Case Studies of Accidents and Their Causes in PV Systems

Structural Performance Evaluation Institute (SPEI)

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Introduction

Following the introduction of the FIT (Feed-In Tariff) system in 2012, the installation of PV Systems in Japan has rapidly increased. However, there has been a significant rise in structural damage to these systems due to natural disasters such as strong wind and heavy snow in recent years. In this presentation, natural disasters will be classified into categories such as earthquakes, strong winds, heavy snow, and torrential rain, and case studies of damage to PV Systems will be provided. Additionally, the characteristics and causes of the observed structural damage will be explained.


Earthquakes


Strong winds


Heavy snow


Torrential rain

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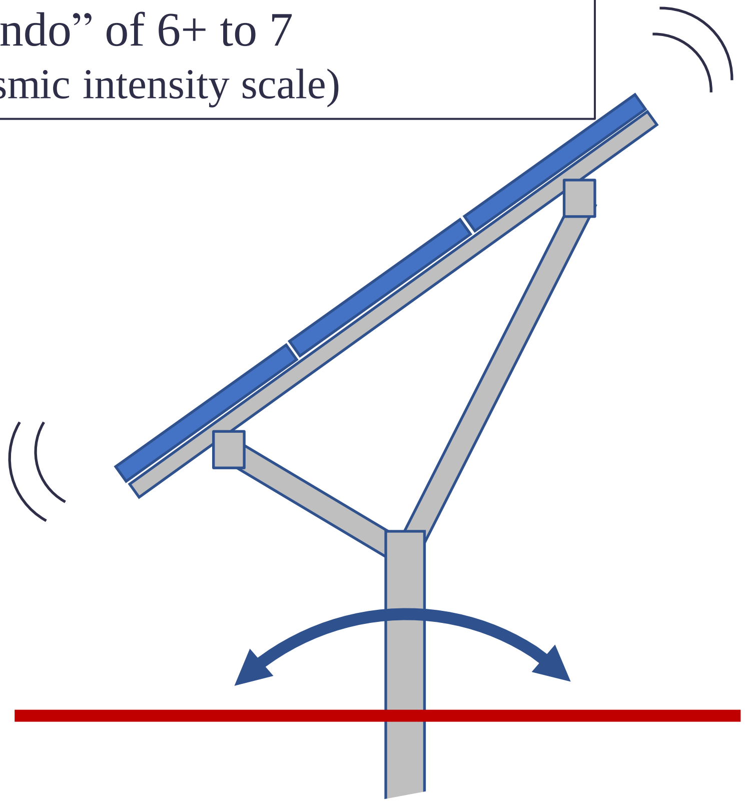
Characteristics of Structural Damage to PV Systems

Earthquakes	PV systems are relatively lightweight compared to buildings and other structures, so they tend to suffer less damage from earthquakes.
Strong winds	However, due to their lightweight, PV systems are more vulnerable to damage from strong winds, with a high incidence of systems being blown off or torn apart.
Heavy snow	In regions with heavy snowfall, snow-related damage is frequent. In some cases, the entire system may be completely destroyed.
Torrential rain	In recent years, Slope-mounted PV Systems has increased, leading to a rise in damage from landslides caused by heavy rain and erosions of the ground due to rainfall.

Examples of Earthquake Damage (Ground-mounted PV Systems)

In Hokkaido Iburi Earthquake (September 2018)

An earthquake with a“ Shindo” of 6+ to 7
(※Shindo is the Japanese seismic intensity scale)



- The single-legged frame type was tilted due to the horizontal forces from the earthquake.
- The single-legged frame type tends to have larger amplitude, which increases the load on the pile foundation.

