The building materials of the Lorenese Forts of the Tuscan coast

# THE BUILDING MATERIALS OF THE LORENESE FORTS OF THE TUSCAN COAST

Silvia Rescic, Fabio Fratini, Manuela Mattone

**Abstract**: This work examines the natural and artificial stone materials (mortars and bricks) used in the construction of the fortifications realized by the Grand Duke of Tuscany Pietro Leopoldo between 1786 and 1793 along the Tuscan coast. The aim is to verify the possible relationship between the materials used and the stone resources and raw materials (clays for bricks and limestone for the production of lime) of the individual territories, or to ascertain a standardised use of materials, with origin from a single production centre. Furthermore, the state of conservation of these fortifications in relation to decay phenomena will be examined, trying to highlight the influence of environmental factors and the characteristics of the stone materials.

**Keywords**: Lorenese Forts, Tuscany, Grand Duchy of Tuscany, Building materials

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## Introduction

The system of fortifications along the Tuscan coast is made up of 160 structures, including fortified centres, individual castles, watchtowers and buildings for the residence of soldiers and guards. Built from the Middle Ages, by the mid-14th century the castles, towers and military posts formed a relatively dense and effective network. In the 16th century, an exceptional increase in piracy along the Mediterranean coast necessitated the reorganisation and reinforcement of the coastal defence system in response to changing offensive techniques. Thus, between the 1630s and the beginning of the 17th century, numerous turreted and bastioned fortifications were built, proposing innovative architectural and technological solutions.

During the 18th century, the European Wars of Succession and the Seven Years' War led to a further strengthening of the Tuscany fortified system: fifty new structures were built and, in 1739, a military genius was appointed to survey, restore and strengthen the existing structures. In particular, under Pietro Leopoldo, six new forts were built along the coast between 1786 and 1793 to protect Tuscany from the threat of pirates and to combat smuggling [1-9]. All of the forts are of the same type, with a quadrangular body and an adjoining semi-circular platform on the sea front: *Cinquale nuovo*, *Forte dei Marmi*, *Marina di Bibbona*, *Marina di Castagneto*, *Marze* and *San Rocco* (Fig.1).

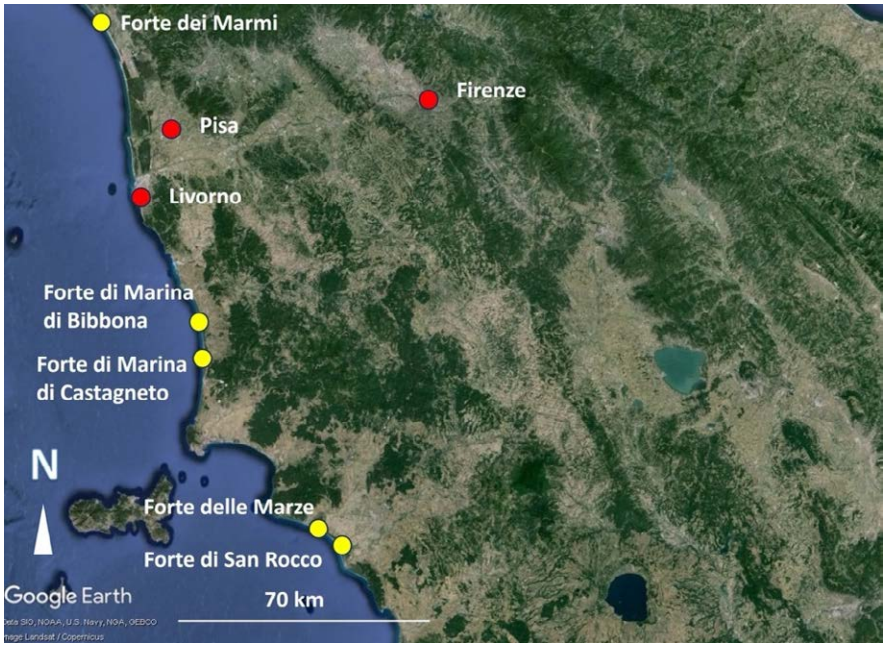



Figure 1 – Localisation of forts (from Google Earth Pro V 7.3.4, (10 April 2013), data Landsat / Copernicus Data SIO, NOAA, U.S. Navy, NGA, GEBCO,43°44'27"N 10°50'47"E, camera 293km, modified [10]).

These forts, except for the one at *Cinquale Nuovo* destroyed during the Second World War, have all been preserved. Some of them have been restored by private and/or public administrations, others are in a state of neglect.

This work examines the natural and artificial stone materials (mortars and bricks) used in the construction of these fortifications. The aim is to verify the possible relationship between the materials used and the stone resources and raw materials (clays for bricks and limestone to produce the lime) of the territories, or to ascertain a standardised use of materials coming from a single production centre. Furthermore, the state of conservation of these fortifications in relation to decay phenomena will be examined, highlighting the influence of environmental factors and the characteristics of the stone materials. In the following, historical and architectural information about the forts will be given together with a concise description of the construction materials and their current state of preservation.

