Land Subsidence in Vernacular Settlements: Assessments from the Heritage Buildings in Semarang, Indonesia

R. Siti Rukayah[1]*, A. Perwira Mulia Tarigan[2]. Rr. Dwinanti Rika Marthanty[3], Budianto Ontowirjo[4] & Fariz Addo Giovano[5]

[1]Architecture Department, Engineering Faculty Universitas Diponegoro
[2] Civil Engineering Department, Engineering Faculty, Faculty Universitas Sumatera Utara
[3] Civil Engineering Department, Engineering Faculty, Universitas Indonesia
[4] Civil Engineering Program Study, FTIK Faculty, Universitas Bakrie
[5] Master Program of Architecture, Engineering Faculty, Universitas Diponegoro, Indonesia
*Correspondence: sitirukayah.tutut@gmail.com

Received	Revised	Published
26.08.2023	21.10.2023	31.10.2023

https://doi.org/10.61275 /ISVSej-2023-10-10-07

Abstract

Among recent studies on land subsidence in vernacular settlements, only a few have discussed it from the architectural point of view. Historical data have shown that Semarang, a vernacular settlement located in North Java has experienced a land subsidence rate of around 20 cm per year. investigate the subsidence phenomenon and to identify the subsidence rate occurring in an area in terms of existing distortion, revealing the land subsidence.

This study uses old photos of a heritage building in this settlement to compare the original architectural dimensions with the latest conditions and. It also employs the data taken from the excavation of the building renovation project.

Findings show that the original floor and toilet levels have been located approximately 100 cm under the present levels. The rate of land subsidence resolved from this analysis is about 3.3 cm/year. This rate is commensurate with the figures of the land subsidence map produced using geospatial data. The architectural approach demonstrated in this study could become a complement tool to investigate the subsidence phenomenon in all vernacular settlements in Indonesia**.**

Keywords: Land Subsidence, Old Building, Semarang, historic area, Conservation.

Introduction

Coastal and delta cities are experiencing severe land subsidence, which often exceeds the absolute sea level rise up to ten times. Many cities including Jakarta, Ho Chi Minh City, Bangkok, and several others will sink below sea level. This increases their vulnerability to floods, leading to major economic damage and loss of lives (Erkens *et al.*, 2015). Land subsidence has been confirmed to be a real phenomenon in several urban areas of Indonesia such as Jakarta, Bandung, and Semarang (Abidin *et al.*, 2004). Experts predict that North Jakarta will sink within the next 30 years, and Semarang is already experiencing deep land subsidence faster compared to Jakarta (Kuehn *et al.*, 2010; H.Z. Abidin *et al.*, 2013; Suripin and Helmi, 2015). Jakarta's coastal city is predicted to sink 600 cm in the next 30 years due to land subsidence of around 20 cm/year (Colbran, 2009; Chaussard, Amelung, and Abidin, 2012). The impact of land subsidence is felt in buildings above ground level. Because land subsidence occurs slowly, the symptoms can be seen in some old buildings. Old buildings built several centuries or several years ago are affected, and their facilities are now below the surface of the road/neighborhood. This leads to a change in the proportion of the height of the building or its burial in the ground, which can be seen in architectural details such as floors, steps, doors, and windows. This paper aims to reveal the depth of land subsidence from an architectural perspective. The findings can complement the land subsidence depth. Some old areas can serve as reference points. While geologists and geodesists conduct depth assessments of land subsidence maps, architectural expertise can provide valuable information on the spatial distribution of descent. By leveraging the architecture of buildings in such areas, we hope to better understand land subsidence.

This research is a complement to the collaboration between the Ministry of Research and Technology and Research (Indonesia) and NWO WORTO Netherlands, from 2019 to 2021, regarding the impact of land subsidence on old buildings on the old coast of Semarang. As a result of this collaboration, a patent was obtained for the Fast Detection Method of Land Subsidence Using Old Buildings Benchmark, with the patent number IDS000002869 (Rukayah and Pribadi, 2020) . This patent was created by visually analyzing architectural dimensions and comparing them to data from old photographs and maps obtained from Dutch libraries such as kitlv.nl, trope museum, and Atlas Mutual Heritage. These findings were then compared to present conditions in the field.

During their research, a team of researchers discovered a renovation work being carried out on the old Johar market building. The building, which was constructed by a Dutch architect named Thomas Karsten, had a two-story mushroom-shaped structure that was considered modern during his era (R. Siti Rukayah *et al.*, 2021). Unfortunately, the market suffered a fire in 2015, which led to the Semarang city government undertaking a renovation project. During the renovation process, the researchers utilized data from excavation methods to gather accurate data, which complemented the architectural data previously obtained.

These findings are important for improving previous patents and creating models for the conservation of Semarang's historic city. Semarang City is designed to resemble Amsterdam's city, with several Dutch colonial works located along the canal. Some buildings require government attention for architectural preservation due to land subsidence and being affected by tidal flooding.

