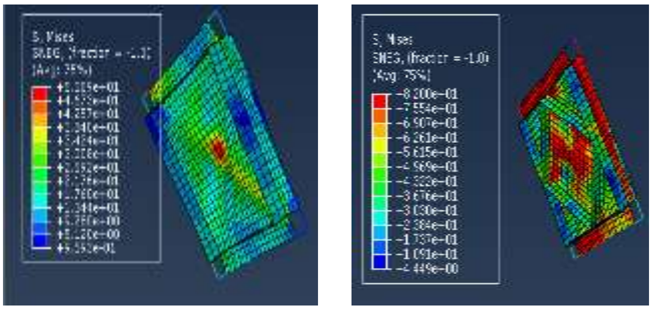
The Load vs Displacement graphs shown in fig. 10 which are obtained from results. Moreover, it is observed that, the proposed panel system adopted stiffeners and panels are suitable for the development of buckling phenomena. The analogy is provided by a displacement of ranging from ±5mm, ±10mm, ±15mm, ±20mm, ±30mm and ±40mm for the characteristics of hysteretic loops, fig. 4. A comprehensive energy absorption capacity of all models assigned with different materials is point of interest of authors of present study.

Uniform pressure applied on the panel, calculated using IS:875, part 3, Fig.8(a). The cladding panel located at the 300m height of the building subjected to fair uniform pressure of 2.115 kN/m^2. S mises stresses of the panel subjected wind response of 2.115 kN/m^2 are as shown in Fig. 9. The greatest value of stress depicted at the center of the panel as 10.85 MPa for Aluminium panel, 7.508 MPa for Duralcan panel and 7.284 MPa for HPL panel. When the highest principal stress reaches in system the failure will occur according to the maximum principle theory.

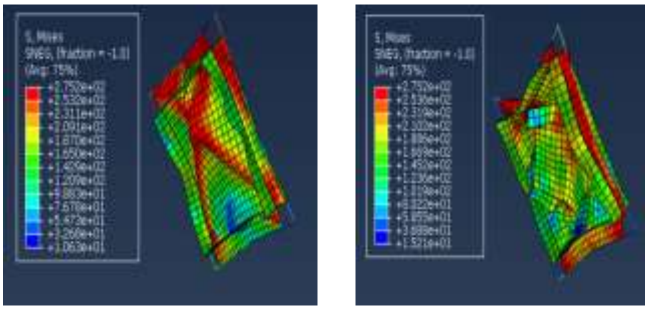
A. Load Vs displacement graph

In fig. 10, the panel hysteretic cycles are expressed in terms of force Vs displacement curves, are provided. The registered cyclic response shown good energy dissipation were different type of behaviour observed. From the analysis, maximum force at maximum displacement of each panel observed as shown in the Fig. 11.