In the case of a single-legged frame, the oscillation tends to become larger

Cause of damage: Insufficient horizontal resistance of the pile foundation

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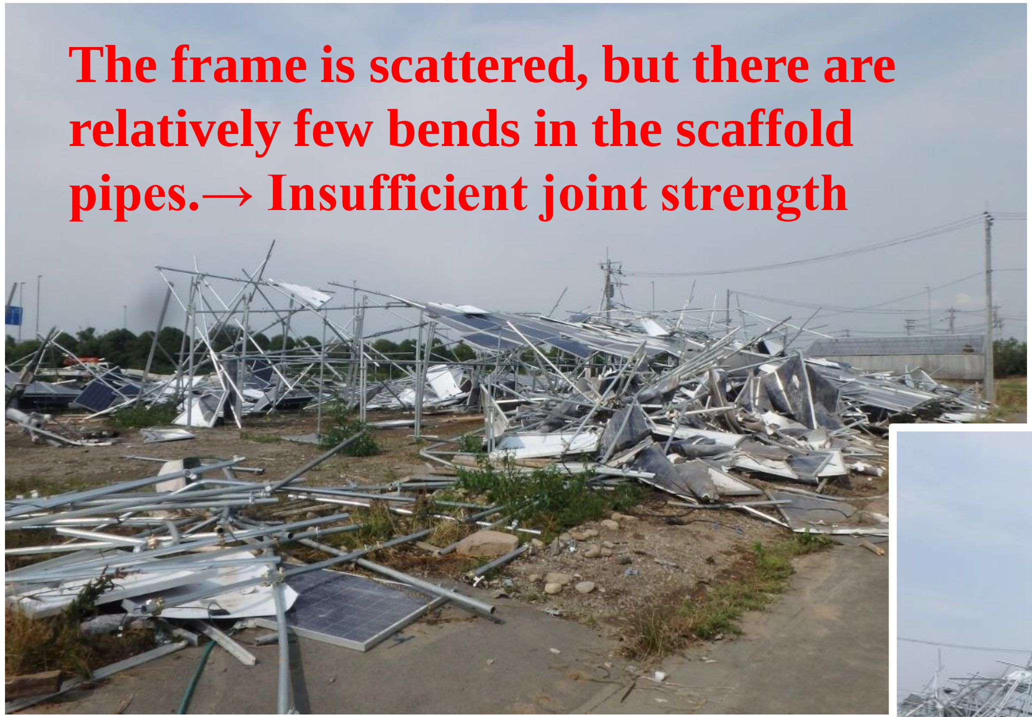
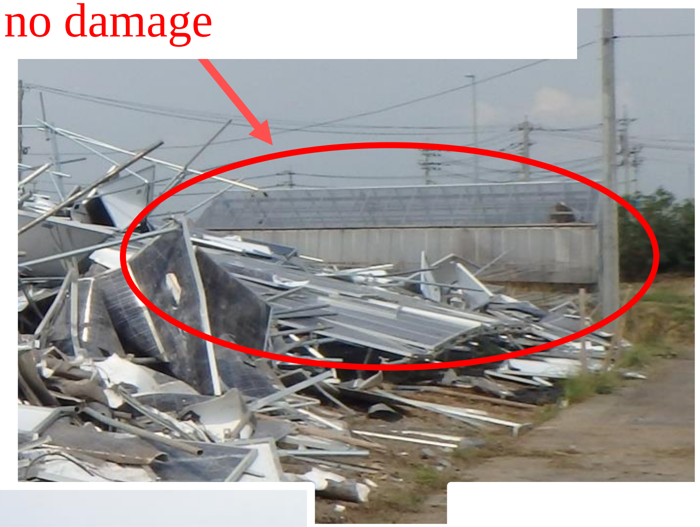
Examples of Strong wind damage Case A（Ground-mounted PV Systems）

In Gunma Prefecture (June 2015)



The frame collapsed and scattered due to a gust of wind, which is believed to have been a downburst. The frame and foundation were constructed using materials from temporary scaffolding used in construction.