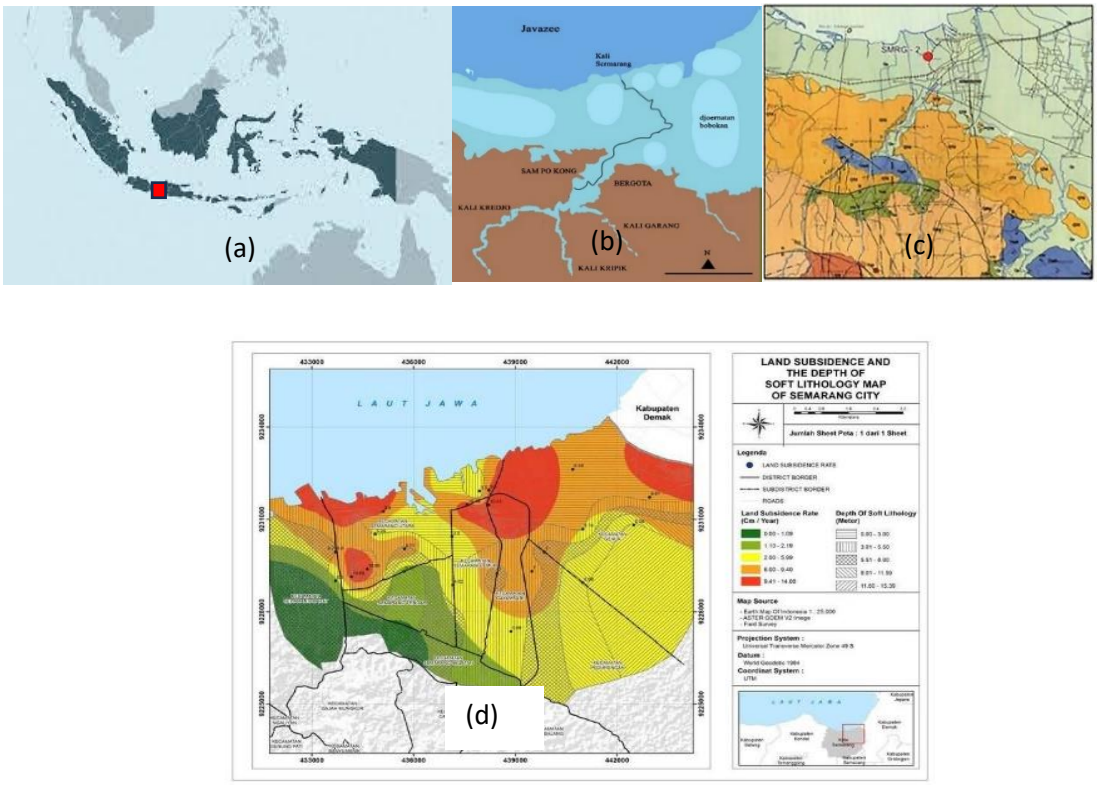


Fig. 1: The location Johar market, in old Semarang coast. a) Indonesian map. B Semarang archipelago in the 8th century AD; c) The sedimentation process turns the Semarang archipelago into a landmass, the red dot is the location of Johar market. d) Semarang landsubsidence map in 2019 , the depth in the Johar market area is around 6cm in light orange area (Widada *et al.*, 2019)

The plains of Semarang were once an ocean (in the 8th century). The history of Semarang City dates back to the 8th century AD, when the Semarang coastal area was known as Pragota (now Bergota) . At that time, the region was a port, with a group of small islands (Bemmelen, 1948) located in front of it. Due to continuous deposition, these islands have now merged to form a landmass. The area is the North Semarang area, which is known today, was once an ocean. In the 14th century, the coastline moved forward to Sleko Area, located 1 km from the current research site (Johar Market) as shown in Figure 1.

The history of the Old City of Semarang began in 1678 after an agreement between the Mataram Kingdom and the (*Verenigde Oost Indische Company)* VOC. At that time, the VOC was interested in controlling the ports along the north coast of Java, including Semarang, the port city of the Mataram kingdom. The VOC was granted rule over the strategic seaport in exchange for its help in suppressing a rebellion against the Mataram Monarch Amangkurat II. In 1708, Semarang became the main post of the VOC in central Java. The VOC built a fort and expanded it into a larger fortress. Around 1760, the fortress /city wall was completed, and it still defines the original outlines of the old European city within the current Kota Lama (Semarang Old City). In addition to the fortress city, the Dutch colonial government also constructed several city facilities such as roads, railways, hotels, post offices, and market.

We can conclude that the colonial fort and some of its facilities were built on a new land area that was previously an ocean.The old city and Johar Market located on new land. Johar Market is situated on the east side of the traditional city square. The Semarang traditional square holds significant historical value as it dates back to the early 15th century and is known as one

of the identities of Semarang City (Rukayah and Bharoto, 2012; R. Siti Rukayah, Bharoto and Malik, 2012).

On the old maps dating back to 1695 and 1789, an area of the traditional city square, known as *alun-alun*, was depicted as the center of local government with a market on its east side. (R Siti Rukayah, Bharoto and Malik, 2012). The market came into existence due to the presence of several neighboring villages around the square, including Malay Village, Kauman Village, and Chinatown Village. Kauman and Chinatown Villages are residential areas that mark the beginning of Semarang City. They are also mixed residential and economic areas, forming a socio-cultural environment with different area systems. These villages are part of the urban area of Semarang City and have a unique structure that contributes to the city's distinctiveness or identity.

Trading activities began in 1860, with many people trading goods in front of the prison located on the eastern side of traditional city square. The area surrounding the prison was lined with Johar trees, a gift from Sunan Pandanaran. Later on, the traditional market which was initially located under the Johar trees was transformed into the modern Johar Market. Its being the largest and most beautiful market in Southeast Asia. The Johar market's construction was completed in 1933 and the architect behind it was Thomas Karsten, one of the most influential Dutch architects in Indonesia at that time.

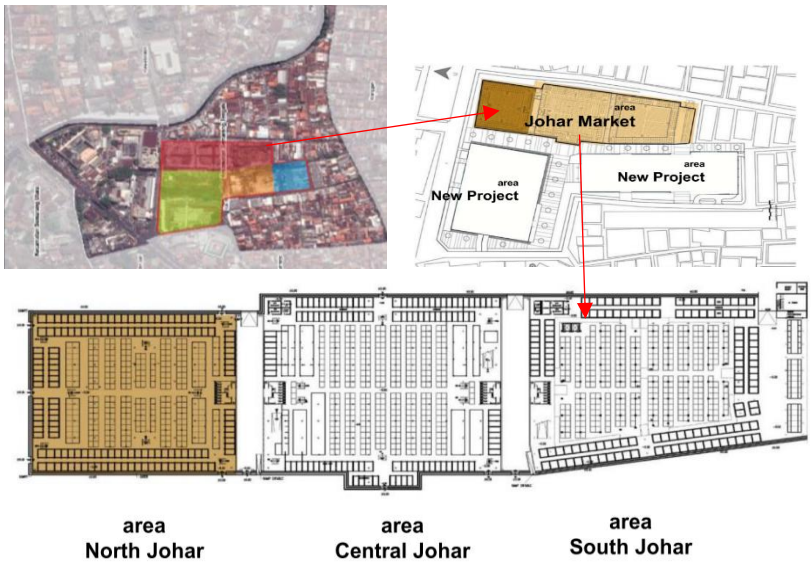


Fig. 2: Plan of the Johar Market.
Source **:** Jati, 2018;Rukayah *et al.*, 2021

The building of Johar market had a magnificent mushroom-like structure that showcased the excellent design of tropical buildings. These buildings are known to survive well in tropical climates, not only in terms of ventilation but also lighting, and natural ventilation. The growth of the Johar area as a centre of commerce started in the early 19th century when boats from various regions could dock up to the Johar area. This further enhanced the image of the Johar area as a commercial centre. (Figure 2)

Unfortunately, Johar market caught fire on May 9, 2015, due to a short circuit. The fire caused severe damage to the Semarang Johar market building, leaving only the main building frame. This incident highlights the need for conservation efforts by the Semarang City Government. In the past, stalls at Johar market were better organized than before the fire. The

lack of arrangement for stalls was caused by traders who exceeded their capacity and some traders who were selling in the circulation route, which impacted visitors' circulation in the increasingly narrow market. This fire incident made heritage building worn and ultimately destroyed for new projects (Umar and Said, 2018). It is essential to consider the loss of heritage values to maintain the cultural values and educational history (Hanafi *et al.*, 2018).

