Red Gym Building Analysis

(2024)

Purpose & Background History

In this report, thermal imaging was used detect subsurface structural defects. In addition to thermal technology, laser scans were conducted to obtain the geometry of the Red Gym to evaluate wall flatness. Different software programs were used to process the point cloud data obtained by laser scans and then evaluated.

Findings

Observed deformation on the exterior and interior of the north wall. Infrared thermal images display stress cracks and heat loss.

Team

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Red Gym: History and Background

The Red Gym, located in Madison, Wisconsin, was placed in the state and national registers of historic places in 1974. The Red Gym has hosted events and activities of local, state and national significance. (p.vii)

The Red Gym has been repurposed many times throughout its history. Conover and Porter, an architectural firm, was responsible for designing the Red Gym (p.xi). The original purpose for the construction of the building was to give students better athletic facilities as well as providing military training for male students. Draft riots and labor unrests in the Midwest was the cause of creating urban armories during the late 1800s (p. xii). In 1890, the Morril Act was passed by congress to provide funding for the construction of the Armory and Gymnasium (p.xii). In 1894, the University of Wisconsin Armory and Gymnasium was open to the public (p. ix). The military and athletic use of the building had declined in the 1920s and 1930s. From 1928 to 1983, the Red Gym was repurposed to be used for student registration (p.xii). The Red Gym was then repurposed as a "gateway to the campus", to provide greater access to the campus for newly enrolled students and the greater community. (p. vii)

Despite the significance of the building's history, many structural defects have been identified and repaired. (Armory & Gymnasium Historic Structure Report)

Red Gym: Structural Background

The Red Gym so far has had retained many of its historical essence, being build with brick and sandstone in its exterior with three major interior spaces. The structural components include the combination of heavy timber and steel trusses. The interior of the building consisted of brick masonry, wood walls, wood columns, beams and trusses using wood and steel (p. xi).

Laser Scanning Building Analysis Report Methodology

Autodesk Recap:

Recap is a point cloud program that allows the users to process point cloud data.

Autodesk Recap supports importing: CL3 (Topcon) ; CLR (Topcon), E57, FLS (Faro), FWS (Faro), LSPROJ (Faro), LAS, PCG, PRJ (Leica), PTG (Leica), PTS, PTX, RCS, RDS (3D only; Riegl), TXT, XYB, XYZ, ZFS (Zoller+Fröhlich), ZFPRJ (Zoller+Fröhlich) extension files (Autodeks Recap.).

Autodesk Recap supports exporting; E57, PTS, PCG, RCP/RCS extension files (Autodeks Recap.).

Registration Data

Registration is important in creating quality and accurate point clouds from laser scans. The point clouds were generated from 19 separate scans focused on capturing the walls in order to inspect for any irregularities. The stations had strong overlap that were detectable by Recap were combined automatically. Some of the point clouds did not have enough overlap to be automatically combined, in which manual registration had to be conducted. After registering the point clouds, a report is generated in order to give data on the registration.

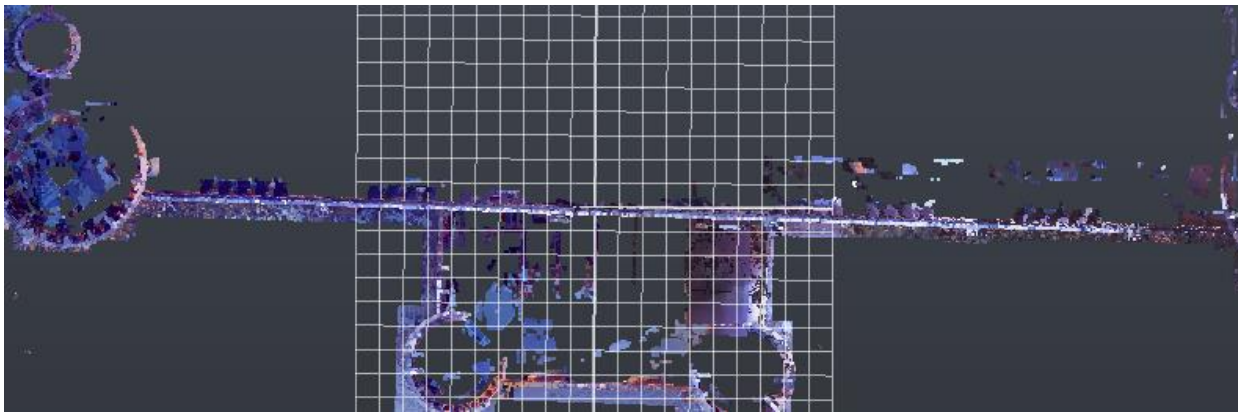
There are three parameters that are given in the Registration Data Report. Overlap is the percentage of common features throughout the stations in the project. A higher percentage in overlap ensures that features are visible after combining scans from multiple perspectives.

Registration Data Report			
Station Number	Overlap	Balance	Points < 6mm
1	63.2%	52.8%	99.6%
2	22.5%	45.8%	88.4%
3	12.1%	59.9%	89.7%
4	21.5%	49.8%	92.1%
5	59.8%	29.3%	99.2%
6	42.6%	1.0%	98.8%
7	51.7%	7.5%	98.9%
8	60.3%	21.6%	99.8%
9	72.9%	20.3%	99.7%
10	40.6%	49.9%	99.4%
11	55.0%	41.7%	97.8%
12	40.5%	57.2%	95.9%
13	38.3%	27.0%	100%
14	63.9%	19.4%	99.9%
15	65.1%	10.9%	99.6%
16	61.5%	13.0%	99.8%
17	69.2%	20.3%	99.5%
18	39.5%	57.1%	99.8%
19	20.2%	53.0%	99.8%

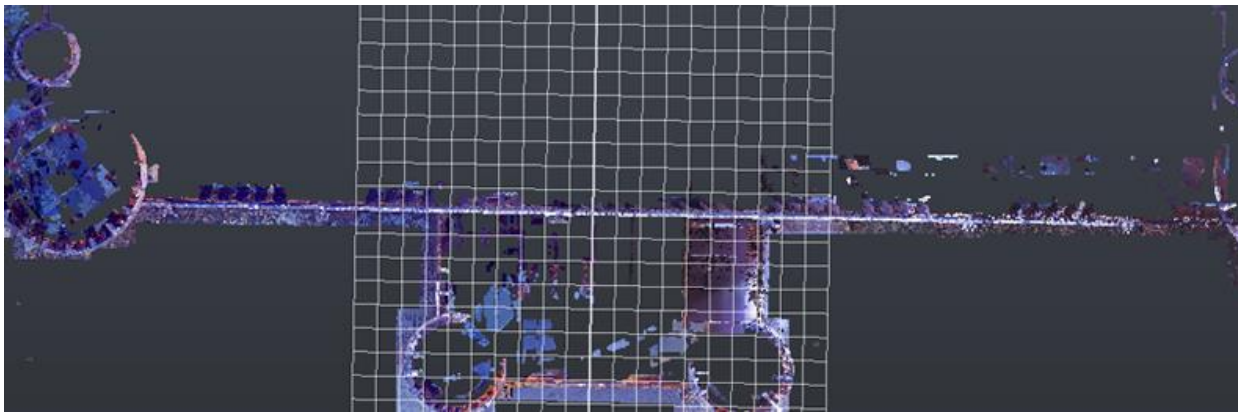
Balance shows the percentage of common features in the scan. A balance greater than 20% indicates that the scans have not encountered errors from sliding surfaces. Recap does not require a high balance ratio. Points (<6mm) shows the percentage of overlapping points within a ¼ inch or 6mm. The value should ideally be greater than 90%. (Autodesk ReCap).