The adjacent agricultural greenhouse sustained no damage



It is highly probable that the design wind speed was not reached.(It is also important to observe the surrounding conditions)

The undamaged frame

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Examples of Strong wind damage Case A（Ground-mounted PV Systems）

In Gunma Prefecture (June 2015)

The penetration depth of the pile foundation is approximately 800 mm

Cause of damage: Insufficient strength of the frame joints / Insufficient pull-out resistance of the pile foundation

Examples of Strong wind damage Case B（Ground-mounted PV Systems）

In Kagoshima Prefecture (September 2016)

- Aluminum components can have their strength increased through heat treatment, but this results in a decrease in toughness.
- If the thickness of the component is reduced, it may fail in a brittle manner.

Cause of damage: Insufficient strength of the components and joints

The array was damaged and scattered by the strong winds of Typhoon No.16 in 2016.

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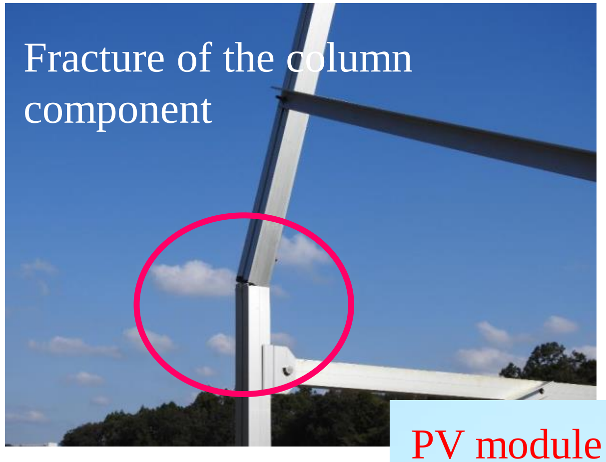
Examples of Strong wind damage Case C（Ground-mounted PV Systems：Agrivoltaics）

In Chiba Prefecture (September 2019)



Damage to the agrivoltaic PV system caused by the strong winds of Typhoon No.19 in 2019. The aluminum frame fractured, and damage at the joints led to the scattering of some PV modules and parts of the frame.

Cause of damage: Insufficient strength of the components and joints.

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Examples of Strong wind damage Case D（Floatvoltaics）

In Osaka Prefecture (September 2018)

AMeDAS Sakai
Maximum wind speed: 20.3 m/s, SSW
Maximum instantaneous wind speed: 43.6 m/s, S

Damage to the Floatvoltaics caused by the strong winds of Typhoon 1821.The Floatvoltaics are anchored by multiple mooring lines arranged around a group of floats. The cause of the damage is believed to be the failure of the connection between the windward mooring lines and the floats. The windward float, with its mooring lines severed, was lifted and twisted by the strong winds.

Cause of damage: Insufficient joint strength between the mooring lines and the floats

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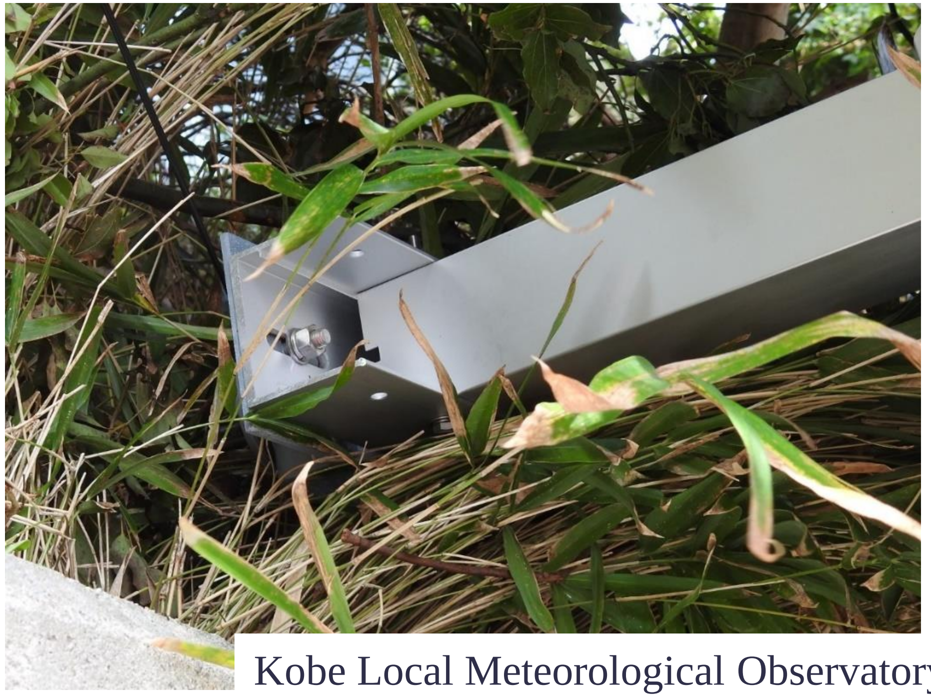
Examples of Strong wind damage Case E（Rooftop-mounted PV system）