## Forte San Rocco

The fort of San Rocco is a coastal fortification in the municipal territory of Grosseto, in the town of Marina di Grosseto. The complex was built by the Lorraines in the second half of the 18th century, where a pre-existing structure with sighting functions had been erected [9]. The new fortress continued to play an important role in coastal control and became a logistical base for hydraulic reclamation works in the area. Upon completion of the canal works, which led to the draining of the ancient inland marshes and historic Lake Prile, the building was converted into a military district. After the annexation of Tuscany to the Kingdom of Italy, the fort was used as barrack for the Guardia di Finanza. Currently it is totally abandoned. Originally built facing the sea, today it is about 500 meters from the shoreline. It consists of three distinct structures: the bastion facing the sea, the central tower-building with four slopes, and the courtyard at the back, protected by a wall (Fig. 2a). The rampart consists of a mighty scarp of masonry 10 meters high and 2.60 meters thick at the base and topped by a large terrace that housed artillery.

The three structures are clad in bricks: larger those of the rampart (dimensions of 28x 17 x 8 cm), shaped to have a smooth surface toward the outside, and set with thin mortar joints (0.5 cm thick); smaller the ones of the central tower and courtyard wall (dimensions of 25 x 12.5 x 4 cm) laid with thick mortar joints. The base of the rampart consists of a plinth in Pietra Panchina [11], which is also found in the stringcourse frame of the rampart itself and in the opening frames of the tower building. The jambs and the pointed vault of the access to the rear courtyard are in organic limestone. Nowadays, the building is abandoned. A restoration of the masonry was carried out adopting pinkish mortar to reintegrate brick gaps. In the rare places where the mortar fell, the bricks are affected by honeycombing (Fig. 2b). This phenomenon is also present in some of the bricks of the central tower and the courtyard wall, sometimes totally eroded. In addition, the masonry of the north-east courtyard wall is completely covered with lichens.

a

b

Figure 2 – Forte San Rocco (a); particular of the alveolisation phenomena that have completely eroded the bricks (b).

A further issue is the severe erosion of the mortar joints, especially on the south-east façade. The Pietra Panchina of the bastion kerb and the stringcourse cornice are in good condition. The marble coat of arms is well preserved but it is affected by a reddish discolouration probably due to lead oxide from the coat of arms' anchoring pins.

## Forte delle Marze

The Marze fort is in the municipality of Grosseto, along the road that connects Marina di Grosseto to Castiglione della Pescaia. It was built in the second half of the 18th century as seawater lifting plant and accommodation for the managers of the new saltworks commissioned by the Lorraines. The grand new salt plant was located between the tombolo and Lake Castiglione in the area known as 'Marze' replacing that of Trappola, too exposed to the floods of the Ombrone river that almost annually covered the basins with mud. Although the Marze fortress did not originally have a defensive function, in 1792-93 it was adapted as a fortress by the Grand Ducal architect Pietro Conti and included in the coastal defence system. After the annexation of Tuscany to the Kingdom of Italy, the fort housed a garrison of the Guardia di Finanza [9]. After its decommissioning, the fort rapidly decayed. Around 1925, the state property granted it to private owners who carried out renovation work becoming a dwelling whose original function is difficult to identify.

The building is located at the back of a low coastal dune, about 20 metres from the shoreline. The complex is composed by two adjoining buildings. The first consists of a bastion facing the sea, with a scarp at the base, above which there is a terrace covered by a loggia with a sloping roof (Fig. 3a). The second, at the rear, is a building with a square plan covered by a four-sloping roof. The rampart of the bastion, partially covered by sand, is made up of well-cut Pietra Serena sandstone ashlars. A stringcourse in the same material separates the rampart from the parapet wall, made of well-cut sandstone blocks of Pietra Bigia [12]. The crowning of the parapet is made of knife-laid bricks. The corners of the

bastion are in rusticated Pietra Serena. The building behind it is made up of ashlar of Pietra Bigia on the first floor and bricks on the second floor. Pietra Bigia was also used for the columns of the loggia. The sandstone ashlars, when not protected by calcite veins, are strongly eroded (Fig. 3b). The bedding mortar joints, with a thickness of 0.5÷1 cm, generally exhibit a high degree of cohesion.

a

b

Figure 3 – Forte delle Marze (a); detail of the Pietra Serena ashlars of the bastion scarp wall (b).

