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INSAR-BASED INVESTIGATION OF SURFACE DISPLACEMENT OVER THE AREA OF THE COLLAPSED BUILDINGS IN ISTANBUL

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ABSTRACT:

In this research, we investigate the surface displacements in the regions where the buildings collapsed. Istanbul has a surface that is active for earthquakes. As the construction regulations have been changed after the year 2000, it is expected that the buildings built after this year, are much safer due to the strict retime series. But the majority of the buildings are at high risk since they are constructed before the year 2000. Therefore suddenly collapsing buildings are an often case in Istanbul, and we have investigated six buildings that collapsed during the six-year time. The used data are Sentinel 1 Radar images. The methodology is SBAS provided by the COMET-LiCS portal. The study area is Istanbul-Türkiye. six buildings are selected for the investigation. The velocity of the displacements and the time series of the whole displacements on the building locations have been plotted. The neighbouring areas of the collapsed buildings are also investigated and analysed if there are any surface displacement changes between them.

1. INTRODUCTION

Istanbul is a city where the surface is dynamic and active for earthquakes. The urbanization rate is also high, 14% according to the Turkish Statistical Office (Web-1,2022). The regulations of the construction were changed and its enforcement was improved at the beginning of 2000 which resulted in the building being safer than before. At the moment, the majority of the building stock in Istanbul was constructed before 2000 and they possess a significant risk.

In this study, six reported that collapsed buildings are selected for the analysis. InSAR technology provides long-time series displacement measurements with the use of Phase information of the radar datasets.

Sentinel 1 Data are useful to identify the displacement of the surface. SBAS is one of the efficient techniques which use the long time series of the data, with analysis of the multi-interferograms. One of the methods which is called LICSAR and it uses SBAS and pre-produced interferograms are provided on the COMET-LiCS portal (Lazecký et al.,2020). The SBAS method uses interferograms generated from SAR pairs with short base distances that maintain high interferometric consistency. For each pixel, SBAS generates a linear surface displacement ratio map calculated by fitting a straight line to the deformation time series for each binary pair, along with the temporal resolution of the SAR gains and the time series of ground deformation (Berardino et al. 2002).

In this study, we investigate to use of Sentinel 1 data and SBAS analysis for the determination of the surface displacement over the collapsed buildings.

2. STUDY AREA

The study area covers six buildings that collapsed on different dates in different quarters of Istanbul as shown in Figure 1.

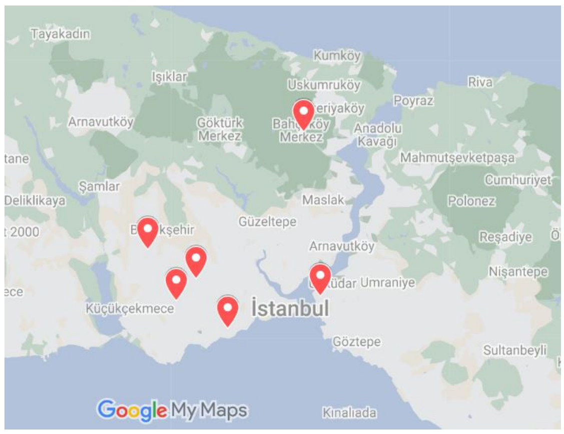

Figure 1. The location of the selected collapsed buildings.

The locations and the collapsing dates are shown in Table 1.