After obtaining laser-scan data by using the Trimble x7 and successfully registering the stations into one comprehensive point cloud, the point cloud data was able to be imported into Autodesk Recap. Despite successfully import the data into Recap, raw point cloud data is relatively noisy as laser scanners do not distinguish between relevant and irrelevant data. The region tools in Autodesk Recap were used to section the different point clouds into manageable sections.

Combined point clouds of the Red Gym inside Autodesk Recap



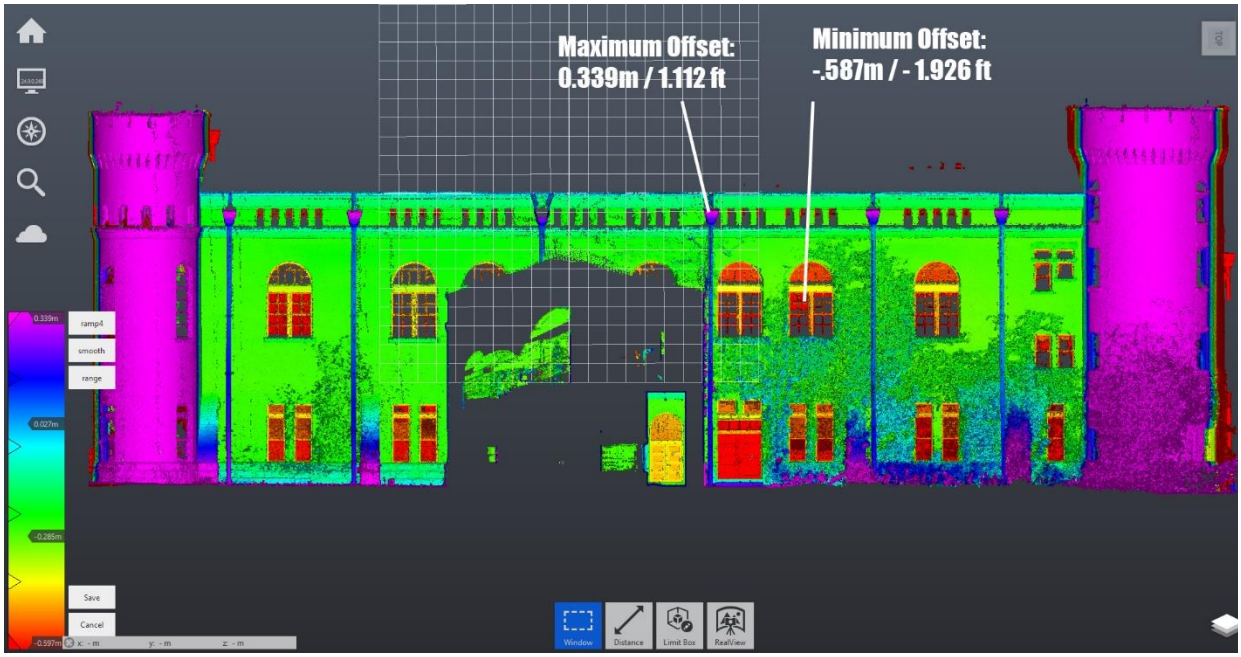
Unaligned orientation with coordinate system.



Reorientated point clouds in Recap.

After the point clouds were separated into regions, the point clouds had to align with the coordinate system in Recap to eliminate inaccurate information. The original point cloud data did not align correctly with the coordinate systems, in which the origin had to be manually updated in order to have the wall aligned with the axis. This is done in order to use the elevation feature

in Recap to detect any wall deformities. There does not seem to be a large variation of wall deformation using Autodesk Recap for the west wall.



(Autodesk ReCap) Reoriented west wall using elevation points.

CloudCompare

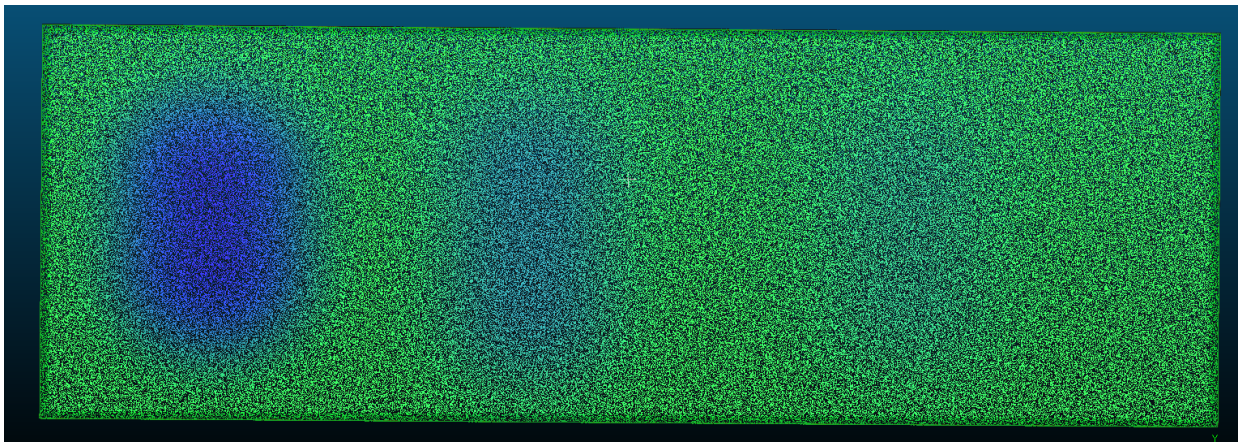
CloudCompare is a program that is used for processing and fixing point cloud data.

After fixing the point clouds inside Autodesk Recap, the point cloud data for the West Wall of the Red Gym were exported using the. e57 file extension, enabling different programs to import the point clouds.