In Hyogo Prefecture (September 2018)

Damage to the rooftop PV system caused by the strong winds of Typhoon No.18 in 2021. The joint between the rooftop surface of the apartment building and the frame was damaged, causing the entire array to be blown 20 m/s and fall.



Kobe Local Meteorological Observatory
Maximum wind speed: 23.0 m/s, ENE
Maximum instantaneous wind speed: 41.8 m/s, E

Cause of damage: Insufficient joint strength between the building rooftop and the frame

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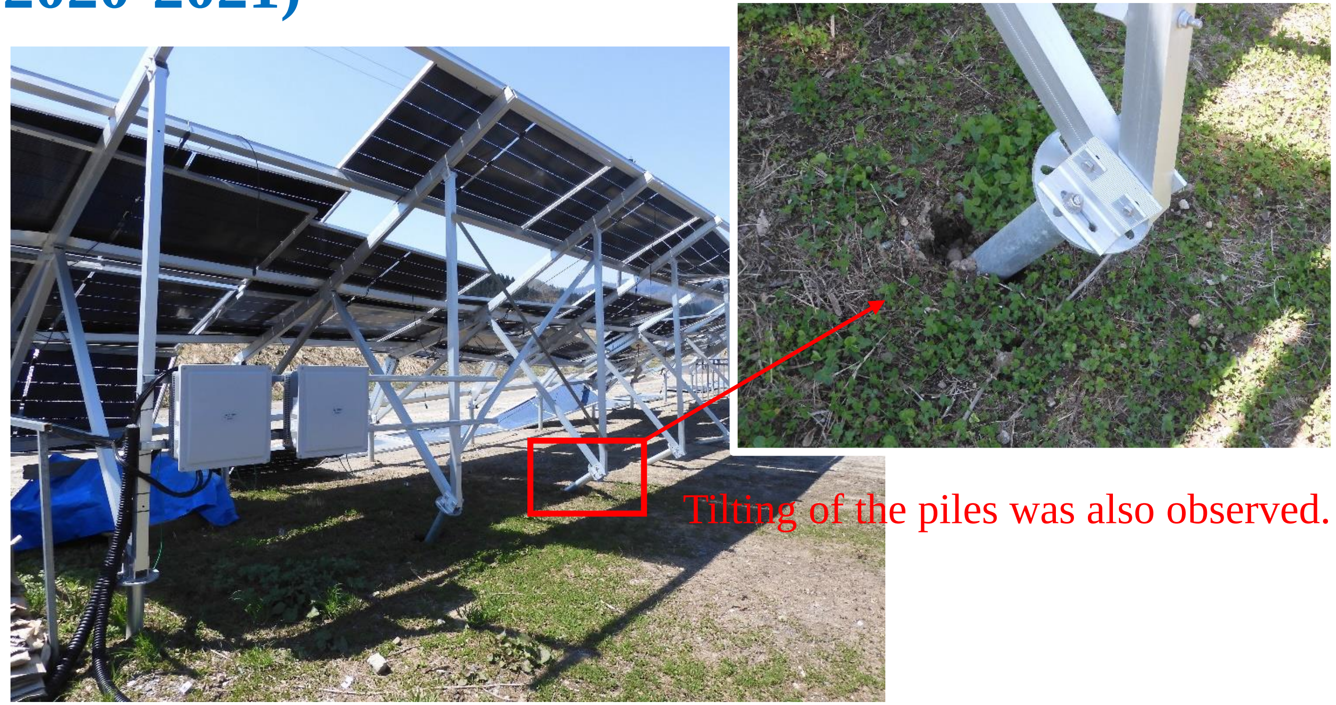
Examples of Heavy snow damage: Case A