Building ID	Lat °	Lon °	Collapsing date
1	28.79782	41.06517	24.08.2021
2	28.85857	41.03716	22.09.2016
3	28.83356	41.01656	21.05.2016
5	28.8983	40.98919	06.05.2021
6	28.9939	41.1768	27.06.2021
7	29.01472	41.02036	16.09.2015

Table 1. The list of collapsed buildings

3. METHOD

For the implementation of the SBAS approach, a variety of tools are available, including GMTSAR (Sandwell et al., 2016), ISCE (https://github.com/isce-framework/), and Mintpy (Yunjun et al., 2019). The LICSAR (Lazeck et al., 2020) package was used in this work. To perform InSAR time series analysis using LiCSAR products (i.e., unwrapped interferograms and coherence), which are freely available on the COMET-LiCS web portal (https://comet.nerc.ac.uk/comet-lics-portal/), use the open-source LiCSBAS package in Python and Bash. The resulting interferograms are published on the COMET-LiCS portal in GeoTIFF format. The relevant data has been processed in a basic manner, and the subsidence maps for the surfaces where each collapsed structure is constructed. All studies are performed with the chosen orbit ascending. We used the Google Colab environment (https://colab.research.google.com) to apply the LICSAR package's stages.

4. RESULTS

The surface displacement has been calculated for the years 2015, 2016, 2017, and 2021 from January to the end of December, covering the dates of each building's collapse. Figure 2 depicts, as an example, the displacement map between January 1, 2016, and January 1, 2017. It was produced in ascending mode.

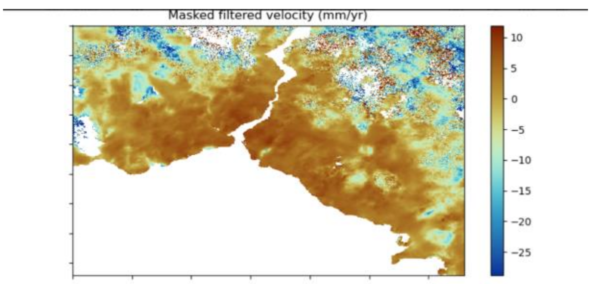

Figure 2. Annual displacement velocity calculated in Ascending mode for Istanbul City (mm/year).

4.1 Analysed Buildings

4.1.1 Building 1

Due to the failure of the retaining wall of the building on the side, the one-story furniture store at Masko Mobilyacilar Sitesi in Ikitelli, Istanbul, collapsed (Web-2). The incident took place on August 23, 2021.

Figure 3 shows the yearly displacement time series. Figure 4 is a photo which shows the collapsing.

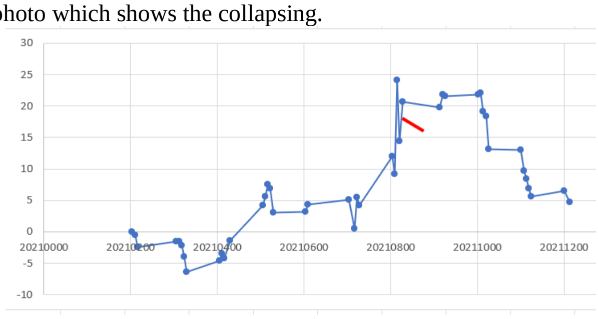

Figure 3. Surface displacement in mm where the collapsed building stands, the redline indicates the date of collapsing 24.08.2021

Figure 4. A picture of te collapsed building (source: DHA, from evrensel.net)

A maximum uplift is depicted in Figure 3 closer to the event's collapse date. The structure collapses shortly after the rising achieves its peak value.

4.1.2 Building 2

Here, we analysed one building which had been collapsed on September 22, 2016 in Bagcilar-Istanbul. The building was a 5-story reinforced concrete frame building (Figure 5a). Dimensions of the building plan area were 21×15 m^2. It was built sometime within the time period from 1980 to 2000 during which many structurally deficient buildings were constructed in Istanbul due to lack of proper seismic design code enforcement. Failure mechanism that was observed after the collapse indicated that building had weak columns and stiff beams which is a typical structural deficiency in substandard buildings (Figure 5b). Moreover, it is seen from the post-collapse photo that the beams along the southern axes of the building spanned in between the 3 columns. As a result, the beams had lengths in the order of 8~9 m which indicates that the axial load ratios in the columns were quite high. Besides the building also had an wedding hall in the basement. Such large open spaces also has the potential for rendering the building unsafe when the material quality is poor and the workmanship is inadequate.