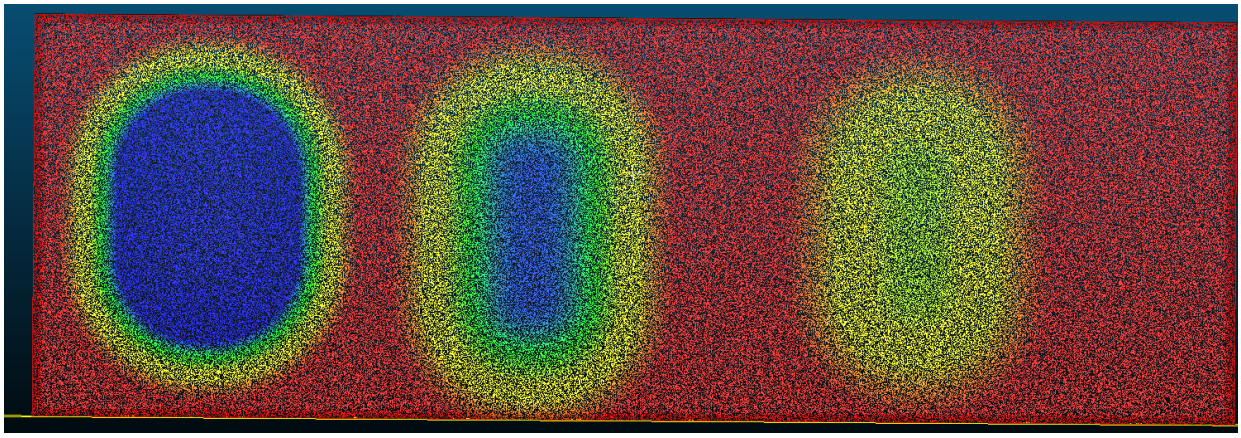
Another method of evaluating plumbness or floor flatness is using the scalar field tools. Exporting coordinates to the scalar fields to the aligned axis will allow users to visually inspect walls for wall deflections.

Scalar Fields in Cloud Compare Viability Controlled Tests

In order to evaluate the efficacy of using scalar fields in Cloud Compare to evaluate floor flatness, wall plumbness and wall alignment, 3d models were created and used as controlled models. A 3d model was created with the dimensions of the west wall which was 150 feet in length and 50 feet in height. Three separate deformations were created in the walls in order to be tested using scalar fields in order to see if the deformations could be detected. The deformation to the left is a 1-foot wall deformation, the middle is a 6-inch wall deformation, and the right is a 3-inch wall deformation.

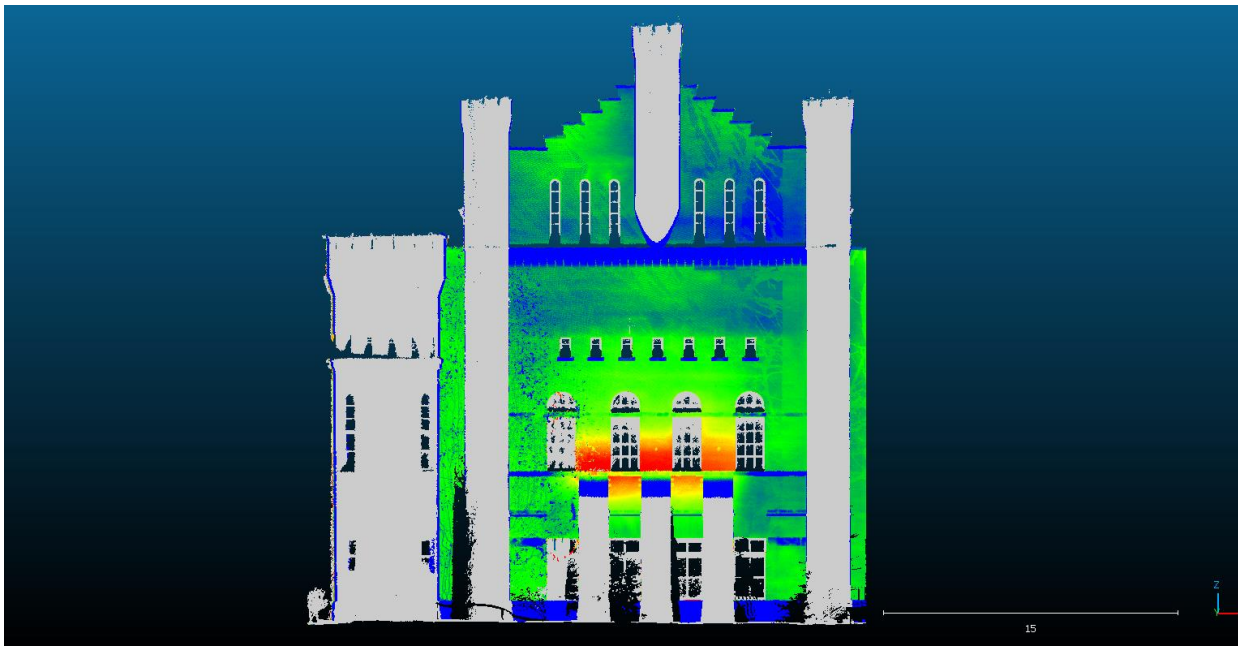


Using scalar fields in CloudCompare with default settings



Using scalar fields with modified parameters in CloudCompare.

Using scalar fields in Cloud Compare to assess west wall deformation.



Using scalar fields in Cloud Compare to assess north wall deformation.

Using scalar fields on the 3d models in CloudCompare showed the viability of using scalar fields in evaluating wall deformations. Using the default parameters to evaluate the 3d wall deformations only displayed a subtle difference between color and deformation. However, after adjusting the parameters, small deformations 3 inches and smaller are able to be detected using scalar fields.

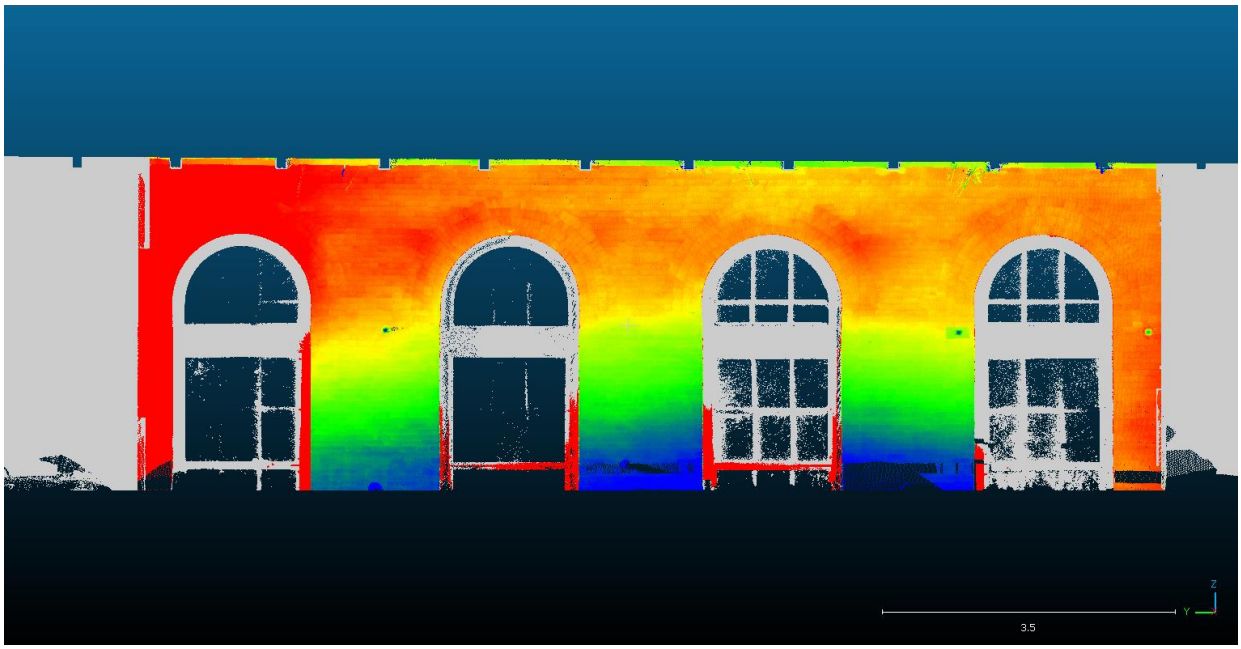
Exterior Findings

The west wall can be observed to have a slight bulge in the upper portion of the wall. In the north wall, the second floor of the building is receding back into the building.

