Analysis of Structure Stability of Building Due To Effect of Solar Panel Installation Arrangements

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Abstract- *Renewable sources of energy are gaining popularity worldwide, with solar energy emerging as one of the prominent sources. However, a cost-effective and safe design for solar panels remains a challenge, as they require accurate information on loads and other factors that affect construction cost. Currently, design standards do not cover effective loads on solar panels mounted on residential buildings. This project aims to analyze the effect of solar panel installation arrangements on the structural stability of a building, using advanced simulation techniques. The study will identify the areas of the building most vulnerable to structural instability due to the installation of solar panels. The findings will provide valuable insights into the design and construction of sustainable buildings, ensuring that the structural integrity of buildings is not compromised by the installation of solar panels, and the buildings remain safe for occupation. This project contributes to the growing body of knowledge on the impact of solar panel installations on building structures, supporting architects, engineers, and builders involved in designing and constructing buildings with solar panel installations.*

Keywords- STAAD-Pro connect, Solar panel, Structural Analysis, structural stability.

I. INTRODUCTION

Many countries are now moving towards renewable source of energy for power generation. Solar energy is emerging as one of the prominent source of energy. There is a renewed interest in using solar panels (photovoltaic/thermal) as a renewable source of energy However, a cost-effective and safe design that will make such energy generation alternative competitive with traditional energy resources remains a challenge.A safe,yet economical, design of the solar panels for wind requires accurate information on the estimation of the loads, among other factors, which can affect significantly the construction cost. Since these structures are relatively new, effective loads on solar panels are hardly covered by current design standards.The existing exercise has less comprehensive data for evaluating loads on solar panels mounted on residential buildings. Furthermore, there is no provision in building codes and standards to guide the design of these types of structures for load.The use of solar energy is becoming increasingly popular due to its numerous benefits such as reducing carbon emissions and providing a sustainable source of energy. One of the ways to harness solar energy is through the installation of solar panels on buildings. However, the installation of solar panels on a building can have an impact on its structural stability.This project aims to analyze the effect of solar panel installation arrangements on the structural stability of a building. The analysis will be carried out using advanced simulation techniques and will focus on identifying the areas of the building that are most vulnerable to structural instability due to the installation of solar panels.The findings from this project will be useful for architects, engineers, and builders who are involved in the design and construction of buildings with solar panel installations. The results will help to ensure that the structural integrity of the building is not compromised by the installation of solar panels and that the building is safe for occupation.Overall, this project will contribute to the growing body of knowledge on the impact of solar panel installations on building structures and will provide valuable insights into the design and construction of sustainable buildings.

II. LITERATURE REVIEW

A. Mihalidis (2009) Suggested the use of renewable energy resources is increasing rapidly. Following this trend, the implementation of large area solar arrays is considered to be a necessity. Several design approaches of the supporting structures have been presented in order to achieve the maximum overall efficiency. They are loaded mainly by aerodynamic forces. International regulations as well as the competition between industries define that they must withstand the enormous loads that result from air velocities over 120 km/h. Furthermore, they must have a life expectancy of more than 20 years.[1]

L. Lisell, T. Tetreault, and A. Watson, et.al (2009) suggested A few simple considerations when designing buildings will facilitate a smooth and cost effective transition to solar later in the building's life. In cases in which solar is not economically feasible during the initial construction phase, making the structure solar ready will help reduce the carbon footprint of the building over its lifetime and lower power costs when the solar system is installed. Furthermore, a solar ready building will position the building owner to take advantage of falling renewable energy prices in the future. Implementing policy that requires some or all new construction to be solar ready is a simple way community leaders can promote solar in their jurisdictions. With the aid of the Solar Ready Building Planning Guide, city planners, policymakers, and developers will be able to lay the foundation for Solar Cities.[2]

Stephen Dwyer Alan Harper, William Lindau et.al (2011) suggested the Structural Considerations for Solar Installers provides a comprehensive outline of structural considerations associated with simplified solar installations and recommends a set of best practices installers can follow when assessing such considerations. Information in the manual comes from engineering and solar experts as well as case studies. The objectives of the manual are to ensure safety and structural durability for rooftop solar installations and to potentially accelerate the permitting process by identifying and remedying structural issues prior to installation.[3]