The government's efforts to renovate and carry out the arrangement of the Johar market Area in Semarang City after the fire were revealed by activities to restore it to its original market form. Information that floors made of andesite in the past need to be proven by excavating floors in the present. After the government excavated the building floor, they found the floor coatings used andesite stone, known for its sturdiness and ability to withstand loads. Karsten believed that andesite stone was easy to clean, making it suitable for traditional market conditions that were easily dirty. Unfortunately, Johar market is often exposed to tidal floods, causing environmental problems. The floor's elevation has been done several times in the market, making the original andesite floors no longer exist.

Review of Literature

Land subsidence is a real phenomenon in a few urban areas of Indonesia, such as Jakarta, Bandung, and Semarang. (Delinom *et al.*, 2009; A.S., Osawa and Merit, 2015; Handoko, Kurniawan and M, 2018; Sarah and Soebowo, 2018). Several other cities like Medan, Surabaya, and Denpasar are also suspected to be affected by this problem. There are four different types of land subsidence that can occur in urban areas, namely subsidence due to groundwater extraction, subsidence induced by the load of constructions, subsidence caused by natural consolidation of alluvium soil, and geotectonic subsidence.(Abidin *et al.*, 2015). Groundwater level observations, geological and hydrological parameters, or geodetic techniques such as Leveling surveys, GPS surveys, and INSAR (Interferometric Synthetic Aperture Radar) can be used to infer land subsidence phenomena.(Yastika, Shimizu and Abidin, 2019; Catalao, Raju and Nico, 2020; He *et al.*, 2021). However, it has yet to be discussed whether traces of the land subsidence phenomenon are visible in ancient buildings and historical areas. Historic areas and ancient buildings are now under the roads and surrounding areas to avoid rob/tidal flooding (Javanese). *Rob* suggested that the building is below sea level.

Land subsidence in Semarang with rates of up to about 19 cm/year was observed during the period of 1999 up to 2011, based on the estimation from Levelling, InSAR, Microgravity, and GPS survey methods. GPS results from 2008 to 2011 show that land subsidence in Semarang has spatial and temporal variations, with spatial average rates of about 6 to 7 cm/year and maximum rates that can reach up to 14–19 cm/year in certain locations. The northern region along the coast shows higher rates of land subsidence compared to the southern region, and this land subsidence is believed to be caused by the combination of natural consolidation of young alluvium soil, groundwater extraction, and load of buildings and constructions. The impact of land subsidence in Semarang is visible in several forms, mainly the wider expansion of (coastal) flooding areas, cracking and damage of buildings and infrastructure, and increased inland sea water intrusion. (Abidin *et al.*, 2013). Experts often write that heavy building types cause land subsidence, but there has been no significant research on the kind of building.

The weakness of that theory is that it still needs to touch on land subsidence and tidal flood measurements, which also impact old buildings. Hence, the reseracher found the detection method for measuring land subsidence uses old buildings as benchmarks in coastal areas (Rukayah and Pribadi, 2020). This invention uses old buildings that can be used as benchmarks/definitive points for the subsidence of the land surface. All buildings are designed with a safe height relative to the surrounding land when they are constructed. However, the

weight of a building and its location in a coastal area with young alluvial soil can cause subsidence over time, leading the building to sink below the surface. The traditional market building, Pasar Johar Semarang, is a clear example of this phenomenon. Despite being the grandest market in Southeast Asia in 1930, it has subsided over time due to its weight and location. (Rukayah *et al.*, 2021).The building has two floors and a mushroom roof, covering an area of 17,225 m2. The symptoms observed in this market building confirm the theory of subsidence due to the weight and location of the building (Jati, 2018).

Two studies have been conducted on the depth of land subsidence in the Kota Lama (Rukayah, Sardjono and Abdullah, 2021) and Chinatown regions of Semarang (Rukayah *et al.*, 2021), from an architectural perspective. The theoretical framework regarding land subsidence and cultural heritage buildings still needs to discuss measuring the depth of land subsidence. The experts' theories usulay use radar-based measurements and satellite imagery. (Yastika, Shimizu and Abidin, 2019; Catalao, Raju and Nico, 2020; He *et al.*, 2021). Meanwhile, previous research that revealed the depth of land subsidence from an architectural perspective needs to be complemented by the phenomenon that tidal flood depth can be an estimate of the depth of land subsidence. We also added the Building excavation activities to find parts of the building that are covered by new floors to avoid seawater flooding, which will be discussed in this paper. This paper presents a validated method to measure the depth of land subsidence by conducting building excavations, which is an approach commonly used by archaeologists.

Research Methods

Johar Market is part of a significant research project on land subsidence along Java's north coast, with Semarang City as its primary focus. It's an old building that's heavy and situated on new land. This market is a two-story building with a modern design from the colonial era. Through historical methods and field surveys, researchers have discovered differences in the building's position relative to the surrounding land. To determine the original shape of the building in the past, researchers obtained old photos of Johar Market buildings from kitlv.nl and Tropenmuseum and compared them with the current condition. Research often employs visual aids to help interpret and understand images. Analyzing these visuals through architectural dimensions is a common approach (Glaw *et al.*, 2017). In addition, (Gerstenblatt, 2013) suggests that old photographs can convey meanings and emotions that are not possible through writing.

As part of the renovation process for the Johar Market building, a sampling method was employed. This involved several steps such as determining the depth of land subsidence, measuring building excavations to find old floors, and comparing old photos with current conditions to determine the extent of subsidence in the Johar Market. Additionally, observation methods, as described in the study by (Antariksa, 2011), were used to identify various activities in the building. These observations aided in assessing building conservation efforts.