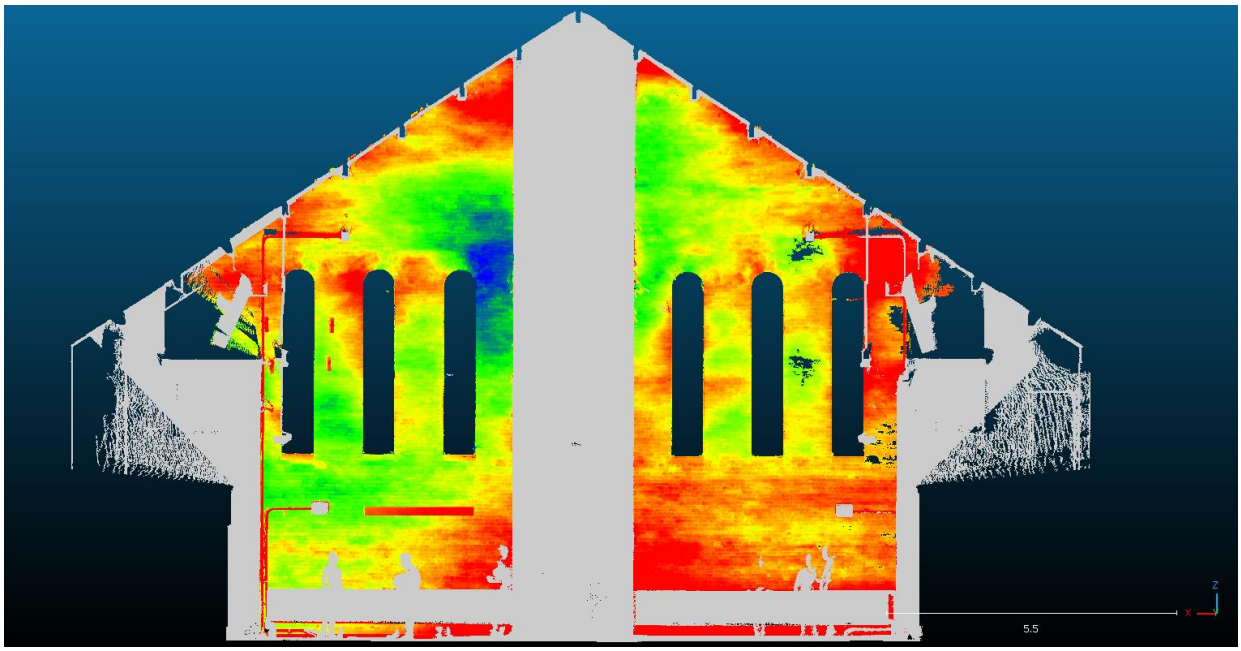
Interior Findings

In addition to scanning the exterior of the west and north wall of the Red Gym, the laser scanner was deployed in the interior of the Red Gym in the north wall. The second and third floor were scanned in the interior on the north wall to detect any wall deformation.

Interesting differences can be observed by using scalar fields. The interior of the 2nd wall seems to have a noticeable wall deformation. The bottom half of the wall is protruding forward. The interior of the north wall on the 3rd floor is observed to have variations in deformation. On the bottom half the wall is protruding. On the upper portions of the windows, there are deformations that seem to align with stress cracks.



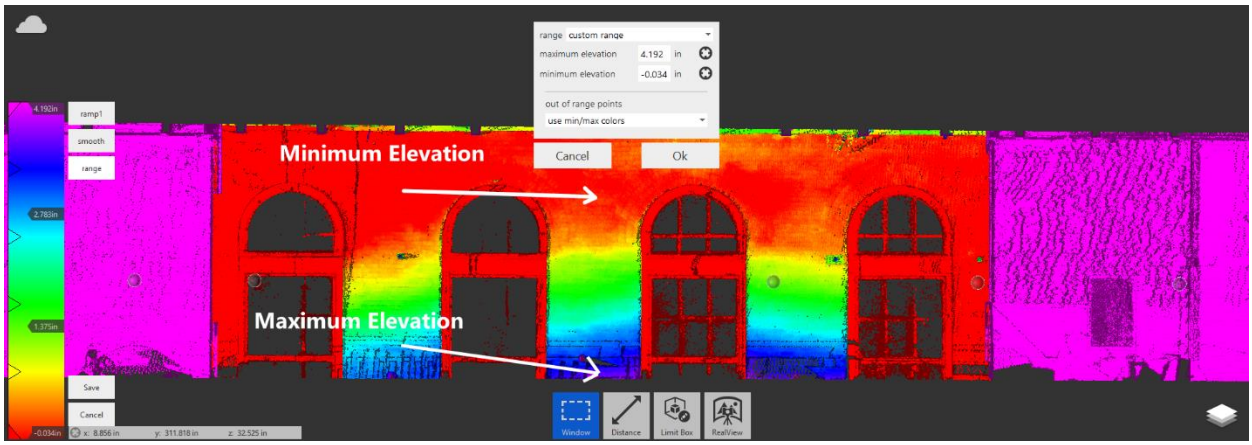
Interior of the 2nd floor north wall.



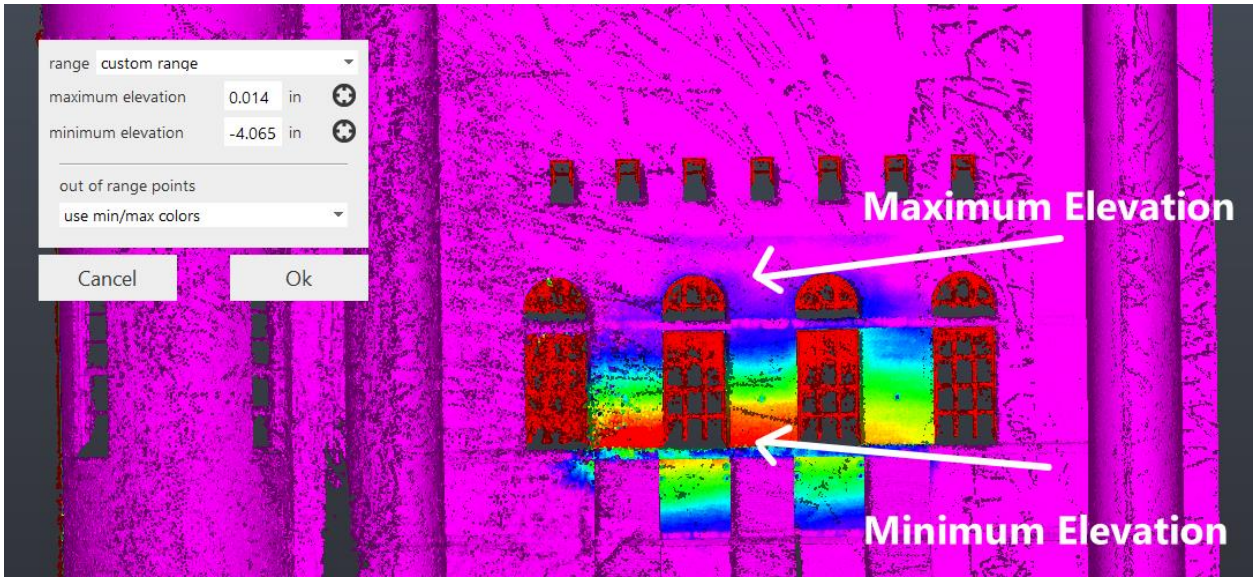
Interior of the 3rd floor north wall.

