PORTLAND AERIAL TRAM
PORTLAND, OREGON

Body Panel Dislocation Incident
Incident Date: December 4th, 2018
Investigation Dates: December 11th & 12th, 2018
Portland Tram Incident Report

Project Information

Project: Portland Aerial Tram

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Revisions:

1. 10 January 2019 – Revised narrative in sections 4 & 5 to reflect current design methodology. Changed image in figure 10 to show new and old tether components.
2. 15 April 2019 – Updated several photos, changed narrative in multiple sections.
The technical material and data contained in this document were prepared under the supervision and direction of the undersigned, whose seal, as a professional engineer licensed to practice as such, is affixed below.

SCOPE OF INSPECTION

The word inspection in this report refers to a visual inspection of the as-built condition of the tramway at the time of our site visit. Evaluation of the existing structure requires that certain assumptions be made regarding conditions existing at the time of the described failure. Elements that could not be observed are excluded from this report. Therefore, this report reflects the findings of our inspection after the described failure and our professional analysis of that failure, but is not intended to be a definitive and certain explanation of the causes of the failure nor a guaranty that such a failure will not occur in the future.

Our inspection was performed in a manner consistent with the degree of care and skill ordinarily exercised by members of the same profession currently practicing under similar circumstances. Ridgeline makes no warranty, certification, or guarantee, express or implied, as to its professional services rendered in the creation of this report.

Prepared by Joel Deis, P.E.
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1. INTRODUCTION

On December 4th, 2018 at 11:52 AM the uphill roof panel from Cabin #2 of the Portland Aerial Tramway fell during a trip. The panel landed on the staircase of the bridge located below and struck a pedestrian. The pedestrian was treated for minor injuries at the scene and refused additional medical care. The purpose of this report is to document the circumstances that led up to this event and what measures should be taken to prevent a situation like this from occurring again in the future.

2. DESCRIPTION OF SYSTEM

The Portland Aerial Tramway first went into service in December of 2006 to assist the transportation of staff, patients and visitors of Oregon Health Sciences University (OHSU). Additionally, the system was designed to move the general public and is owned by the Portland Bureau of Transportation (PBOT). This system is unique in that it was constructed not only to be an integral part of the City’s transportation system, it is also a landmark with several architectural features designed to improve the aesthetics of the system. One of these features is the overall shape of the cabins. Typically, aerial tramway cabins have a rectangular profile rather than the curved shape of the cabins in this system. Examples of two different cabins can be seen below:

Figure 1 – Portland Tram Cabin (Left); “Typical” Rectangular Tram Cabin (Right)
The cabins for the Portland Aerial Tram were designed and manufactured by Gangloff Cabins in Switzerland. Their construction is unique in that they are essentially a rectangular cabin, similar to a more typical installation, with decorative paneling wrapped around to give them their unique shape. Figure 2 & Figure 3 below show a cabin in service and what the top looks like with the paneling removed.

![Figure 2 – Portland Tram Cabin](image)

![Figure 3 – Tram Cabin from Above with Decorative Paneling and Hangar Arm Removed](image)
On December 4th, 2018 one of these decorative panels came free from the cabin and fell to the ground. Figure 4 below shows Cabin #2, the one involved in the incident, with the panel that fell removed.

Figure 4 - Cabin #2 With Panel Removed
3. ANALYSIS OF FAILURE

For one of the decorative panels to fall from the cabin the panel latch and tether system must fail. Each panel is held in place by multiple spring latches and two tethers, therefore a panel cannot disengage unless both the spring latches and the tethers fail at the same time. The panel in question includes 8 latches distributed around the perimeter of the panel shown in Figure 5 below. The latches that failed during the incident are removed from the panel and can be seen in Figure 6.

Figure 5 - Panel Removed from Cabin; Latch Locations Circled in Red

Figure 6 – Spring Latches Removed from Panel
While it is impossible to conclusively say why the panel was pulled from the cabin, based on the information that was observed during our visit, it seems that the most likely reason the panel came loose was from lack of stiffness of the panel. Wind traveling over a panel of this shape produces an uplift force. This uplift force causes the panel to flex upward which in turn causes the sides of the panel to pull inward. As the sides move inward the contact area between the latches and their attachment to the cabin goes down until the point where they completely lose contact and the panel is pulled from the cabin. A schematic illustration of this situation can be seen below in Figure 7.

![Figure 7 - Schematic of Panel Latch Failure; Clouded Area Shows where Latches Lost Contact with Cabin](image-url)
The incident report provided by Doppelmayr, the tram operator, states that the wind was gusting as high as 38 mph at the time of failure. Considering this wind speed, and the formulas for calculating wind pressure in ASCE7-10, the estimated uplift force from the wind at the time of the incident was just under 500 pounds. Applying this force to our 3D stress analysis model of the panel produced the following result:

![Figure 8 – Diagram of Deflected Roof Panel Under Load; Original Panel Shape in Gray, Deflected Shape in Colored Plot, Deformations Exaggerated for Clarity](image)

The cabin manufacturer provided a tether system to catch the panels in the event that they came loose from the cabin. The size of the hardware used in the system indicates that the tether was likely designed to prevent the panel from falling to the ground if a technician were to accidentally drop it during maintenance. The design of the hardware was inadequate to restrain the wind forces on the panel during the incident. Images of the tether system, including the carabiner that failed can be seen in the following figures.