In Yuzawa City, Akita Prefecture (Winter 2020-2021)

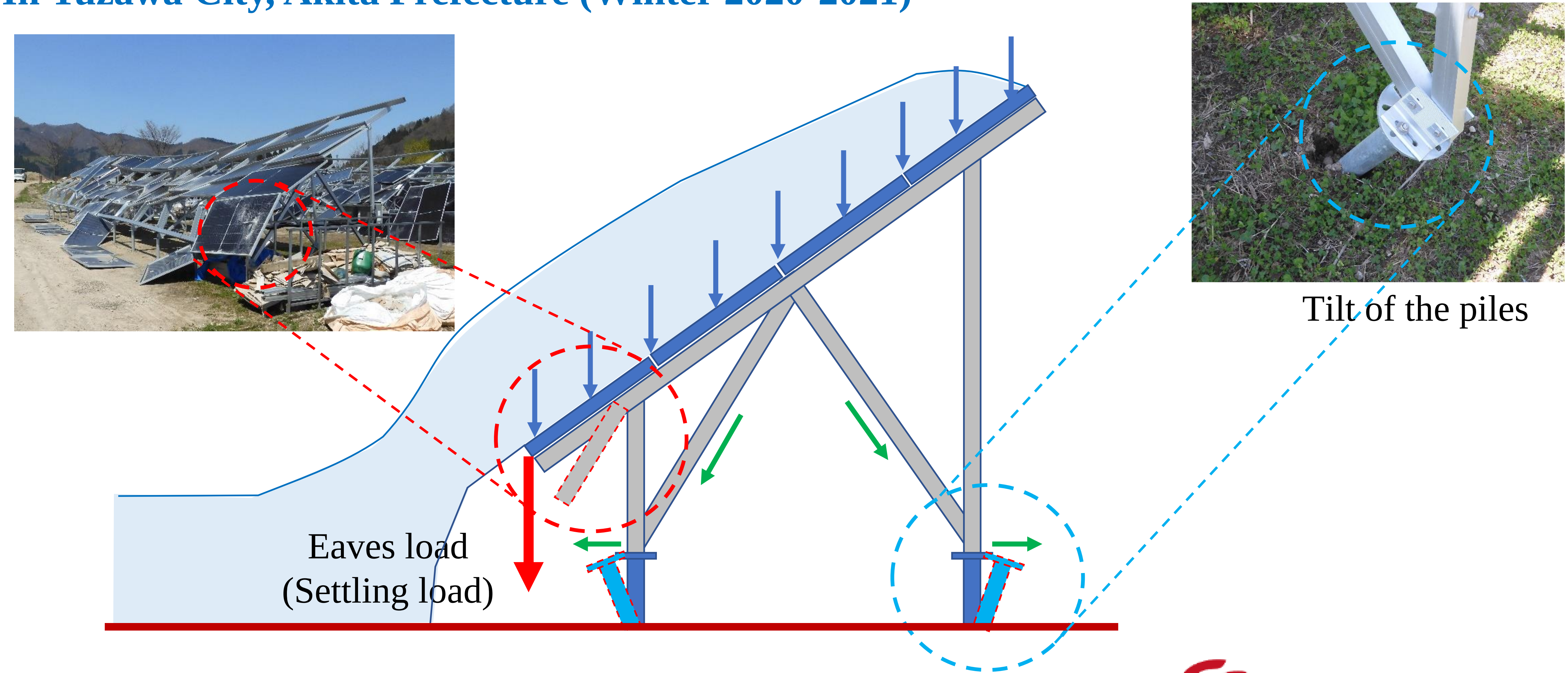


Deformation (fracture) of the aluminum frame, detachment of the PV modules, and tilting of the pile foundation were observed. It is presumed that the primary cause of the damage was the load acting on the eaves.