Autodesk – Measuring Deformation

Using the Autodesk Recap elevation tools, it can be observed that there is an approximate 4-inch deformation in the north wall on the second floor. The deformation originates between the windows and the top of the brick supports on the exterior.



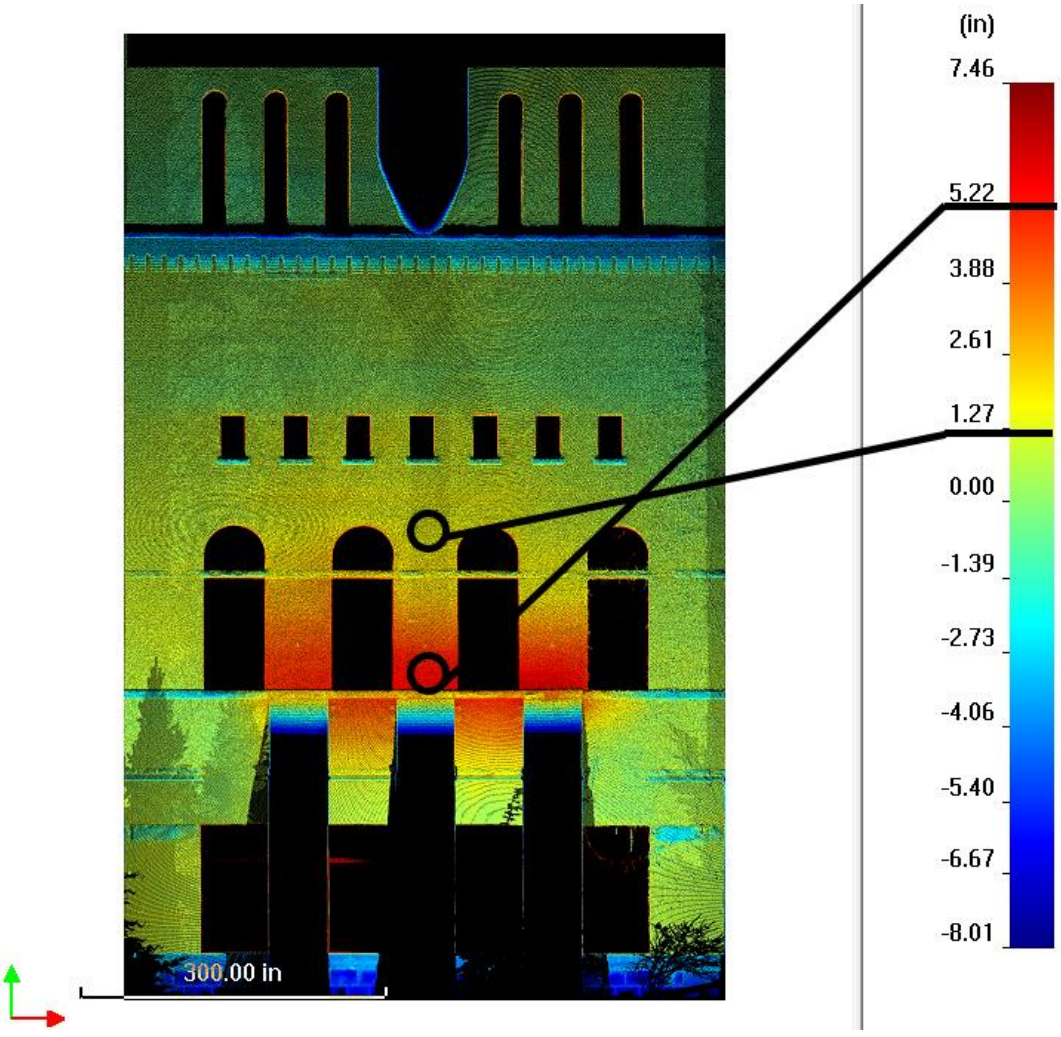
Red Gym Interior North Wall Second Floor (Recap)



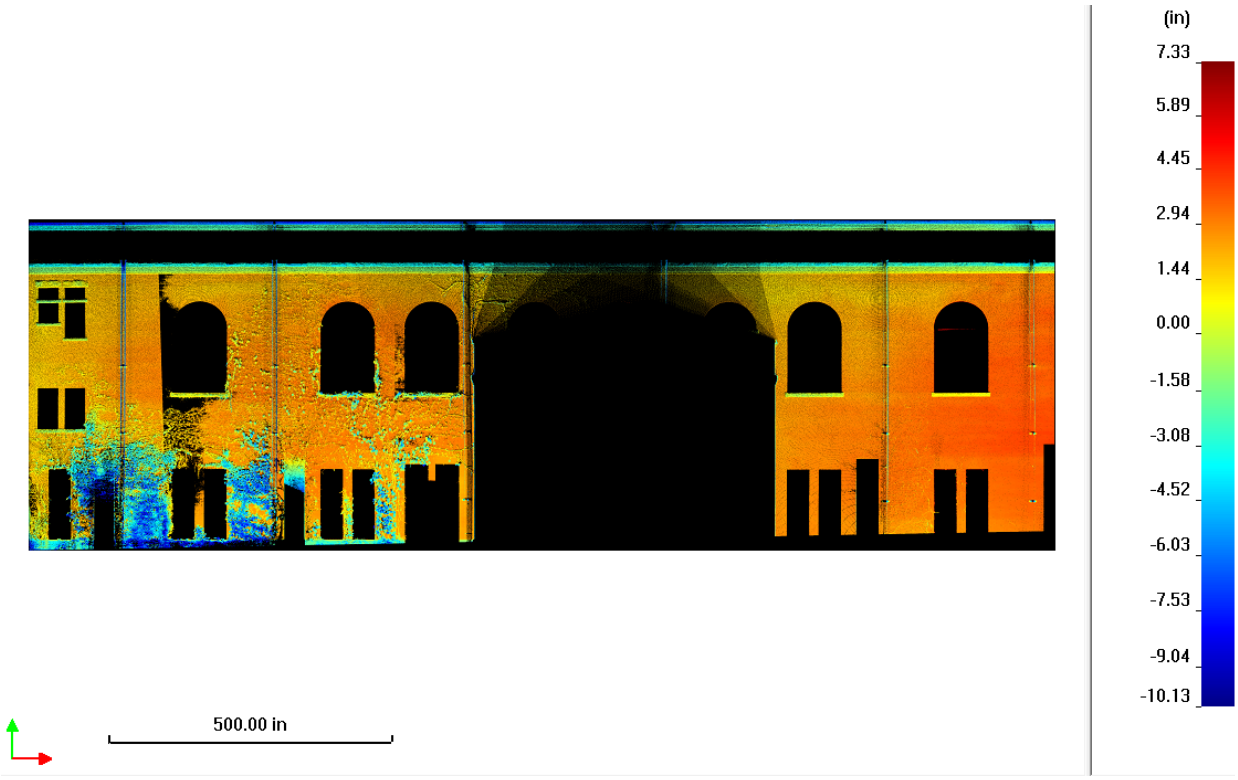
Red Gym Exterior North Wall Second Floor (Recap)