![Figure 9 – Original Carabiner (Left); Recovered Portion of Broken Carabiner (Right)](image)
4. DOCUMENT REVIEW AND MAINTENANCE PROCEDURES

Gangloff, the cabin manufacturer, did not provide any maintenance procedures or inspection criteria for the tram cabins. As such, the operations and maintenance documents do not provide any guidance for PBOT or Doppelmayr, the tram operator, to follow. Currently, there is no documentation in place that specifically details when the panel attachment to the cabin was last inspected. It should be noted, however, that other maintenance procedures that are currently in place require the removal and reinstallation of these panels at least twice per month. The frequency of the panels being indirectly inspected through other maintenance activities points towards a design failure not inadequate maintenance. Since the incident occurred, Doppelmayr has created a new maintenance program, 1M34, to address the future inspection of the panels, latches and updated tether system.

5. REMEDIATION

Since the tram opened in 2006 it has completed over 600,000 trips. During this time, the panel latch and tether system has malfunctioned twice and had one complete failure during the incident on December 4\textsuperscript{th}, 2018. During both malfunction events a panel came loose from the cabin but was prevented from falling by the tether. Conversations with the Tram staff indicate that after each of the malfunctions the panel latches were revised in an attempt to prevent future failures. During the most recent malfunction, which occurred in January of 2014, the size of the restraint latches was increased, and a second tether was added to each panel. Ridgeline recommends that both the panel latch and safety tether components of the system are revised to prevent a future incident of this nature.
Panel Latch System
The recent incident has proven that the spring latch system that was originally designed by the cabin manufacturer Gangloff is inadequate to resist the wind forces on the cabin. Ridgeline recommends that the roof panels are mechanically attached to the cabin using bolts which restrain movement in all directions rather than in a single direction like the spring latches in the current design.

Safety Tether System
At the close of operations on the day of the event, tram maintenance staff installed a new interim safety tether system consisting of two tethers per panel, fabricated from rock climbing hardware, to all removable panels on both tram cabins. The strength of this system, 22 kN MBS lanyard and 7 kN MBS carabiner, is far superior to that of the failed tether. Ridgeline recommends that the permanent tether system includes both a revised lanyard system as well as stronger anchor points.

6. INTERIM OPERATIONS

Given the timeframe required to fabricate and install the new components discussed in this report, Ridgeline recommends making the following changes to system operations with respect to wind:

Current Condition of Tram:
• Tram should not be operated with cabin roof air vents open above sustained wind speeds of 20 mph.
• Tram should not be operated with cabin air vents open or closed with sustained wind speeds above 30 mph.

Operations After Ridgeline Designed Safety Tether is Installed:
• Tram should not be operated with cabin roof air vents open above sustained wind speeds of 35 mph.
• Tram should not be operated in wind conditions that exceed those described in the Operations Manual.

Note: Tether will restrain the full force of a panel detaching from the cabin, however, the current latches may not be adequate to hold the panel in place, especially if one or more of the roof panels are removed from the tram. Operator to monitor the wind and any movement of the panels carefully in this condition.

Operations After Ridgeline Designed Safety Tether & Panel Latch System are Installed:
• Resume normal operations as described in the Operations Manual.

Ridgeline recommends fabricating and installing the new safety tether system as soon as possible. Wind conditions are unpredictable and can change drastically during the time it takes to complete a trip. Conditions should be monitored closely until the new safety tether system is in place.

7. CONCLUSION

A new permanent panel anchorage and safety tether system has been designed by Ridgeline Engineering Company and is expected to be installed before the end of Summer 2019. This new system is designed to meet the wind requirements of IBC 2015, as referenced by ANSI B77.1 – 2017, using a basic wind speed of 115 MPH which is in excess of the maximum operation wind speed per the Operations Manual. Once
the new system is implemented normal operations can be resumed as described in the Operations Manual.
APPENDIX A
ADDITIONAL PHOTOS
Photos of Panel That Fell From Cabin
Photos of Panel That Fell From Cabin
Photos of Panel That Fell From Cabin
APPENDIX B

DOPPELMAYR INCIDENT REPORT
Incident Details: At 11:52 AM, Cabin 2 called on the radio to come up to the dock from attendant Stephaine Diouf. Arriving onto the dock, we had noticed that the large pannel on top of Cabin 2 was off. Looking up at the tower, I noticed it just below the Pedestrian Bridge. Went up to look and saw Miss Sprauer sitting on the stairs, then I proceeded to ask if she needed medical attention and she replied that she didn't need it. After I relocated the pannel to the inside of the tower. An inspection was done to make sure that the remaing panels were secure in there positions and resumes operations around 12:05.

Cabin 2 uphill large roof pannel

Small bump on right side of females head.

(For Additional Space See Page 2)
At the time of the incident, another pedestrian had called paramedics. Ian Glazebrook stayed with Miss Sprauer until medics showed up. She refused help and walked away freely under her own power. The cabin attendant Stephaine stated he heard one “whoosh” sound and people in the cabin said something had fallen off. The tram was traveling downhill over the tower at 7 m/s (full speed over tower). There has been a steady east wind averaging 25 mph with gusts as high as 38 mph according to our anemometer. It is concluded that the carabiner had failed.