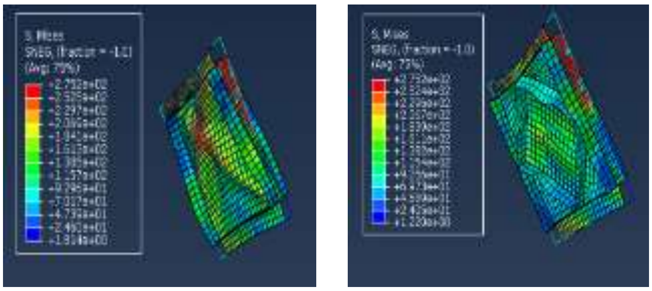
B. Stress results



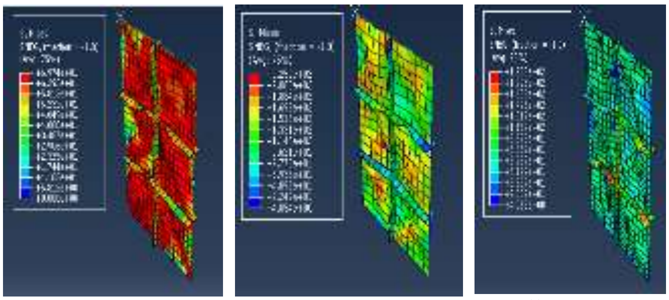
(a) SPA1 (b) SPA2



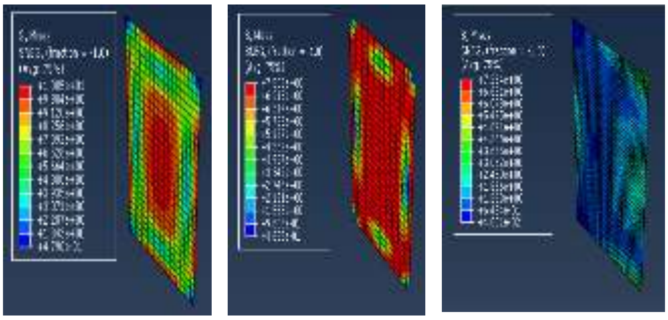
(c) SPD1 (d) SPD2



(e) SPC1 (f)SPC

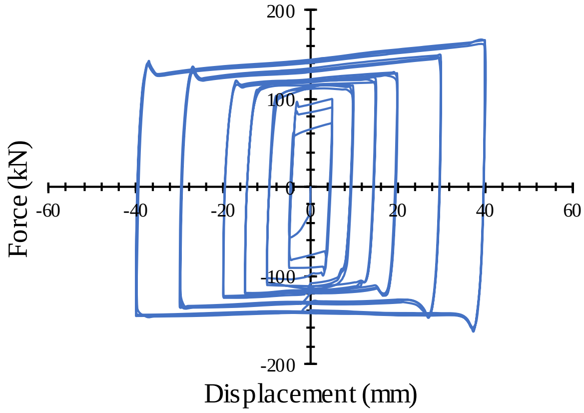


(g) SPA3 (h) SPD3 (i) SPC3

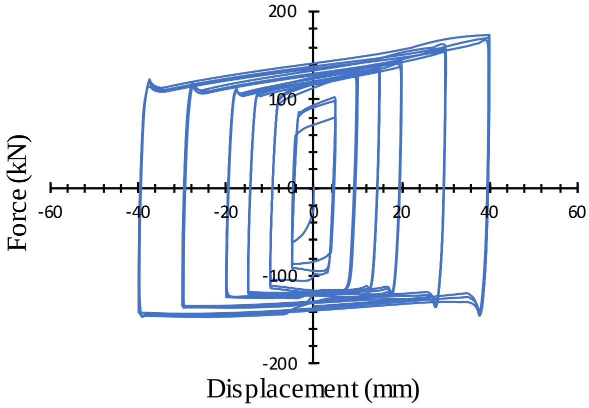


(a) SPA4 (b) SPD4 (c) SPC4

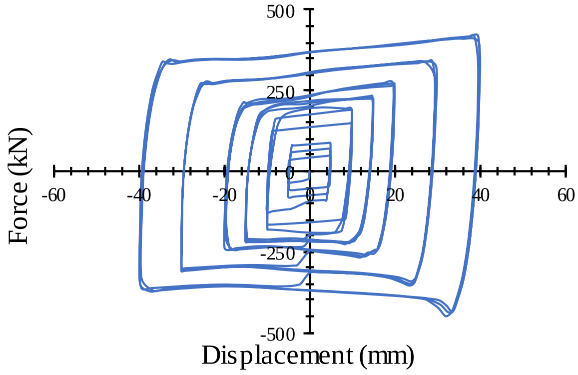
Fig. 9. Stress results for all models


Force (kN)
Displacement (mm)
200
100
0
-100
-200
-60
-40
-20
0
20
40
60

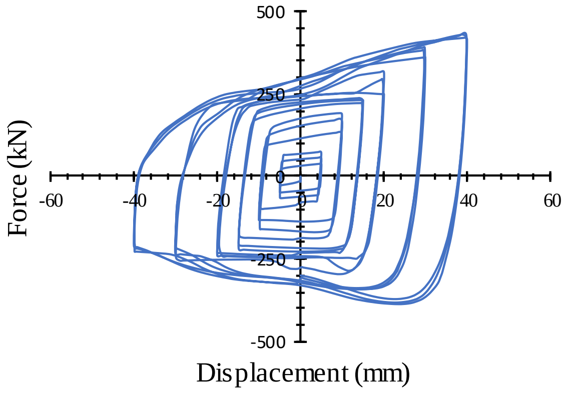
(a)