Trimble RealWorks

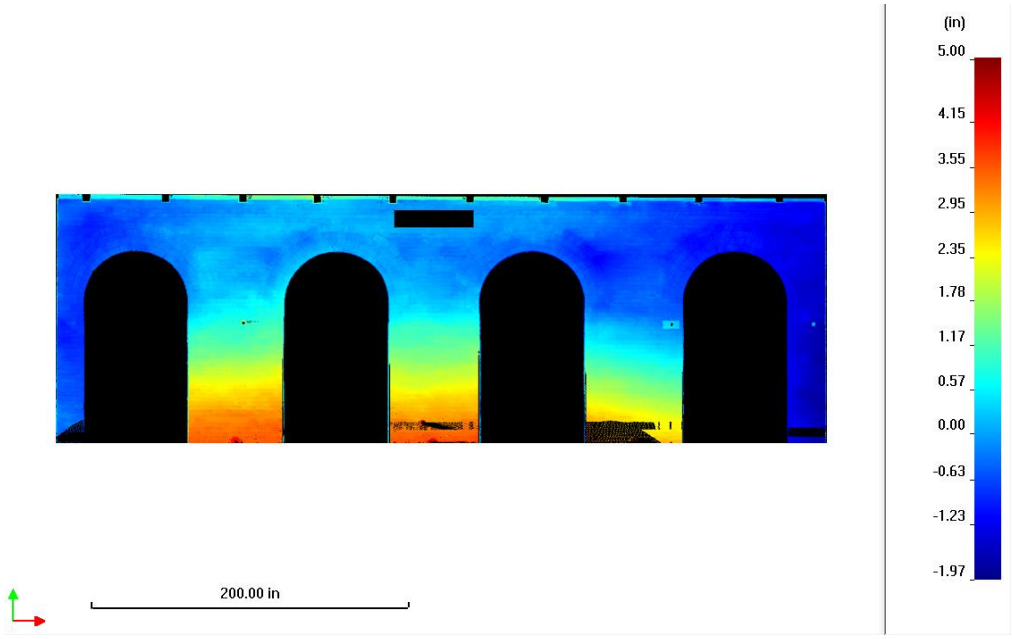
Trimble Realworks was used for verification after using CloudCompare and Autodesk Recap to check for deformations. Trimble RealWorks is a professional program used in point cloud registration, processing, modeling and inspection (Trimble RealWorks). The Surface to Model inspection tool was used to quantify the level of deformation. The results from RealWorks verified the previous findings of the deformations being approximately 4 inches.



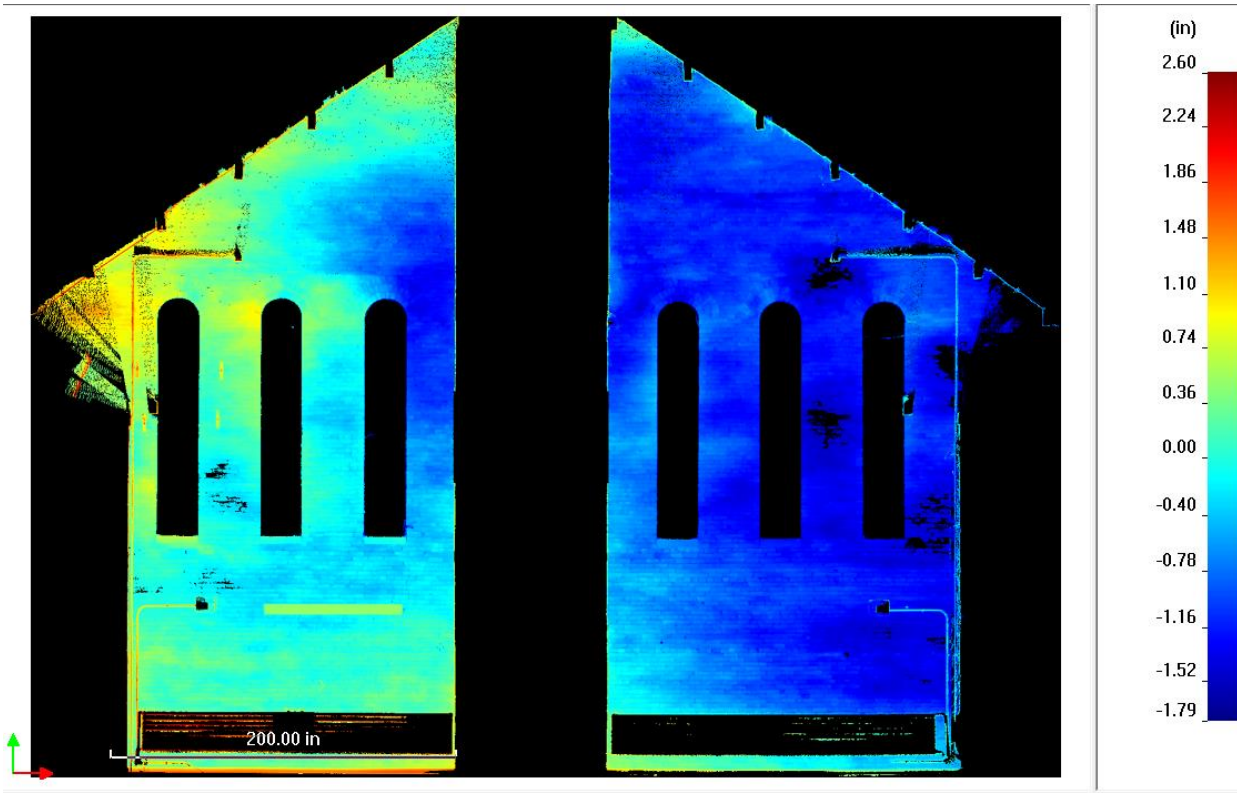
Exterior inspection map of the Red Gym's north wall.



Exterior inspection map of the Red Gym's west wall.



Interior inspection map of the Red Gym's north wall 2nd floor.