## Forte di Marina di Bibbona

The construction of the Fort of Bibbona is closely linked to that of the nearby Fort of Castagneto. The twin complexes were completed around 1789-1790. The building housed the premises for the guardhouse and stables serving the Cavalleggeri, who had the task of patrolling the coast along the nearby border between the Marquisate of Cecina and the jurisdiction of the Torre di San Vincenzo [9]. In 2019, the property was transferred from the State Property Office to the Municipality of Bibbona in order to make it more accessible to the public through an enhancement programme.

The fort, originally built on the sea, is now about 100 metres from the shoreline. It consists of two buildings: the bastion facing the sea, with a mighty scarp wall of about 10 metres with chamfered angles, surmounted by a large terrace that housed the artillery; and the three-storey tower-building, with a four-sloping roof (Fig. 4a). The rampart is clad in bricks measuring 30 x14 x 6.5 cm with smooth outward surface. They are walled with 1.5 cm thick mortar joints. The base of the bastion consists of a plinth in Pietra Panchina, which is also found in the stringcourse frame of the bastion itself and in the opening frames of the tower building. The tower-building is plastered, but where the plaster has fallen off, it is possible to observe that the masonry is composed of unhewn blocks of Pietra Panchina and rare bricks walled with abundant mortar.

The bricks of the south-facing bastion are often spalling and honeycombed with eroded mortar joints. In some places, particularly in the south-eastern corner, they have been replaced. The Pietra Panchina of the rampart kerb and the stringcourse cornice are generally in good condition. However, exfoliation

phenomena can be observed when the ashlars are laid parallel to the surface of the masonry (Fig. 4b). Some replacements and cement additions are also evident.

a b

Figure 4 – Forte di Marina di Bibbona (a); particular of exfoliation phenomena caused by improperly installed Pietra Panchina (b).

## Forte di Marina di Castagneto

At the beginning of the 18th century, the municipal territory of Castagneto had several harbours, including the 'Renaione' (port of Bolgheri) and the 'Seggio'. Near the latter, in 1786, Pietro Leopoldo built the Fort of Donoratico (or Marina di Castagneto), followed closely by that of Marina di Bibbona. The Fort became a customs post and a reference point for exchange and shipments of goods by sea, thus bringing prestige and advantages to the northern Maremma [9]. In 1862, with the advent of the Kingdom of Italy, the fort became the seat of the Guardia di Finanza garrison and was later assigned to the Della Gherardesca family and the Municipality of Castagneto. Since July 1977, it is abandoned, although in 2019, an adaptive reuse project was approved for its redevelopment.

This fort was originally built on the sea but today is about 100 metres from the shoreline. Similarly to its twin fort at Marina di Bibbona, it consists of two buildings: the bastion facing the sea, with of a mighty scarp wall, about 10 metres high, with chamfered angles, surmounted by a large terrace that housed the artillery, and the three floortower-building, with a four-sloping roof (Fig. 5a). The rampart is clad in bricks, with dimensions of 28.5 x14 x 4.5 cm, and is walled with mortar joints approximately 1 cm thick. The base of the bastion consists of a plinth of Pietra Panchina, which is also found in the stringcourse frame of the bastion and in the frame of the openings of the tower building. The tower-building is plastered but given the extreme similarity of this fortified complex with the fort of Marina di Bibbona, it is presumable that it was built similarly, i.e., with rusticated blocks of Pietra Panchina and rare bricks walled with abundant mortar.

The bricks and the Pietra Panchina of the lower part of the bastion have been affected by graffitis. They are both very porous materials, and a cleaning operation is hardly able to remove them. Regarding natural decay, the bricks on

the south-facing side of the bastion are often heavily eroded or showing spalling and honeycombing phenomena. Erosion affects also many mortar joints and there are numerous incongruous interventions such as reintegration of the joints and filling of missing bricks made with cement mortar. The part of the bastion facing north-east is covered with lichen (Fig. 5b). The Pietra Panchina of the rampart kerb and the stringcourse cornice are generally in good condition, and often the surface finish of the ashlar with ribbon and vertical grooves is still visible.

a b

Figure 5 – Forte di Marina di Castagneto (a); particular of biological growth phenomena (lichens) and brick erosion (b).

## Forte dei Marmi

Forte dei Marmi was built in 1788 by Pietro Leopoldo I Grand Duke of Tuscany with the intention of strengthening the defence system of the coastal towers. The structure was also used as a marble warehouse during the period when the local pier was a commercial port, thanks to its strategic position [2-4].

The fort is located approximately 400 m from the shoreline (Fig. 6a). It consists of a bastion facing the sea, made up of a wall about 5 metres high with chamfered corners, surmounted by a large terrace and behind it a two-storey building with a four-sloping roof. The wall is faced with bricks measuring 28.5 x 14 x 3 cm. The mortar joints are about 0.5 cm thick. A base is not observed, but this may be since the current forecourt surrounding the fort is at a higher level than the original one. The stringcourse cornice and the openings of the tower building are made of white veined marble. The tower building is completely plastered, and therefore it is not possible to observe the masonry apparatus.