Force (kN)
Displacement (mm)
200
100
0
-100
-200
-60
-40
-20
0
20
40
60

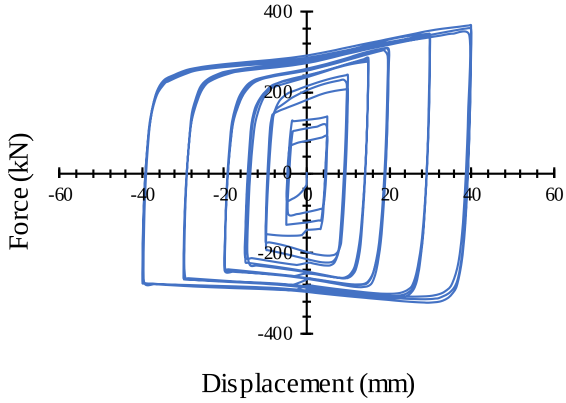
(b)


Force (kN)
Displacement (mm)
500
250
0
-250
-500
-60
-40
-20
0
20
40
60

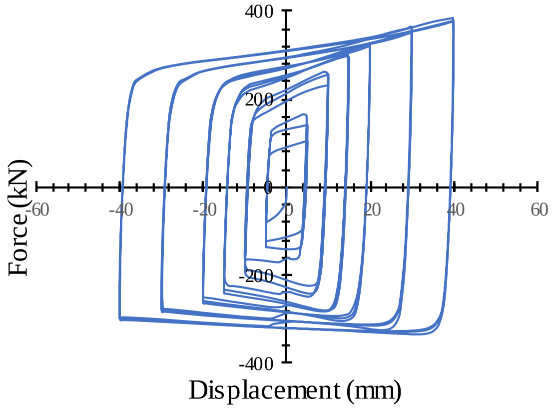
(c)


Force (kN)
Displacement (mm)
500
250
0
-250
-500
-60
-40
-20
0
20
40
60

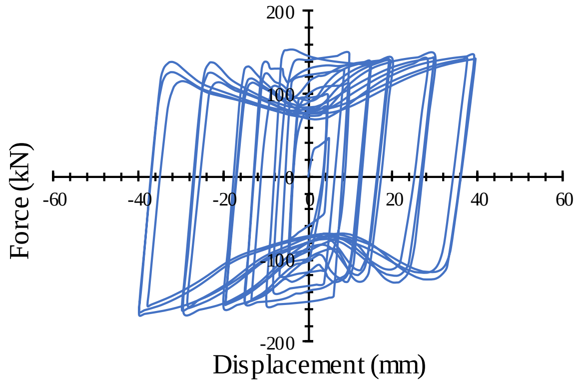
(d)


Force (kN)
Displacement (mm)
400
200
0
-200
-400
-60
-40
-20
0
20
40
60

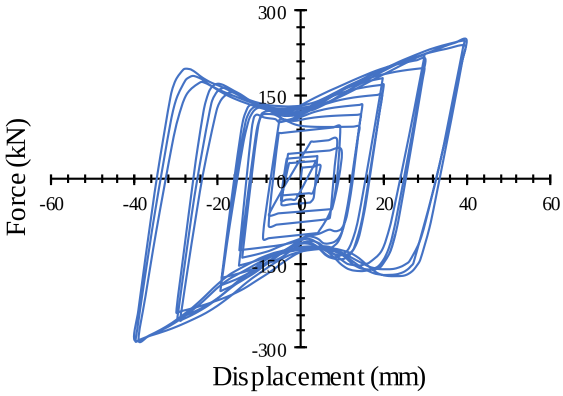
(e)


Force (kN)
Displacement (mm)
400
200
0
-200
-400
-60
-40
-20
0
20
40
60

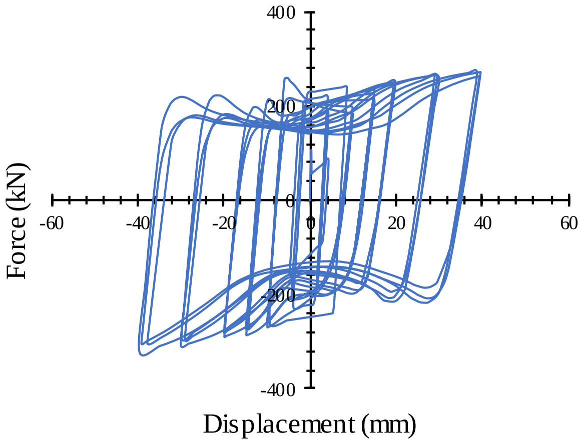
(f)