Interior inspection map of the Red Gym's north wall 3rd floor.

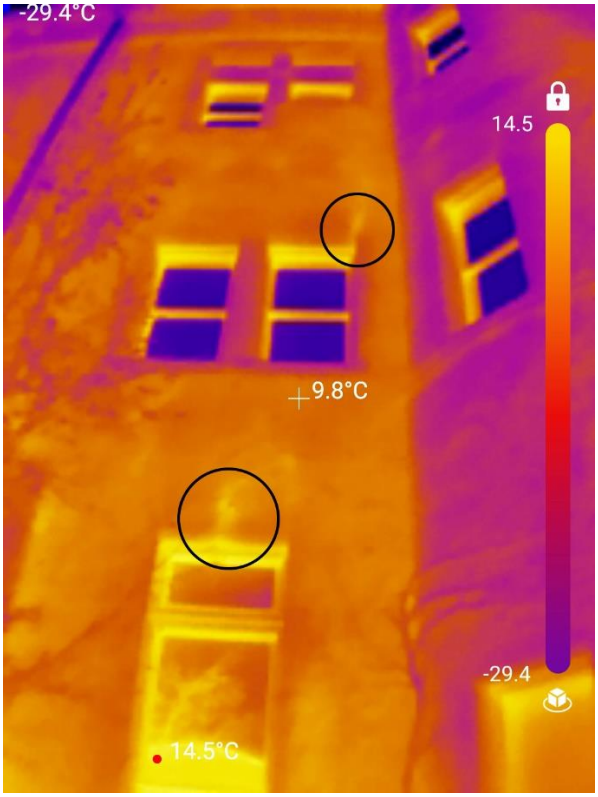
Final Findings

After applying various methods to inspect the west and north walls of the Red Gym, it can be determined that there are a few areas of the walls that have wall deformations. The biggest deformations can be detected on the exterior of the north wall, and the interior of the 2nd floor on the north wall. Minor wall deformations of approximately 1 inch can be detected on the interior of the third floor. There is also an inch deviation that can be detected from the two sides of the west side wall.

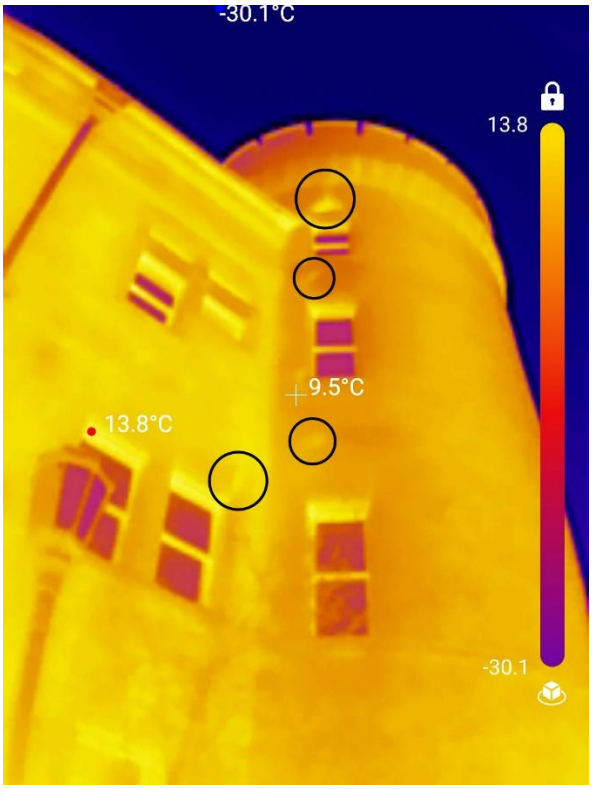
Thermographic Evaluations

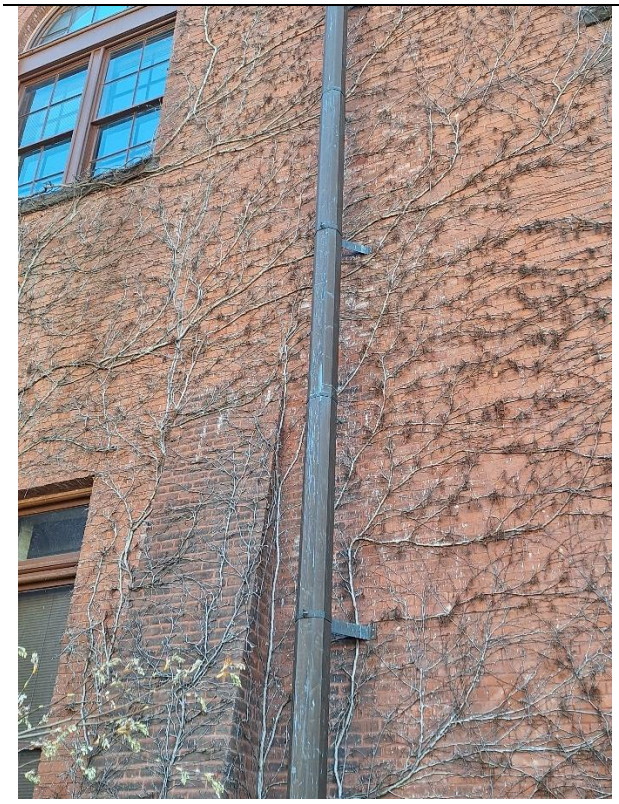
Thermal images were captured by using a Galaxy A54 5G smartphone, with a thermographic camera attachment. A TC001 from TOPDON was used to capture the thermal images. The TC001 is capable of capturing infrared images with a resolution of 256 x 192 pixels. The temperature range of the device range from -4℉ to 1022℉ (-20℃ to 550℃). The TC001 can display surface temperature variations as little as 0.1ºC. The spectral range is from 8~14µm. The temperature accuracy is ±3.6ºF(2ºC) (TOPDON USA. (n.d.)).