(a) (b)

Figure 5. Investigated building: (a) before collapse and, (b) after collapse (Modified from Google, 2022; IHA, 2016)

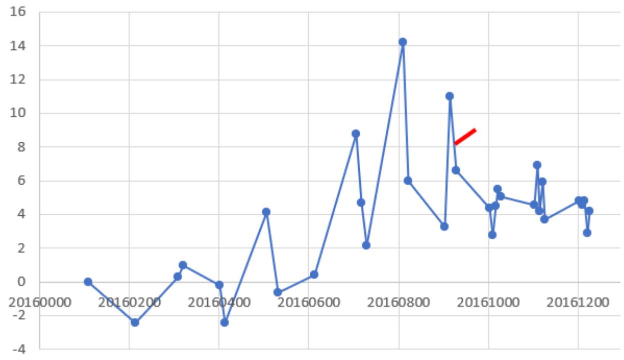

Figure 6. Surface displacement in mm, where there is the collapsed building, the redline indicates the date of collapsing.

Figure 6 demonstrates how the surface acted most uplifted over the year prior to the collapse.

4.1.3 Building 3

Due to the threat of collapsing, a building on Istanbul's Bahçelievler Kocasinan Mahallesi Nurlu Street has already been totally evacuated. The evacuated building eventually collapsed on May 21, 2016. Despite claims that the nearby foundation excavation caused the building's destruction, a total of seven nearby structures were evacuated (Web-3).

Figure 7. The collapsed building (Web-3)

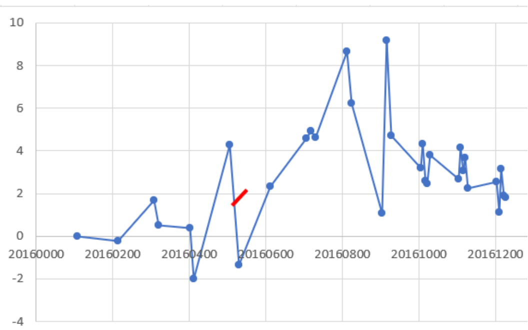

Figure 8. Surface displacement in mm, where there is the collapsed building, the redline indicates the date of collapsing.

The surface displacement relative to the January 1st is shown in Figure. Here, we see again an high uplift surface displacement before the collapsing event.

4.1.4 Building 4

This building was located in Zeytinburnu Sümer Neighborhood. The 5-storey building had been evacuated already because its windows exploded and crackling sounds were heard one day before as stated in the newspaper Hurriyet (Web-4). The Figure 9 shows the collapsed state.

Figure 9. The collapsed building (Web-4)

The graphic depicts an upward movement trend on the surface that reached a height of around 12 cm before the event collapsed.

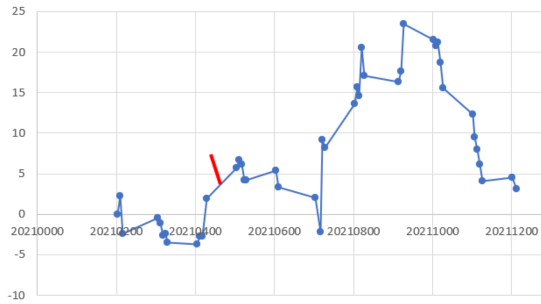

Figure 10. Surface displacement in mm, where there is the collapsed building, the redline indicates the date of collapsing.

4.1.5 Building 5

According to the press, the 10-storey building, located between Bahçeköy Yenimahalle Doğanbey Street and Leylak Street in the town of Sariyer, which was noted to be illegally built, collapsed with a great noise on 27.06.2021. Stating that the building was built gradually without any engineering services (Web-5).