Cause of damage: Inadequate setting of eaves load, insufficient horizontal resistance of the piles

Examples of Heavy snow damage: Case A

In Yuzawa City, Akita Prefecture (Winter 2020-2021)



Examples of Heavy snow damage: Case B

In Iwamizawa City, Hokkaido (Winter 2020-2021)

Deformation (tilting) of the horizontal rail

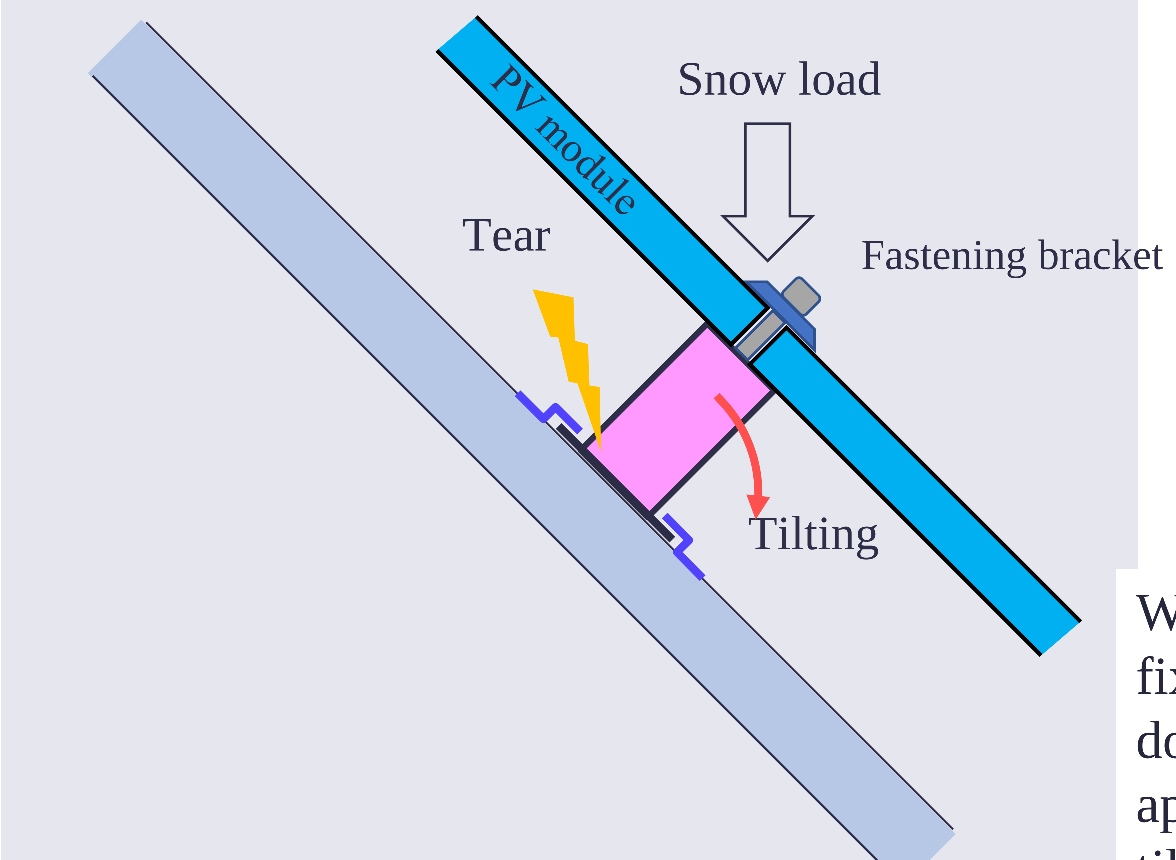
Tear at the joint of the horizontal rail

Detachment of PV modules was observed due to the deformation of the horizontal rails of the aluminum frame. It is presumed that the primary cause of the damage was insufficient joint strength between the vertical and horizontal rails. Tilting of the pile foundation was also observed.