The data collection was carried out in several stages, with the first stage being finding the area's characteristics to identify potential and problems. The second stage involved exploring the identity of the building area, size, and other aspects. This activity describes construction details that describe the building's height. The last stage involved sketching old buildings/old photos and current conditions. By using a sketch image approach and standard architecture, the researchers were able to obtain data on the depth of land subsidence. The results were then compared with data from building excavations that found old floors. The architectural consulting bureau that did the building's renovation had already found the position of the original floor of the building at a depth of 100 cm. The position of the original floor of the building indicated the depth of the building's subsidence so far.

Findings

Measuring the Land Subsidence Depth

Johar Market is situated on K.H Agus Salim Street, near Kauman village in Semarang. There are multiple ways to reach this market. The primary access can be through Pemuda Street, heading to the northeast, and then turning right towards KH Agus Salim Street. Alternatively, one can take Mataram Street, then travel to Bubakan Street, and continue towards KH Agus Salim Street.

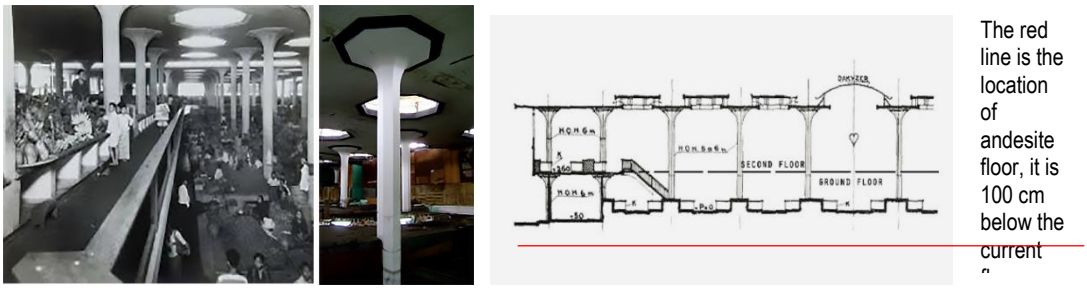
The history of Johar Market dates back over a century ago, to 1860. At that time, the market was located in the eastern part of the city square, surrounded by rows of Johar trees on the roadside. This is how the market got its name. The location of the market, which was close to the prison, made it a convenient place for people to visit acquaintances or relatives who were in prison. Over time, the market became increasingly crowded and needed more space for expansion. (Novendasyarizky, 2014). Figure 3 shows a visual representation of the modern Johar Market built during the colonial era.

Fig. 3 : Photos of the old Johar market which will be compared with the latest condition
Source**:** Anonym, 1938

Johar market was eventually expanded by cutting down Johar trees to build some stalls and booths for traders. In 1931, the old prison building near the market was demolished to make way for the modern market. The modern market was established to merge the five existing markets, including Johar market, Pedamaran, Beteng, Jurnatan, and Pekojan. The market sites included the Pedamaran market site, Johar market, the prison house site, several shops, part of the Kanjengan courtyard, and part of the square (Novendasyarizky, 2014). In 1933, Ir Thomas Karsten made the first draft for the modern market, which included a two-story building with a concrete roof arrangement on the second floor. The market was multilevel, taking into account the high land prices in the area. Johar market was once famous for being the largest and most beautiful market in Southeast Asia. (Novendasyarizky, 2014). The column depicted in the figure 4 below resembles a mushroom and serves as the main structure of Johar market.

Based on the observations from figures 4a, it seems that the ground floor portion of the building appears shorter than the second floor. As per architectural standards, the floor-to-floor height of a building is usually 400 cm, which means that the total height of the building should be 800 cm. However, the current height of the building is only 650 cm, indicating a decrease of 150 cm in the height of the ground floor. This decrease in height is in line with the standards that dictate a floor-to-floor height of 150 cm for the buried part of the ground floor. The

architectural section image below clearly shows that this decrease in height of the ground floor adheres to standard architectural design principles.



(a) (b) (c)

Fig. 4: Totally the high dimension of column is 800 cm. The first floor becomes 250 cm height because the ground floor position is always raised to avoid tidal flooding a) The column of Johar market's mushroom; b) Johar market column height should be 800 cm. c) section plan of Johar market, .
Source: Co, 1938 and Detail Image of PT. Yodya Karya

Johar Market is considered a cultural heritage and registered in Information Systems Semarang City Cultural Heritage (Anonym, 2023). Over the years, the market has grown due to an increase in the number of traders. However, this growth has led to a change in the physical structure of the market, with stalls being placed in a disorganized manner. The increase in the number of traders has also resulted in the construction of non-permanent buildings to cater to the needs of the traders. Unfortunately, this has led to the basic structure of Johar Market being covered with additional structures. When compared to its original structure, the design of the market has not changed much physically, but it is evident that there are many non-permanent buildings added to accommodate the booming number of traders. Karsten designed the Johar market with the ideal architectural standards. The market ceiling is high and supported by mushroom-shaped pillars, and the roof has several ventilation holes to promote free air flow (R. Siti Rukayah *et al.*, 2021) (see figure 3). Karsten also designed the landscape to allow for easy movement of buyers within the market area, and to encourage comfortable interaction and price negotiations between buyers and sellers. The market has stone foundations and reinforced concrete structures with a fungal system in the columns, with each column having a 6-meter module and octagonal cross section.

The tidal phenomenon occurs frequently in this area and can reach knee-high levels for adults, indicating that the flood-stricken region is below sea level. Therefore, people often raised the building's floor to avoid tidal flooding. Although construction of polders and water pumps has reduced the extent and depth of the tidal basin in this area, it remains a warning that the decline in buildings is still ongoing. because tidal flood indicates that the area is below sea level, we use it as an estimation point for the depth of land subsidence. Therefore, the researchers concluded that there was a distortion in the height of the building on the 1st floor because traders raised the floor height to avoid tidal floods.

Building Excavation and Land Subsidence Depth.