Force (kN)
Displacement (mm)
200
100
0
-100
-200
-60
-40
-20
0
20
40
60

(g)


Force (kN)
Displacement (mm)
300
150
0
-150
-300
-60
-40
-20
0
20
40
60

(h)



(i)

Fig. 10. Force vs. Displacement relationship of models (a) SPA1, (b) SPA2, (c) SPD1, (d) SPD2, (e) SPC1, (f) SPC2, (g) SPA3, (h) SPD3, (i) SPC3

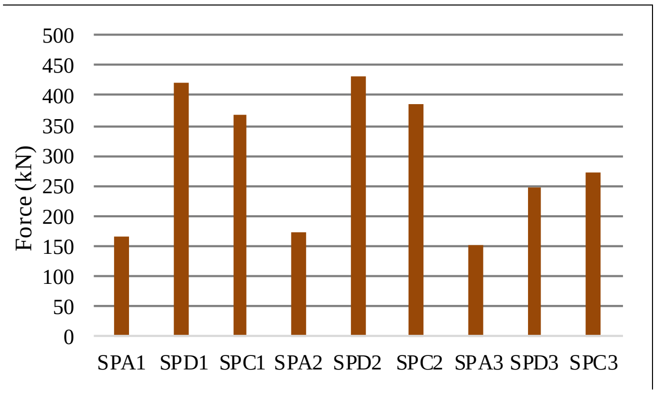


Fig. 11. Ultimate force @ 40 mm displacement for all models

V. CONCLUSION

In the current study, numerical analysis on Pure Aluminium (AW-1050), Duralcan(A380) and their composite (HPL) panels have been presented and deeply analysed. The investigation in reference to Fig. 11, four types of models based on different materials are discussed with respect to their load carrying capacity and energy absorption capacity in reference to observation of load vs displacement graph and stress contours obtained through FE analysis. In comparison of panels having size of 640×640mm and 1000×1500mm, it can be observed, Duralcan has the best outcome as it achieved the maximum force compared to models developed using AW-1050 and HPL. In fact, it is cast alloy and some of its properties does not adequate to use Duralcan panel as wall cladding in a high rise. Furthermore, the maximum capacity of Aluminium is less compared to Duralcan, Although HPL, composite of Aluminium and Duralcan depicts higher energy absorption capacity and resistance against wind pressure at a height of 300m. As per the study, conducted in the research work, it is found that the overall performance of HPL is considered as the best material that can be used for wall cladding in tall buildings as environmental exposure is adequate for, in addition to its structural performance and stability.

REFERENCES

[1] M. T. Naqash, "Design and Fabrication of Aluminum Cladding and Curtain Wall of a Sports Club," Open Journal of Civil Engineering, 9, 1-17, 2019.

[2] D. Angelski, V. Mihailov, "The influence of various types of adhesive on the adhesion strength between bonded HPL and furniture boards,"Annals of Warsaw University of Life Sciences - SGGW Forestry and Wood Technology No. 98, 5-10, 2017.

[3] S. Magina, M. D. Santos, J. Ferra, P. Cruz, "High-Pressure Laminates with Antimicrobial Properties," Materials, 9, 100, 1-12.

[4] S. A. Sief," Comparison of Different Facades for High-rise Buildings in Hot and Cold Climates in terms of Material Usage," M.Tech Thesis,2014.

[5] "Design of Aluminum structures prEN 1999-1-1," Final Draft, EUROCODE 9, 2006.

[6] P. Vitulo, "HPL-GEM: Controlling High-Pressure Laminates bulk resistivity with GEMs," 1-9.

[7] G. Brando, G. D. Matteis, "Experimental and numerical analysis of a multi-stiffened pure Aluminium shear panel," Thin-Walled Structures 49 (2011) 1277–1287, July 2011.

[8] IS:875-Part 3, "Wind Load Bureau of Indian Standard", Manak Bhavan, New Delhi.

[9] De Matteis G, Brando G, Panico S, Mazzolani FM. Bracing type pure aluminium stiffened shear panels: an experimental study. International Journal of Advanced Steel Construction (IJASC) 5(2):2009;100–19 [ISSN 1816-112X]. Chan SL, Chen WF, Zandonini R, editors.