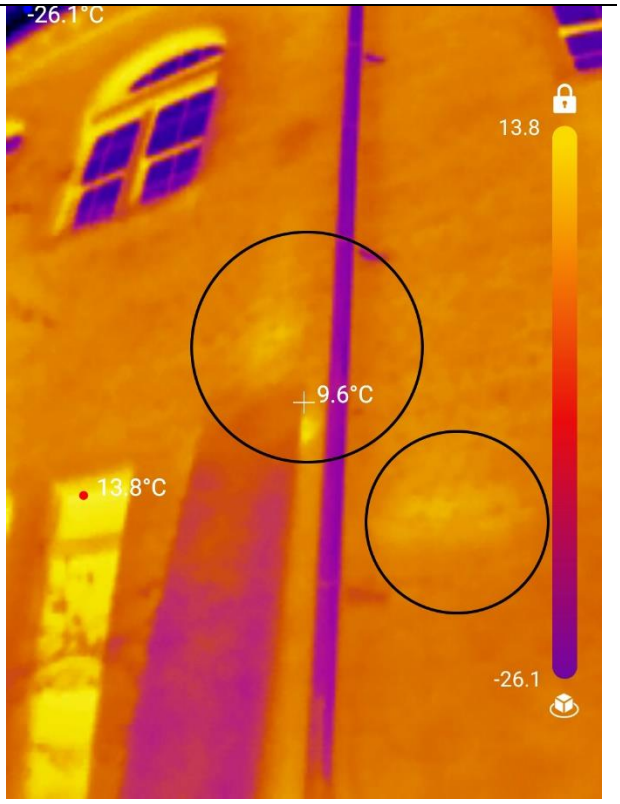
Normal RGB photo

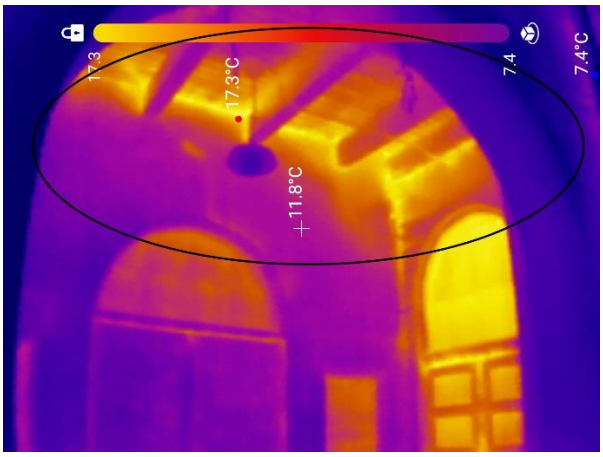


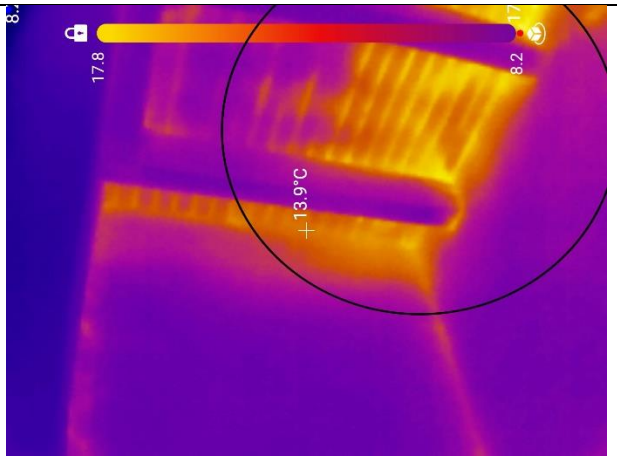
Thermographic images with hidden cracks.

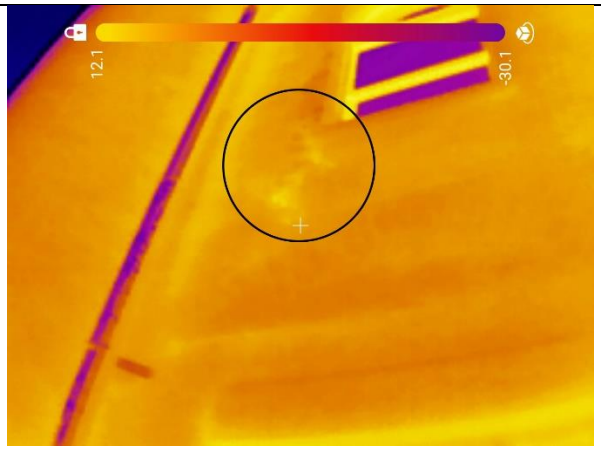

-30.1°C
13.8
9.5°C
13.8°C
-30.1

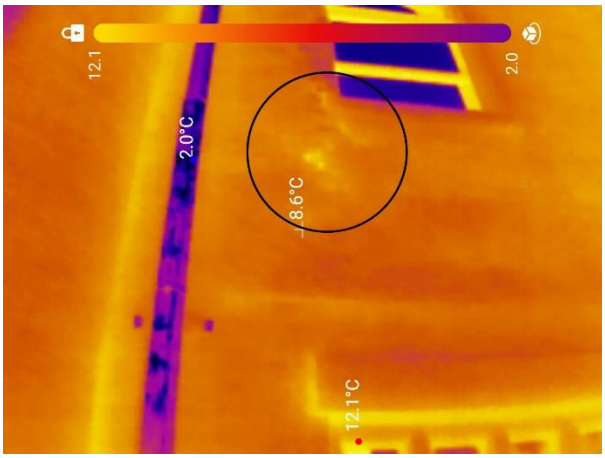



-26.1°C
13.8
9.6°C
13.8°C
-26.1

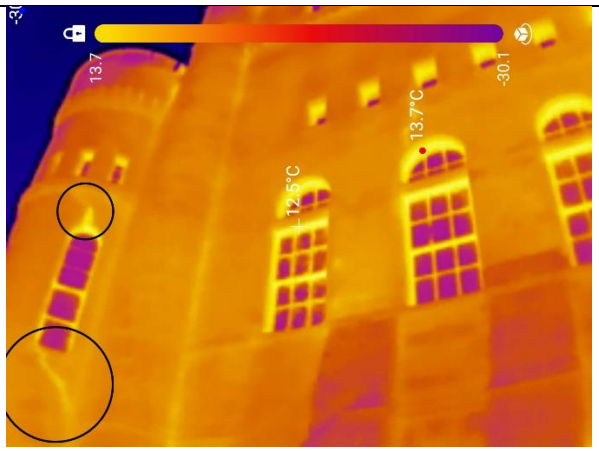

17.3
17.3°C
11.8°C
7.4
7.4°C

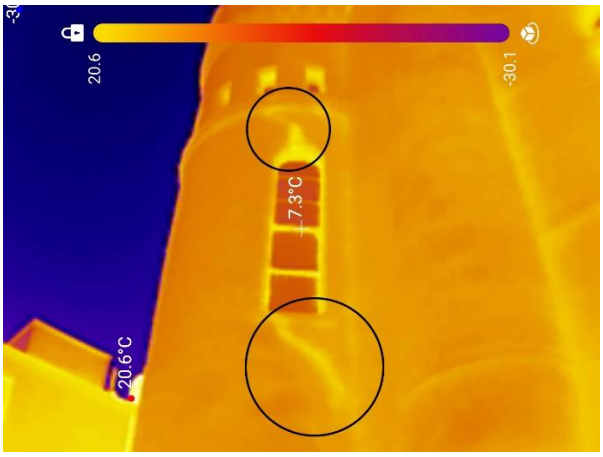

17.8
13.9°C
8.2


12.1
-30.1


12.1
2.0
2.0°C
8.6°C
12.1°C


4.4
11.4
4.4
11.4°C
10.1°C


13.7
-30.1
12.5°C
13.7°C


20.6
-30.1
7.3°C
20.6°C


12.0
-28.4
12.0°C


18.0
-30.1°C
-30.1

Citation

Autodesk 3DS MAX. (n.d.). Point Cloud Object. https://help.autodesk.com/view/3DSMAX/2020/ENU/?guid=GUID-49CE0ACB-1345-4D50-B6E5-361DBFDB5B33

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TOPDON USA. (n.d.). *TC001 (Android devices)*. TOPDON USA. https://www.topdon.us/products/tc001