Despite being the largest market in Southeast Asia, Johar Market has been facing the problem of flood and tidal issues, which are common in Semarang City. The land subsidence rate in Semarang City ranges from 0.8 cm/year to 13.5 cm/year (H.Z. Abidin *et al.*, 2013), and this is caused by the consolidation of young alluvial deposits and excessive groundwater

extraction, along with loads in the form of landfill and building loads (Suhelmi, 2012). The subsidence rate is more significant towards the north and the time is getting longer (Soedarsono and Arief, 2012). To deal with tidal flooding in the area around Johar Market, the government raised several surrounding roads. This is what causes the Johar market to be located below road level. The reduction of the heigh is estimated to be about 100 cm bellow the street.

The Johar Market falls under the Central Semarang District, which is located in front of the Semarang River and stretches 6,264 m (Kurniawati and Suwandono, 2015).. During the rainy season, the intensity of flooding is high enough to flood buildings nearly three times a week. Land subsidence in the area happens periodically due to subsurface conditions, including the presence of a thick layer of clay under the surface (Eko Subowo, Dwi Sarah, Dodit Mudoharjono, 2014) . Research shows that the Johar Market area to Tanjung Mas Port has a depth of tidal flooding around -500 to -1,000 cm. The reduction in floor area, where the road elevation is 200 height cm from the east side building at Padamaran street or Agus Salim Street. (See Figure 5). The structural column visually has also undergone a significant decrease (Sarah *et al.*, 2011).

(a) (b)

Fig. 5: The depth of land subsidence in the Johar market. a) Sketch of architectural size of Johar Market which explains the building subsidence; b) The the east side building at Padamaran street, only half a column is visible.
Source: Anonym, 1920, author's sketch and field survey 2020

Recent flooding caused by high tides has had a significant impact on the local economy, especially on the traders at Johar Market. According to research conducted by Kurniawati and Suwandono in 2015 (Kurniawati and Suwandono, 2015), around 40% of economic activity in the affected area was disrupted due to flooding that lasted for a day. For flooding that lasted 12 hours, approximately 20% of the economic activity was impacted. As a result of the flooding, those who relied on economic activities in the affected areas have experienced a decrease in income. The traders at Johar Market reported facing issues with damaged road access and collapsed sewers in the market environment. The constant flow of heavy trucks carrying produce, such as chilies and potatoes, has caused the roads to deteriorate, and visitors have been hesitant to shop in the affected area.

Eexcavation and the Andesite Floor 100 cm depth

The Government and the Ministry of Public Works and Public Housing (the ministry of Pekerjaan Umum dan Perumahan Rakyat/ PUPR) carried out revitalization activities in order to improve the condition of Johar market due to tidal floods and fires in 2015. The Ministry of PUPR carried out the revitalization of the Johar market Semarang cultural heritage in the central and northern parts of the market with a construction contract value of Rp. 146.09 billion with the contractor PT Nindya Karya. The work carried out included rehabilitation of buildings,

curved roof trusses, mechanical, electrical installation, paving installation, installation of tiles for meat sellers, painting of stall table frames, and construction of drainage control tanks. The development also included complete facilities, especially in the aspect of security. At the time of construction, there was some photo documentation. When carrying out renovation activities, one of them was the discovery of the original floor in Figure 6. There was a toilet that was suspected to be the original part of the building (Figures 6a, b and c). The toilet floor have small squares pattern. It is the original floor of the building. Photos from building excavations also shows the old floor position about 100-120 cm from the present floor.

It is worth noting that old photos from the KITLV, a website containing various old Dutch colonial photographs, have revealed additional evidence of the Johar market conditions during the colonial era. The pictures show that numerous traders were conducting business in the area. One photo in particular displays a floor with the same small square pattern as the one seen in figure 6b and c. It is suspected that the original floor may have been covered with a new one, and the elevation of the floor was likely done to avoid tidal flooding. Raising the floor was the most efficient way to prevent tidal flood from entering the building, and was achieved by elevating the building higher than the level of the road. As a result, the elevation of the floor to avoid the tidal flooding has caused the building to appear shorter than its original condition.

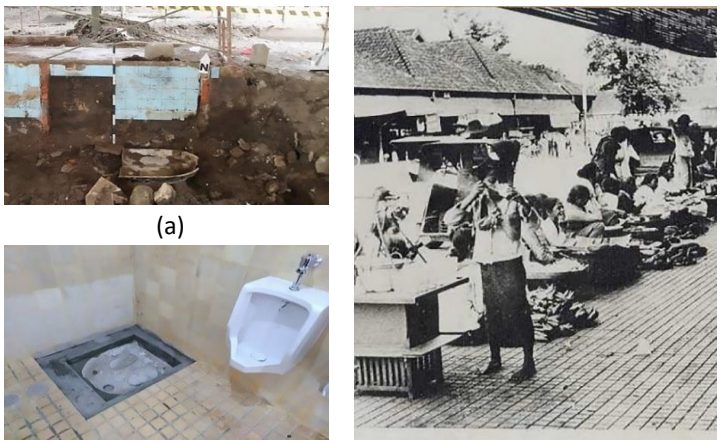


Fig. 6: Viasible signs of subsidence
Source: Anonym, 1920, author's sketch and field survey 2020

The Depth of Subsidence in the Johar Market

The coast of Semarang stretches along the coast from the Bodri estuary in Kendal district in the west, to the estuary in Demak district in the east. It covers a length of about 104 km and consists of both water and land areas. However, due to its natural conditions and developments, the coast of Semarang Bay is currently facing complex problems such as tidal flooding, land subsidence, and coastal abrasion.

Between 2008 and 2011, land subsidence in Indonesia varied. It was at its lowest in 2008-2009, at -12.4 cm, increased in 2009-2010 to -20.4 cm, and then decreased again to -10.5 cm in 2010-2011. A study conducted by KOICA-BAPPENAS in 2012 (Koica Bappenas, 2012) found that land subsidence ranges from 0-1 cm/year in some districts such as Tugu, West Semarang, Central Semarang, and East Semarang, and 8-9 cm/year in others like North Semarang and Genuk. Land subsidence can occur either locally or regionally, and can be caused by several factors, such as natural subsidence due to geological processes, the extraction of liquid materials like groundwater or petroleum, the presence of voids below the soil surface, and

the compaction/management of soil layers caused by building structures and mining activities. In this study, the factors contributing to land subsidence are reviewed, including changes in land surface, land cover conditions related to building loads, and levels that occur (Reddish and Whittaker, 2012).