James Rossman Anderson, Cody Anthony Beckel, Mariela Lizet Castillo, et.al (2012) suggested a Small, residential solar power can be part of the solution to the energy crisis. However, there are very few options for a homeowner to purchase household solar mounting systems. To meet this need, a single solar panel ground mounting system has been designed that is functional, economical and easy to install. The design includes a base with a detachable center square pole and an angle adjuster allowing residential use throughout the US. The retail price is less than $1,500 and includes the mounting system, solar panel, power converter, and easy to follow instructions for installation.[4]

Aly Mousaad Aly (2012)suggested the existing literature has limited aerodynamic data for the evaluation of design wind loads for solar panels. Furthermore, there are no provisions in building codes and standards to guide the design of these types of structures for wind. This paper presents a systematic wind tunnel study to evaluate wind loads on solar panels mounted on low-rise gable buildings. A preliminary geometric scale effect study using a simple isolated solar panel was carried out to permit design appropriate wind tunnel experiments. Following the scale effect study, wind loads on solar panels mounted on different critical zones of low-rise residential roof are systematically investigated. The results of the current paper provide useful information for the design of the solar panels.[5]

Yixian Lee, Andrew A. O. Tay, et.al (2012) suggested Snow loading poses a significant problem to the integrity of photovoltaic (PV) modules. The weight of accumulated snow exerted on the PV modules can cause breakage of the glass cover and cells. The mechanical load test in IEC 61215 is designed to test the reliability of PV modules subjected to 2400 Pa, and subsequently to 5400 Pa of uniform load, in the revised standard. In this paper, finite element analysis is conducted to study the stresses in PV modules with non-tempered float glass, subjected to conditions in the mechanical load test. In this analysis, residual stresses that are induced during the module lamination process are taken into account in order to give an accurate representation of the existing stresses in the module. These residual stresses arise when the temperature of the PV laminate is lowered from the lamination temperature (typically 145 ºC) to room temperature, due to the differences in coefficient ofthermal expansion (CTE) of the constituent PV laminate materials.[5]

Eleni Xypnitou (2012)suggestedthe scope of this study was to better understand the wind pressure distribution on stand-alone panel surfaces and panels attached to flat building roofs. For this purpose, sophisticated physical models of solar panels of different configurations wereconstructed and appropriate instrumentation was used during the experimental process in the boundary layer wind tunnel in order to evaluate relevant wind-induced loads. A complex model was constructed using a 1:200 geometric scale. Three model panels were equipped with 36 pressure taps in total (both surfaces) for point and area-averaged pressure/force measurements. Pressure and force coefficients were computed for every pressure tap and for all the panels. Different configurations were tested under similar conditions in order to examine the effect of each parameter on the experimental results.[6]

Alex Mathew (2013)suggestedthe design and stability analysis of a solar panel supporting structure used as a fuel station in green automobile engineering. The present work is a part of the project named “Sun 2 Car” of Mahindra Reva Ltd and the design is used by the company to meet their industrial needs. The design of solar panel supporting structure and the effects of wind force on its structural stability is discussed in this paper. The measures for preventing the overturning of the structure are also discussed. Due to the wind force, a reaction force is experienced on the structure and the structure will retain its stable state, only if this reaction force is compensated by the force due the self-weight of the structure. The structure under consideration is able to hold 8 solar panels of 1kW capacity each and can withstand the wind velocity experiencing at different locations of India. This structure can use anywhere in India (calculations are based on wind zones of India), and can freely place anywhere as the base has no holding arrangements. The design is optimized for easy assembly, dismantle and transportation.[7]

Hema Venkatesh Bezawada (2014)suggested solar energy has a large potential to become the fuel of the future. The challenge however remains to effectively capture the available solar energy and efficiently convert the captured solar energy into electrical energy. The project is a definitive attempt to explore the opportunities in effectively capturing the solar energy by designing a mechanical system and support structure to rotate a set of photo voltaic modules which are capable of generating 1 kWh electricity. Large scale solar power generation is the broad framework of the current problem statement.[8]

III. AIM AND OBJECTIVE OF THE PROJECT

The aim of the project is Analysis of structure stability of building due to effect of solar panel and different panel arrangement installation.

A. Objective

The objective of the project are as follows,

- To study the impact of solar panel installation on the structural stability of the building.
- To analyze the various solar panel arrangements, such as parallel connection, and their effects on the building's structure.
- To evaluate the load distribution and stresses exerted on the building's structure by different solar panel configurations.
- To assess the structural integrity of the building under different solar panel installation arrangements, including varying angles, weights, and positions.