Cause of damage: Inadequate setting of eaves load, possible insufficient strength of the components.

Examples of Heavy snow damage: Case B

In Iwamizawa City, Hokkaido (Winter 2020-2021)



Mechanism of tilting of the horizontal rail

When the horizontally fixed rail is pushed downward, a moment is applied in the direction of tilting of the component.

Examples of Heavy snow damage: Case C

In Iwamizawa City, Hokkaido (Winter 2020-2021)

Only the PV modules have been damaged.
It is important to select modules that are compatible with the local snow load (design snow load).

The glass surface of the PV modules bends significantly under snow load (or wind pressure load), leaving marks where it has contacted the horizontal rails.

Cause of damage: Incorrect selection of PV modules (insufficient strength)

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Examples of Torrential rain damage: Case A

In Hyogo Prefecture (July 2018)

Damage from the Western Japan Heavy Rain Event of July 2018 : The ground at Slope-mounted PV Systems along the Sanyo Shinkansen line collapsed, and debris threatened the Shinkansen tracks, leading to partial suspension of service.

Cause of damage: Insufficient ground construction (poor drainage ditches and retaining walls)

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Examples of Torrential rain damage: Case B

In Kumamoto Prefecture (July 2020 Kyushu Torrential rain)

Damage to the drainage ditch due to soil erosion, exposure of pile foundations.

Cause of damage: Inadequate drainage system

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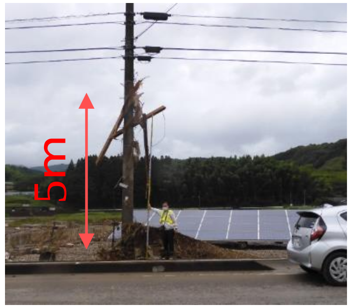
Examples of Flood damage (River Overflow)

In Joso City, Ibaraki Prefecture (September 2015)

Due to the heavy rainfall from Typhoon No.15 in 2018, the levee of the Kinugawa River collapsed, and the PV system was submerged. Because of the high flow velocity, many PV systems were damaged.

Cause of damage: Location of the PV systems

In Kuma District, Kumamoto Prefecture (July 2020)



Due to the heavy rainfall from the July 2020 Kyushu floods, the Kuma River flooded, submerging the PV systems. However, because the flow velocity at the location of PV system was slow and the water level gradually rose (by approximately 5 meters), no damage to the frame was observed.

Characteristics of structural accidents

- Characteristics of Frame Damage
  - There is a frequent occurrence of joint damage (often due to the lack of structural calculations for the joints)
  - In cases where design loads or structural calculations are incorrect, components can break.
- Characteristics of Foundation Damage
  - Many cases of damage are caused by insufficient resistance of pile foundations.
  - Pile foundations are often pulled out due to strong winds.
  - There are cases where pile foundations collapse due to snow load.
- Characteristics of Ground Damage
  - Slope collapse occurs due to inadequate site preparation.
  - Lack of maintenance leads to soil erosion, which can result in serious consequences.

Formulation of guidelines

- In order to reduce accidents related to PV systems, guidelines for design and construction are being developed as part of a commissioned project by NEDO*.
  - Design and Construction Guidelines for Ground-Mounted PV Systems, 2024
  - Design and Construction Guidelines for Slope-mounted PV Systems, 2023
  - Design and Construction Guidelines for Agrivoltaics, 2023
  - Design and Construction Guidelines for Floatvoltaics, 2023
  - Design and Construction Guidelines for Building-Mounted PV Systems, 2024

＊ : New Energy and Industrial Technology Development Organization, Japan

The end

Thank you for your attention

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