According to Yuwono's research conducted in 2013 (Yuwono, 2013) (see Figure 1a) (Widada *et al.*, 2019), Semarang had experienced a significant decline due to tidal flooding. The comparison of two maps (see Figure 1a) shows a difference in the extent of the decline. The map by Widada et al. (2019) shows a decrease of only about 6 cm because the government prioritized handling tidal floods in the central and western regions during the period of 2007-2015 (Erlani and Nugrahandika, 2019). Standard architectural and excavation methods indicate that the building subsidence is 100-120 cm depth from the present floor, but the current floor condition is about 100 cm below the neighborhood road. So the total decline of the building from the environmental road is 220 cm. By measuring the height of the tidal flood surrounding the building, it was found that the land subsidence in the field is knee-high for an adult, as deep as 30 cm. If we add the depth of the tidal flood as deep as an adult's knee (around 30 cm), then the total estimation point for the depth of land subsidence is 250 cm. Let's compare visually the first floor of the building that is visible now is around 150 cm. The total subsidence of the building is 250 cm, which is obtained from on the comparison of old photos and current conditions using standard architectural. Johar market, which is 90 years old and built in 1930, experiences an annual decline of 3.3 cm/year.

The authors also made a comparison between this data and the land subsidence map in 2019. On this map, it is stated that in the area, there has been landing subsidence of 2-4 cm/year. Land subsidence data using the architectural standard comparison method by comparing old photos and current conditions and excavation methods in the field show that there is a similarity in the depth of subsidence according to the subsidence map, which is in the range of 2-4 cm/year depth.

It can be helpful to use architectural standards and excavation methods to determine the depth of building subsidence, in addition to the land subsidence map from 2013 and the 2019 tidal flood map that were created using radar/satellite imagery and verified with field data. Although the government has taken steps to address tidal flooding in Semarang by installing suction pumps in various locations and building polders on the north side of Johar market area near Tawang Station, the occurrence of land subsidence is still a cause for concern. This is because the Semarang area is experiencing rapid decline, and the historical region and ancient buildings are in danger. Based on research findings, the rate of building decline is 3.3 cm per year, meaning that in the next 10 years, buildings will sink to a depth of 33 cm.

Johar market has been experiencing land subsidence and in order to determine the causes, it is important to understand the area's history. Johar market is situated in the lower Semarang area, which is a young alluvial land formed through a process of sedimentation that unified the Semarang Island cluster in the 8th century and became the mainland in the 14th century. This sedimentation process is still ongoing and is marked by changes in the location of the port.

The weight of the building load is another factor contributing to subsidence. Johar market, a modern concrete structure, was a new concept to the locals who were more accustomed to wooden structures at the time of its construction. The building consists of two floors, with an atrium in the middle and a mezzanine around the edge. The floors are connected by stairs on all four sides and there are ramps in the north and middle of the building. The building area is 17,225 square meters and the weight of the building load and activities that require soil compaction before construction are contributing factors to the subsidence. The measurement results from the field indicate a decrease of about 20-40 centimeters in adjacent buildings built

in the closest period, such as the large Kauman mosque, showing that the subsidence is not significant.

Groundwater extraction has been identified as a leading cause of building deterioration, according to research. It is believed that the high demand for clean water by the community and traders for market activities is linked to this issue. This phenomenon provides an opportunity to conduct further research. Traders have reported tidal flooding in Semarang since the 1980s and 1990s. During this period, there was a significant increase in the use of groundwater and the reclamation of Semarang's beaches for housing and industrial development. This information could be relevant to understanding the tidal phenomenon.

Conclusions

Johar Market is one of the oldest buildings in the North Semarang area, which used to be a coastal area in the 14th century. The two-story modern building has been around for 90 years and is situated on the East side of the traditional square. Unfortunately, the building has been experiencing land subsidence, which has caused a level difference of about 150 cm between the road and the front side of the building. In 2019, during the renovation work of a building that had suffered a fire in 2015, the Semarang city government discovered the original floor of the building. After conducting building reliability and structural tests, it was found that the building can be renovated according to its original condition, designed by Dutch architect Thomas Karsten. During the renovation, the designers found that the original floor with old tiles and bathrooms was at a depth of 100-120 cm from the present floor. Thus, it can be concluded that the total land subsidence in the building is 250 cm. Given that the building is 90 years old, the annual land subsidence is 3.3 cm/year (300 cm / 90 years).

This paper achieves the research aims and indicate that old buildings in Semarang City experience an annual land subsidence of 3-4 cm. The study also confirmed a visual method for measuring land subsidence by comparing old photos with current conditions. Excavation activities also confirmed the location of the old toilet and floor. The land subsidence map shows that the rate of land subsidence in Semarang City is between 3-6 cm/year based on various measurements taken between 2007-2012, including GPS survey, slope, flat, and InSAR measurement. The heavy loads on the soil from building structures cause soil compaction and consolidation, which is known as settlement. Koica Bappenas's research conducted in 2012 indicates that the rate of land subsidence in North Semarang and Genuk districts is 8-9 cm/year, which is higher than the previous data. However, the old building of Johar Market in the North Semarang area has a lower subsidence rate of about 3-4 cm/year, indicating that soil investigation and processing of building pods were considered during construction.

Acknowledgments

Thanks to PT Yodya Karya, KITLV. NL, Tropenmuseum, for providing data on the renovation and the old photos of Johar Market building. The authors would like to pay their special regards to all key persons for their constructive feedback. This research was conducted within the framework of land subsidence in North Java. Thank you to NWO WORTO (Netherlands) and the Ministry of Research and Technology and Research Indonesia, who have facilitated collaborative research and postdoctoral research at IHE Delf with Contract No: 257-91 / UN7.6.1 / PP / 2020. In 2023, we will continue that research within the Indonesian Collaborative Research framework, which Diponegoro University as host, and North Sumatra University and the University of Indonesia as co-host. This research collaboration gets funding from the Indonesian Ministry of Research and Technology through Decree Number 235/UN7.A/HK/V/2023 and Agreement/Contract Number 391-03/UN7.D2/PP/V/2023.