IV. OUTLINE OF PROJECT

The work to be carry out is divided into different phases which are given as follows,

Selection of site

1) Selection of structure/building for the project.
2) Overview of the building and solar panel installation arrangements.
3) Goals and objectives of the project.

Project Scope

1) Scope and extent of the structural analysis required.
2) Methodology and tools for conducting the analysis.
3) Assumptions and limitations of the analysis.

Solar Panel Installation Arrangement

1) Description of the different installation arrangements being considered.
2) Technical details of the solar panels and their mounting systems.
3) Environmental factors affecting the performance of the solar panels.

Structural Analysis

1) Methodology and tools for conducting the structural analysis.
2) Modeling and simulation of the building and solar panel installation arrangements.
3) Analysis of the structural stability of the building under different installation arrangements.

Result and Finding

1) Summary of the analysis results.
2) Comparison of the structural stability of the building under different installation arrangements.
3) Identification of any structural issues or concerns.

Recommendations

1) Recommendations for optimizing thesolar panel installation arrangements for structural stability.
2) Suggestions for improving the structural design of the building to accommodate the solar panels.

Conclusion

1) Summary of the project and its outcomes.
2) Lessons learned and recommendations for future projects.

V. METHODOLOGY

Collect data

This step involves collecting the necessary data for the project. This could include data on the building structure, solar panel installation arrangements, and weather conditions.

Analyze data

This step involves analyzing the collected data using appropriate tools and techniques. This could include computer simulations, mathematical models, and statistical analysis.

Identify potential issues

Based on the data analysis, potential issues related to the installation of solar panels on the building structure can be identified. This could include issues related to weight, wind load, and structural integrity.

Develop solutions

Based on the identified issues, solutions can be developed to mitigate the potential risks. This could involve modifying the solar panel installation arrangements or strengthening the building structure.

Evaluate solutions

This step involves evaluating the effectiveness of the proposed solutions through further simulations and analysis.

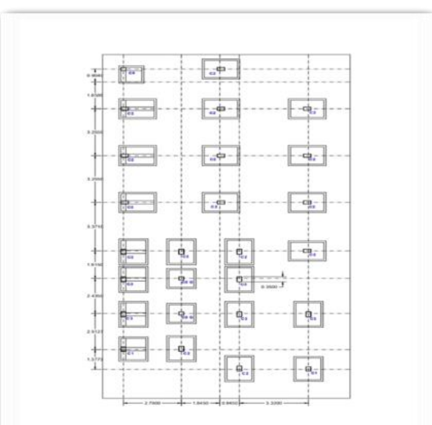
Report findings

The final step involves documenting the findings of the project and presenting them in a clear and concise manner. The report should include an overview of the project, the data collected, the analysis conducted, the identified percentage variation, proposed solutions, and evaluation of the solutions.

VI. ANALYSIS OF BUILDINGS AND SOLAR PANEL ARRANGEMENT

A. Case 1

1) Foundation plan



:-Foundation plan of building.

Table A1:- Strucural analysis details

Sr. No.	*Content*	*Details*
1	Building Type	Commercial + Residential
2	Building location	Tumsar, bhandara
3	Construction completed	2010
4	No.ofstories	4
5	FloortoFloorheight	3.65m
6	FoundationHeight	3m
7	Totalheight	14.6 m
8	GradeofConcrete	M25
9	Rebar	Fe415&Fe500
10	SlabThickness	125 mm
11	Beamsize	B1 :-230 x 300 mm B2 :- 230 x 450 mm
12	Columnsizes	C1:- 230 x 300 mm C2 :- 230 x 450 mm
13	Dead load	3.125 KN/m^2
14	Liveload	2KN/m^2
15	Floor Finishes load	1.5 kN/m^2
16	Wallload	Outer wall=17.00KN/m Internal wall = 9.57 KN/m Parapet wall =2.3KN/m
17	Load Combination factor	1 and 1.5
18	Load Combination I	1.0 (DL+LL)
19	Load Combination II	1.5(DL+LL)