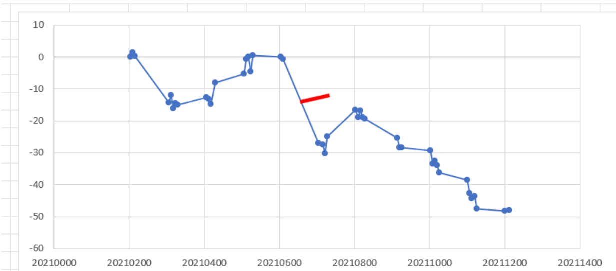

Figure 11. Surface displacement in mm, where there is the collapsed building, the redline indicates the date of collapsing.

This building shows considerable subsidence shortly prior to the incident that caused it to collapse. Subsidence occurs when the surface displacement rises in the same direction. At the conclusion of the year, the overall subsidence was around 5 cm.

4.1.6 Building 6

A 4-storey building on Üsküdar Halk Caddesi was destroyed as a result of the collapse in the construction area behind it, according to the newspaper Cumhuriyet (Web-5) The surface displacement graph demonstrates the subsidence (Figure 12) that occurs before to collapse, as was also highlighted in the news article.

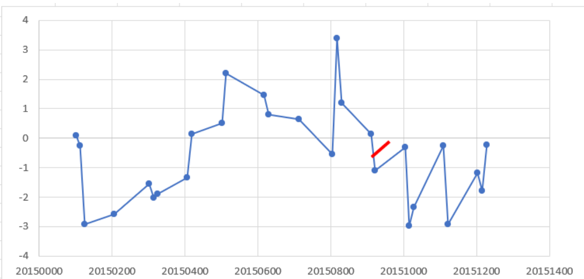

Figure 12. Surface displacement in mm, where there is the collapsed building, the redline indicates the date of collapsing

5. DISCUSSION

The results show that the uplift movement is evident across all situations when measured in relation to the year's beginning. However, it should be emphasized that the measurement's accuracy depends on the wavelength used, which is 5.54 cm from Sentinel 1 datasets. Any movement below 2.27 cm, as is the case in each structure, makes the results in this scenario unreliable. In order to determine whether the primary movement of the buildings had any impact on the plots, we calculated these data for four structures that are next to the grid of the collapsed buildings. The neighbor grids in the east, south, west, and north are examined and plotted appropriately.

The collapse of building 1 had actually occurred on August 24th, 2021. With the exception of the time of observation immediately before the collapse, the grid containing the building in Figure behaves almost exactly like its neighbours. The building's grid reveals a subsidence in comparison to the neighbours (Figure 13).
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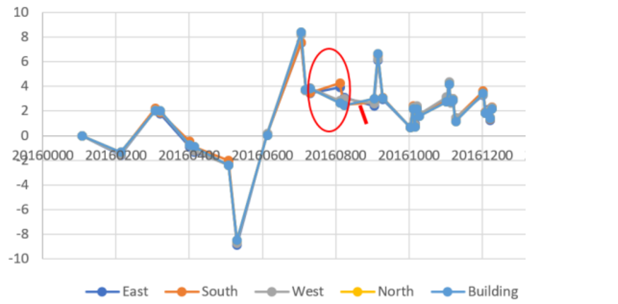

Figure 13. The displacement plots of the building 1 with its neighbours.

The circled area in Figure 14 represents building 2, which has subsidence movement once more compared to its neighbors before the collapse event.

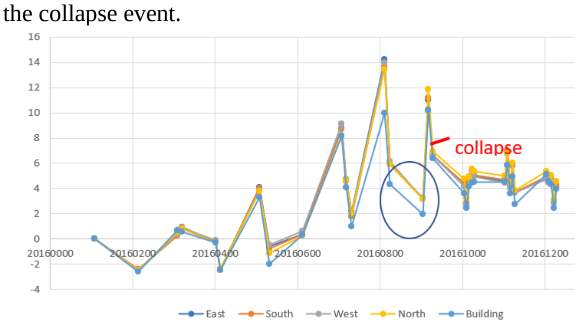

Figure 14. Displacement on Building 2 location, and its neighbours.

Focusing on building 3 reveals a slight variation in movement for the building's grid, once more in the direction of subsidence in Figure 15.