Reference

A.S., S., Osawa, T. and Merit, I. (2015) 'Land Subsidence in Semarang', *Ecotrophic: Journal of Environmental Science*, 7(2), pp. 115-111

Abidin, H. Z. *et al.* (2004) 'Capabilities and constraints of geodetic techniques for monitoring land subsidence in the urban areas of Indonesia', *Geomatics Research Australia*, 81(January), pp. 45–58. Available at: https://www.researchgate.net/publication/241788135_Capabilities_and_Constraints_of_Geodetic_Techniques_for_Monitoring_Land_Subsidence_in_the_Urban_Areas_of_Indonesia/link/0c96052bab0dfab2e1000000/download.

Abidin, H.Z. *et al.* (2013) 'Land subsidence in coastal city of Semarang (Indonesia): characteristics, impacts and causes', *Geomatics, Natural Hazards and Risk*, 4(3), pp. 226–240. doi: 10.1080/19475705.2012.692336.

Abidin, H. Z. *et al.* (2015) 'Environmental Impacts of Land Subsidence in Urban Areas of Indonesia', in *Conference: FIG Working Week 2015 From the Wisdom of the Ages to the Challenges of the Modern World*. Sofia, Bulgaria: Office International du Cadastre et du Régime Foncier (OIRCF) by International Federation of Surveyors (FIG), pp. 1–12. Available at: https://www.oicrf.org/-/environmental-impacts-of-land-subsidence-in-urban-areas-of-indonesia.

Anonym (1920) *De Pasar Djohar te Semarang (Djohar Market in Semarang), KITLV*.

Anonym (1938) *Pasar Djohar te Semarang, KITLV*. Available at: http://hdl.handle.net/1887.1/item:840525.

Anonym (2023) *Sistem Informasi Cagar Budaya Kota Semarang (Information Systems Semarang City Cultural Heritage), Semarang, Pemerintah Kota*. Available at: https://cagarbudaya.semarangkota.go.id/#.

Antariksa (2011) *Metode pelestarian arsitektur (Architectural preservation methods), antariksa blog*.

Bemmelen, R. Van (1948) *Geology of Indonesia Vol-IA General*. Nederland: Nederland: Government Printing Office.

Catalao, J., Raju, D. & Nico, G. (2020) 'Insar maps of land subsidence and sea level scenarios to quantify the flood inundation risk in coastal cities: The case of Singapore', *Remote Sensing*, 12(2). doi: 10.3390/rs12020296.

Chaussard, E., Amelung, F. & Abidin, H. (2012) 'Sinking Cities In Indonesia : Space-Geodetic Evidence Of The Rates And Spatial Distribution Of Land Subsidence', in *Proc. 'Fringe 2011 Workshop', Frascati, Italy, 19–23 September 2011 (ESA SP-697, January 2012)*. Elsevier Inc., pp. 1–8. Available at: https://earth.esa.int/eogateway/documents/20142/37627/Sinking-cities-Indonesia-space-geodetic-evidence-rates-spatial-distribution-land-subsidence.pdf.

Co, A. O. H. & (1938) *De Pasar Djohar (Djohar Market), Tropenmuseum*. Available at: https://collectie.wereldculturen.nl/?query=search=*=TM-60052565#/query/72c37227-5b68-4970-b83a-2ea3dc866a88.

Colbran, N. (2009) 'Will jakarta be the next atlantis? Excessive groundwater use resulting from a failing piped water network', *LEAD Journal (Law, Environment and Development Journal)*, 5(1), pp. 20–37. Available at: http://www.lead-journal.org/content/09018.pdf.

Delinom, R. M. *et al.* (2009) 'Land Subsidence and Urban Development in Jakarta (Indonesia)', *Spatial Data Serving People: Land Governance and the Environment - Building the Capacity*, 7(October 2009), pp. 5–16.

Eko Subowo, Dwi Sarah, Dodit Mudoharjono, T. W. (2014) 'Geologi Bawah Permukaan Wilayah Amblesan Tanah Di Kota Semarang (Subsurface Geology of Land Subsidence Areas in Semarang City)', *Pemaparan Hasil Penelitian Pusat Penelitian Geoteknologi LIPI Tahun 2014*, pp. 57–63.

Erkens, G. *et al.* (2015) 'Sinking coastal cities', *Proceedings of the International Association of Hydrological Sciences*, 372, pp. 189–198. doi: 10.5194/piahs-372-189-2015.

Erlani, R. and Nugrahandika, W. H. (2019) 'Ketangguhan Kota Semarang dalam Menghadapi Bencana Banjir Pasang Air Laut (Rob) (Semarang City's Resilience in Facing the Sea Water Flood (Rob) Disaster)', *Journal of Regional and Rural Development Planning*, 3(1), p. 47. doi: 10.29244/jp2wd.2019.3.1.47-63.

Gerstenblatt, P. (2013) 'Collage portraits as a method of analysis in qualitative research', *International Journal of Qualitative Methods*, 12(1), pp. 294–309. doi: 10.1177/160940691301200114.

Glaw, X. *et al.* (2017) 'Visual Methodologies in Qualitative Research: Autophotography and Photo Elicitation Applied to Mental Health Research', *International Journal of Qualitative Methods*, 16(1), pp. 1–8. doi: 10.1177/1609406917748215.

Hanafi, M. H. *et al.* (2018) 'Essential Entities Towards Developing an Adaptive Reuse Model for Organization Management in Conservation of Heritage Buildings in Malaysia', *6th AMER International Conference on Quality of Life*.

Handoko, E. Y., Kurniawan, A. and M, A. S. (2018) 'Land Subsidence Di Surabaya (2007-2010)', *Geoid*, 7(1), pp. 40–43. doi: 10.12962/j24423998.v7i1.4218.

He, Y. *et al.* (2021) 'Integration of InSAR and LiDAR Technologies for a Detailed Urban Subsidence and Hazard Assessment in Shenzhen, China', *Remote Sensing*, 13(12), p. 2366. doi: 10.3390/rs13122366.

Jati, W. D. Y. (2018) *Revitalisasi Dan Penataan Kawasan Pasar Johar Sebagai Pusat Perdagangan Kota Semarang (Revitalization and Arrangement of the Johar Market Area as a Trade Center for the City of Semarang)*. Universitas Muhammaadiyah Surakarta.

Koica Bappenas (2012) 'Disaster Survei and Thematic Map Building in Semarang Area'.

Kuehn, F. *et al.* (2010) 'Detection of land subsidence in Semarang , Indonesia , using stable points network (SPN) technique', pp. 909–921. doi: 10.1007/s12665-009-0227-x.