Table A2:- Analysis of Solar panel Arrangements

Sr. No.	*Content*	*Details*
1	Solar Type	Monocrystalline 72 cell solar panel (jinko solar panels)
2	Solar watt	320 watt
3	Solar panel dimensions	(1956 x 992 x 40) mm
4	Solar panel weight	25 kg
5	No.ofpanel	20
6	Total Weight of solar panel	500 kg
7	Supported with	M.S. angle frame
8	Total Weight of supported system	1242 kg
9	PedestalSize	0.3 x 0.3 x 0.6 mm
10	No. of pedestal	20
11	Total Weight of Pedestal	2484 kg
12	Wind zone	Zone III – Nagpur = 44 m/s
13	Wind load	0.768 KN/m^2
14	Total load of increase on Terrace floor	1.02 KN/m^2

2) Analysis Result

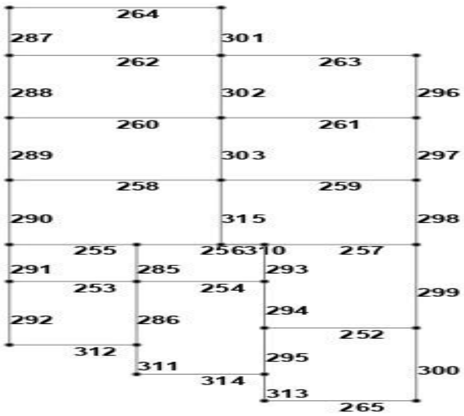


FIG 2 :- Terrace floor beam plan of building.

Table A3:- for Intermediate terrace beam no. 303

Sr. No.	*Parameter*	*With solar panel arrangement*	*Without solar panel arrangement*	*% Variation*
1	Shear Fy	33.44 KN	29.322 KN	12.31 %
2	Bending Mz	22.109KN.m	19.343 KN.m	12.51 %
3	Deflection	-0.746 mm	-0.684 mm	8.31 %

Table A4:- for Intermediate terrace beam no. 297

Sr. No.	*Parameter*	*With solar panel arrangement*	*Without solar panel arrangement*	*% Variation*
1	Shear Fy	23.40 kN	21.307 KN	8.97 %
2	Bending Mz	14.276 KN.m	12.776 KN.m	10.50 %
3	Deflection	-0.746 mm	-0.684 mm	8.31 %

B. ***Case 2***

1) Foundation plan

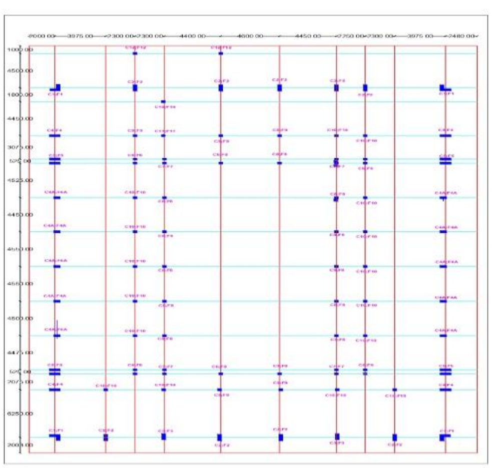


Table B1:- Structural analysis details

Sr. No.	*Content*	*Details*
1	Building Type	Commercial (Hospital Building)
2	Building location	Lodhikheda , chindwada ,MP
3	Construction completed	2005
4	No.ofstories	4
5	FloortoFloorheight	3.65m
6	FoundationHeight	3.65m
7	Totalheight	14.66 m
8	GradeofConcrete	M25
9	Rebar	Fe415&Fe500
10	SlabThickness	125 mm
11	Beamsize	B1 :-300 x 400 mm B2 :-300 x 500 mm
12	Columnsizes	C1:- 300 x 850 mm C2 :- 300 x 400 mm
13	Dead load	3.125 KN/m^2
14	Liveload	$2KN/m^2$
15	Floor Finishes load	1.5 kN/m^2
16	Wallload	Outer wall=17.00KN/m Internal wall = 9.57 KN/m Parapet wall =2.3KN/m
17	Load Combination factor	1 and 1.5
18	Load Combination I	1.0 (DL+LL)
19	Load Combination II	1.5(DL+LL)