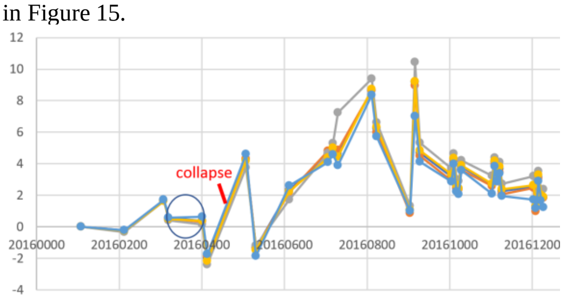

Figure 15. Displacement on Building 3 location, and its neighbours.

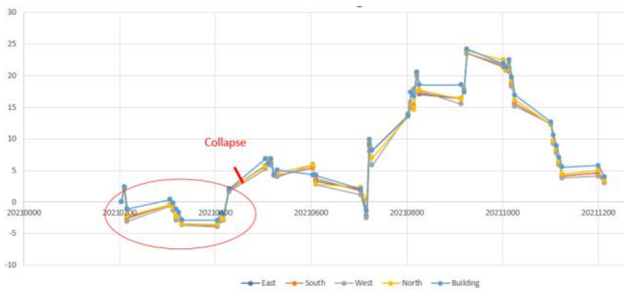

Figure 16. Displacement on Building 4 location, and its neighbours.

Figure 16 shows all neighboring grids have the same surface displacement except the one that has the building.

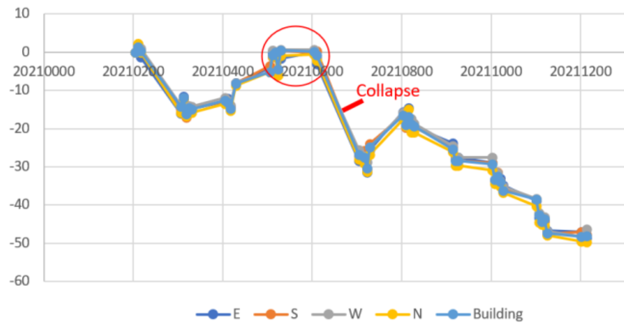

Figure 17. Displacement on Building 5 location, and its neighbours.

The plot (Fig. 17) of the Building 5 does not differ among the neighbors and with the grid with collapsing. Only a minor relative change is shown just before the collapse of the building. The relative difference between the building grid and neighbors reach ca 2 mm in this period.

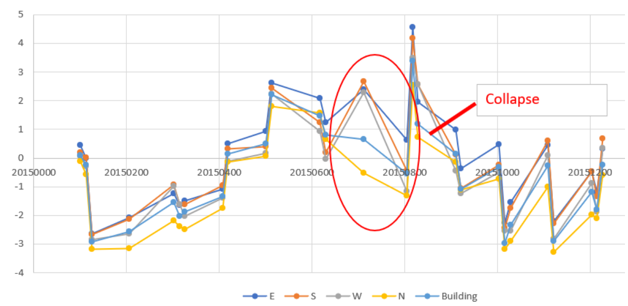

Figure 18. Displacement on Building 6 location, and its neighbours.

The collapse of building 6 took place on September 16, 2015. The plot makes it abundantly clear that the timeline just prior to the event differs noticeably from the other neighboring grids in a way that is not depicted in other timelines.

6. CONCLUSIONS

An effective method for monitoring surface displacement is inSAR technology. The purpose of this work is to demonstrate the capability of risk assessment while looking into the displacement in the areas where the buildings collapsed. The precision of the results is directly influenced by the wavelength and resolution of the produced results. The displacement plots have the potential to monitor risks, but they cannot serve as a toolkit because no tangible result has been produced in this case. It's crucial and significant to pay attention to neighboring displacement. As a result, the results should only be used as a dataset for subsequent, higher resolution investigations. X band datasets for inSAR analysis on a single building scale.The future work will cover to do this analysis with use of different methodologies.

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