Kurniawati, W. and Suwandono, D. (2015) 'Pengaruh Bencana Banjir dan Rob Terhadap Ketahanan Ekonomi Kawasan Perdagangan Johar di Kota Semarang (The Influence of Flood and Rob Disasters on the Economic Resilience of the Johar Trading Area in Semarang City)', *Ruang*, 1(4), p. 261. doi: 10.14710/ruang.1.4.261-270.

Novendasyarizky, H. (2014) 'Evaluasi Kebijakan Penataan Pasar Johar, Pasar Bulu Dan Pasar Jatingaleh (Evaluation of Johar Market, Fur Market and Jatingaleh Market Arrangement Policies)', *Jurusan Ilmu Pemerintahan Fakultas Ilmu Sosial dan Ilmu Politik Universitas Diponegoro*, 53(9), pp. 1689–1699. doi: 10.1017/CBO9781107415324.004.

Reddish, D. J. & Whittaker, B. N. (2012) *Subsidence: occurrence, prediction and control*. Elsevier.

Rukayah, R. S. *et al.* (2021) 'Measuring land subsidence of buildings in Semarang Chinatown', *IOP Conference Series: Earth and Environmental Science*, 623(1), p. 012073. doi: 10.1088/1755-1315/623/1/012073.

Rukayah, R. Siti *et al.* (2021) 'The Conservation of Old Johar Market Building', *Asian Journal of Environment-Behaviour Studies*, 5(17), pp. 49–62. doi: 10.21834/ajebs.v5i17.375.

Rukayah, R. S. and Bharoto (2012) 'Bazaar in Urban Open Space as Contain and Container Case study: Alun-alun Lama and Simpang Lima Semarang, Central Java, Indonesia', in *Procedia - Social and Behavioral Sciences*, pp. 741–755. doi: 10.1016/j.sbspro.2012.08.077.

Rukayah, R. Siti. & Bharoto and Malik, A. (2012) 'Between Colonial, Moslem, and Post-Independence Era, Which Layer of Urban Patterns should be Conserved?', *Procedia - Social and Behavioral Sciences*, 68, pp. 775–789. doi: 10.1016/j.sbspro.2012.12.266.

Rukayah, R Siti & Bharoto and Malik, A. (2012) 'Between Colonial, Moslem, and Post-Independence Era, Which Layer of Urban Patterns should be Conserved?', *Procedia -*

Social and Behavioral Sciences, 68, pp. 775–789. doi: 10.1016/j.sbspro.2012.12.266.

Rukayah, R. S. and Pribadi, S. B. (2020) 'Metode Deteksi Penurunan Tanah Dengan Mengggunakan Bangunan Kuno Sebagai Benchmark Pada Kawasan Pesisir (Land Subsidence Detection Method Using Old Buildings As Benchmarks In Coastal Areas)'. Indonesia: Direktorat Jenderal Kekayaan Intelektual. Available at: https://pdki-indonesia.dgip.go.id/detail/SID201903869?type=patent&keyword=metode+pesisir.

Rukayah, R. S., Sardjono, A. B. and Abdullah, M. (2021) 'Inventory of old buildings and land subsidence in Semarang Old Colonial City', *IOP Conference Series: Earth and Environmental Science*, 623(1), p. 012072. doi: 10.1088/1755-1315/623/1/012072.

Sarah, D. *et al.* (2011) 'Identifikasi Faktor Geoteknik Penyebab Amblesan Di Kota Semarang (Identification of Geotechnical Factors Causing Subsidence in Semarang City)', *Prosiding Geoteknologi Lipi*, (1990), pp. 199–203.

Sarah, D. and Soebowo, E. (2018) 'Land subsidence threats and its management in the North Coast of Java Land subsidence threats and its management in the North Coast of Java', in *Global Colloquium on GeoSciences and Engineering 2017*.

Soedarsono, S. and Arief, R. B. (2012) 'Prediksi Amblesan Tanah (Land Subsidence) Pada Dataran Aluvial di Semarang Bagian Bawah (Prediction of Land Subsidence in Alluvial Plains in Lower Semarang Area '', in *Prosiding Seminar Nasional Kebijakan dan Strategi Pembangunan Infrastruktur Pengembangan Wilayah Berbasis Green Technology*. Semarang: UNNISULA, pp. 2–9. Available at: http://research.unissula.ac.id/pages/prosiding.php?id=OTM2YXBheWFlbmtyaXBzaW55YT8=.

Suhelmi (2012) 'Kajian dampak land subsidence terhadap peningkatan luas genangan rob di Kota Semarang: Impact of land subsidence on inundated area extensivication at Semarang City', *Ilmiah Geomatika*, 18(1), pp. 9–16.

Suripin, S. and Helmi, M. (2015) 'The lost of Semarang coastal areas due to climate change and land subsidence', *International Conference on Coastal and Delta Areas*, 1(1), pp. 98–108. Available at: http://jurnal.unissula.ac.id/index.php/ICCDA/article/view/611.

Umar, S. B. and Said, I. (2018) 'Conservation Challenges of Heritage Building Reuse in Nigeria: A review of decision-making models', *Asian Journal of Environment-Behaviour Studies*, 4(12), pp. 16–36. doi: 10.21834/aje-bs.v4i12.336.

Widada, S. *et al.* (2019) 'Distributian of Depth and Clay-Silt to Sand Ratio of Land Subsidence in Coastal Semarang City by Resistivity Methods', *Jurnal Kelautan Tropis*, 22(1), p. 63. doi: 10.14710/jkt.v22i1.4463.

Yastika, P. E., Shimizu, N. and Abidin, H. Z. (2019) 'Monitoring of long-term land subsidence from 2003 to 2017 in coastal area of Semarang, Indonesia by SBAS DInSAR analyses using Envisat-ASAR, ALOS-PALSAR, and Sentinel-1A SAR data', *Advances in Space Research*, 63(5), pp. 1719–1736. doi: 10.1016/j.asr.2018.11.008.

Yuwono, B. D. (2013) 'Korelasi Penurunan Muka Tanah Dengan Penurunan Muka Air Tanah Di Kota Semarang (Correlation of Land Subsidence with Decrease in Ground Water Level in Semarang City)', *Teknik*, 34(3), pp. 188–195. doi: 10.14710/teknik.v34i3.6725.