[10] Nakagawa S, Kihara H, Torii S, Nakata Y, Matsuoka Y, Fujisawa K, et al. Hysteretic behavior of low yield strength panel Shear walls-Experimental investigation. In: Proceedings of the 11th WCEE, Acapulco, Mexico; 1996.

[11] De Matteis G, Landolfo R, Mazzolani FM. Seismic response of MR steel frames with low-yield steel shear panels. Engineering Structures—The Journal of Earthquake Wind and Ocean Engineering 2003;25(2):155–68. Elsevier, ISSN 0141-0296.

[12] Rai DC, Wallace B. Aluminium shear-link for enhanced seismic resistance. Journal of Earthquake Engineering and Structural Dynamics 1998;27:315–42.

[13] De Matteis G, Mazzolani FM, Panico S. Pure aluminium shear panels as dissipative devices in moment-resisting steel frames. Earthquake Engineering and Structural Dynamics 2007;36:841–59. Wiley InterScience, doi:10.21002/ eqe.

[14] De Matteis G, Mazzolani FM, Panico S. Pure aluminium shear panels as passive control system for seismic protection of steel moment resisting frames. In: Proceedings of the IV International Conference STESSA '03 (Behaviour of Steel Structures in Seismic Areas), Balkema, Naples, Italy; 2003. p. 609–14.

[15] De Matteis G, Panico S, Mazzolani FM. Experimental tests on pure aluminium shear panels with welded stiffeners. Engineering Structures June 2008;30(6):1734–44 printed by Krips b.v., Meppel, The Netherlands, Elsevier.

[16] D. Matteis G, S Panico, Mazzolani FM, "Experimental study on pure Aluminium shear panels with different stiffener types," In: Proceedings of the V International Conference STESSA '06 (Behaviour of Steel Structures in Seismic Areas),Yokohama, Japan; 219–24,August 2007.

[17] De Matteis G, Brando G, Panico S, Mazzolani FM. Pure Aluminium, an Innovative Material in Structural Engineering. In: Proceeding of the EUROSTEEL 2008 Conference. Graz, Austria, 03–05 September; 2008. p. 1885–90 [ISBN:92-0147-000-90].

[18] De Matteis G, Brando G, Panico S, Mazzolani FM. On the experimental response of bracing type pure aluminium stiffened shear panels. In: Beale RG editor. Proceeding of the sixth international conference on steel and aluminium structures (ICSAS '07), Oxford, UK, 24–27 July 2007, Oxford Brookes University. p. 164–71 [ISBN:978-0-9556254-0-4].

[19] De Matteis G, Brando G, Mazzolani FM. Hysteretic behaviour of bracing type pure aluminium shear panels by experimental tests. Earthquake Engineering and Structural Dynamics 2010; Published online in Wiley Online Library (wileyonlinelibrary.com), doi:10.1002/eqe.1079.

[20] De Matteis G, Formisano A, Panico S, Mazzolani FM. Numerical and experimental analysis of pure aluminium shear panels with welded stiffeners, Computers and Structures 86(6):2007;545–55, ISSN: 0045-7949, Oxford, England: Pergamon-Elsevier Science Ltd. doi:10.1016/j.compstruc.2007.05.027.

[21] Formisano, A, Mazzolani, FM, Brando, G, De Matteis, G. Numerical evaluation of the hysteretic performance of pure aluminium shear panels. In: Proceedings of the V international conference STESSA ’06 (Behaviour of Steel Structures in Seismic Areas), Balkema, Yokohama, Japan; 2006. p. 211–7.

[22] ABAQUS Inc., 2004. ABAQUS/Standard User Manual, Version 6.5. Providence, Rhode Island, USA; 2004.

[23] J. V. Soni, V. R. Panchal, N. A. Patel, “Study on plain surface with wave type configuration bar reinforced concrete frame subjected to lateral loads,” International Journal of Emerging Technology and Advanced Engineering, may 2018.

[24] V. desai, V. R. Panchal, V.M. Patel &N.A. Patel “ Influence of opening on stress reduction factor of unreinforced masonry panels,” Global journal of engineering science and researches, Feb. 2019.

[25] B. I. Patel, V. R. Panchal, N. A. Patel, “performance of channel and tee types of shear connector in composite slab with steel decking at elevated temperature,” International Journal of Emerging Technology and Advanced Engineering, may 2018.

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