Table B2:- Analysis of Solar panel Arrangements

Sr. No.	*Content*	*Details*
1	Solar Type	Monocrystalline 72 cell solar panel (jinko solar panels)
2	Solar watt	320 watt
3	Solar panel dimensions	(1956 x 992 x 40) mm
4	Solar panel weight	25 kg
5	No.ofpanel	120
6	Total Weight of solar panel	3000 kg
7	Supported with	M.S. angle frame
8	Total Weight of supported system	7452 kg
9	PedestalSize	0.3 x 0.3 x 0.6 mm
10	No. of pedestal	120
11	Total Weight of Pedestal	14904 kg
12	Wind zone	Zone III – jabalpur = 47 m/s
13	Wind load	0.768 KN/m^2
14	Total load of increase on Terrace floor	1.02 KN/m^2

2) Analysis Result

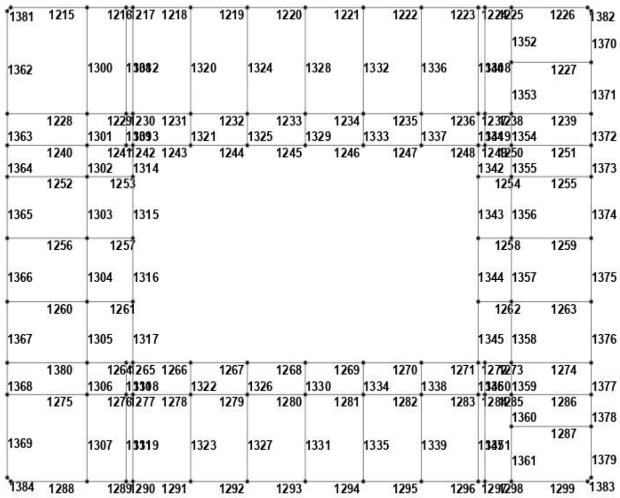


FIG 3:- Terrace floor beam plan of building.

Table B3:- for Intermediate terrace beam no. 1328

Sr. No.	*Parameter*	*With solar panel arrangement*	*Without solar panel arrangement*	*% Variation*
1	Shear Fy	186.416 kN	169.236 KN	9.21 %
2	Bending Mz	178.231KN. m	163.933 KN.m	8.02 %
3	Deflection	-1.65 mm	-1.572 mm	5 %

Table B4:- for Intermediate terrace beam no. 1221

Sr. No.	*Parameter*	*With solar panel arrangement*	*Without solar panel arrangement*	*% Variation*
1	Shear Fy	55.703 kN	51.743 KN	7.10 %
2	Bending Mz	50.081 KN.m	46.306 KN.m	7.53 %
3	Deflection	-1.645 mm	-1.572 mm	5 %

VII. RESULT

Table 1:- Shear moment on Intermediate beam

Sr. No.	*Shear Y*	*% Variation*	*Average shear Y*
1	Case 1	12.31 %	
2	Case 2	9.21 %	

Table 2:- Bending moment on Intermediate beam

Sr. No.	*Shear Y*	*% Variation*	*Average shear Y*
1	Case 1	12.51 %	10.265 %
2	Case 2	8.02 %	

Table 3:- Shear moment on End beam

Sr. No.	*Shear Y*	*% Variation*	*Average shear Y*
1	Case 1	8.97 %	8.035 %
2	Case 2	7.10 %	

Table 4:- Bending moment on End beam

Sr. No.	*Shear Y*	*% Variation*	*Average shear Y*
1	Case 1	10.50 %	9.015 %
2	Case 2	7.53 %	

Table 5:- Deflection on Intermediate beam

Sr. No.	*Shear Y*	*% Variation*	*Average shear Y*
1	Case 1	8.31 %	6.655 %
2	Case 2	5 %	

Table 6:- Deflection on End beam

Sr. No.	*Shear Y*	*% Variation*	*Average shear Y*
1	Case 1	8.31 %	6.655 %
2	Case 2	5 %	

VIII. CONCLUSION

Based on the results of our project, it can be concluded that the installation of solar panels on a building can have an impact on the building's structural stability. The variations in shear, bending moment, and deflection among the different cases suggest that the position, weight, and angle of the solar panels can affect the structural integrity of the building. Therefore, it is essential to carefully evaluate and analyze the impact of solar panel installation on the building's structure to ensure its stability and safety. The analysis of shear and bending moment on intermediate and end beams showed variations in different cases. The deflection on the beams also varied with different solar panel arrangements. Overall, it is important to carefully analyze and evaluate the structural integrity of a building when installing solar panels. The results of this project can provide valuable insights for architects, engineers, and builders who are considering the installation of solar panels on buildings. Further research can also be conducted to explore the long-term effects of solar panel installations on building structures.

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