The building was completely restored in 2004, and it is in good condition. During the restoration work, the most decayed bricks, especially those affected by honeycombing and spalling phenomena, were integrated with a mortar imitating the bricks themselves, others were replaced, and the mortar joints were re-pointed (Fig. 6b). Some of the decayed bricks showing spalling phenomena are still visible (Fig. 6b). The marble architectural elements are in excellent condition but given the long years of exposure to weathering and marine aerosols, it is probable that they were replaced with new ones during the restoration.

a

b

Figure 6 – Forte dei Marmi (a); particular of re-pointed mortar and brick erosion phenomena (b).

## Materials and methods

Bricks and bedding mortar were sampled from all the forts (except for Forte dei Marmi) taking advantage of the detached fragments so as not to damage the masonry. In particular:

- Forte San Rocco: two bedding mortars and two bricks from the bastion, two bedding mortars and two bricks from the tower building;
- Forte delle Marze: two bedding mortars from the bastion;
- Forte di Marina di Bibbona: two bedding mortar and two bricks from the bastion;
- Forte di Marina di Castagneto: three bedding mortars and two bricks from the bastion.

The following investigations were carried out:

- the mineralogical composition was determined on the ground samples using a PANalytical X'PertPRO diffractometer with CuK1 = 1,545 Å radiation, operating at 40 KV, 30 mA, investigated range $2\theta$ =3-70°, equipped with an X' Celerator multidetector and High Score data acquisition and interpretation software;
- the petrographic study was carried out on thin section (30 microns thick) observed under a transmitted polarised light optical microscope (ZEISS Axioscope. A1 equipped with a camera (5-megapixel resolution).

Regarding the mortars, there are many characteristics to investigate, such as the amount and type of binder, the grain size and composition of the aggregate, the type of lime lumps. This makes it possible to differentiate them, to confirm different construction phases and to identify new ones. Concerning the binder, the study of lumps gives information about the kind of carbonate stone that was burnt to produce the lime [13-15]. As for the bricks, it is possible to recognize the amount and kinds of framework (use of a lean or fat earth). Moreover, the mineralogical analysis through x ray diffraction gives information about the possible use of a marly clay (presence of calcium silicates) and an estimation of the firing temperature.

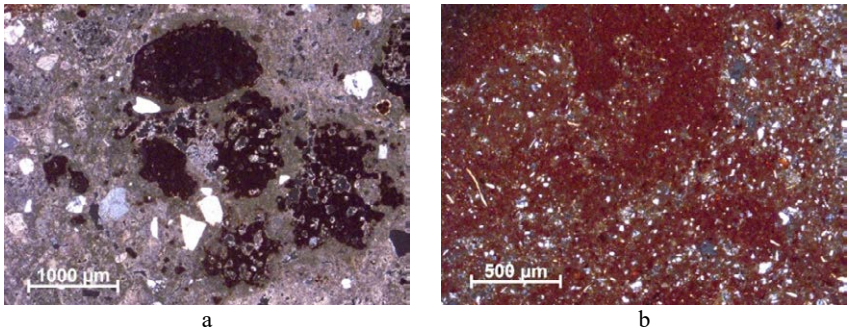
## Results

### *Forte San Rocco*

The bastion bedding mortars have an abundant to medium binder (binder/aggregate ratio from ~ 1/1 to ~ 1/3) consisting of aerial lime with a micritic appearance, hydraulicized with the addition of scarce pozzolan in both coarse and finely ground fragments. The aggregate is homogeneously distributed with unimodal grain size (200÷400 μm) and consists of subangular to subrounded granules of quartz, sparitic calcite, fragments of organogenic carbonate rocks, and feldspars. Lime putty lumps and under-burnt remnants of organogenic limestones are present. Macroporosity consists of irregularly shaped pores and shrinkage fractures (Fig. 7a).

The bedding mortar of the tower shows a medium to abundant binder (binder/aggregate ratio ~ 1/2-1/3) consisting of hydraulic lime. The aggregate is homogeneously distributed with bimodal grain size (200-400 μm predominant fraction, 1.5-2 mm secondary fraction) and consists of angular-shaped granules of sparitic calcite, marble fragments, quartz. Macroporosity is scarce and subspherical in shape.

The bricks of the bastion and tower are similar to each other. They were obtained by firing an almost pure clay. The framework is almost absent (rare quartz granules of size 200÷300 μm are present) (Fig. 7b). The groundmass is opaque, indicative of a firing temperature above 800 °C. Macroporosity is scarce and regular in shape.




a b

Figure 7 – Images at the optical microscope in thin section, crossed polarized light: bedding mortar of the bastion with presence of pozzolan (a); brick with opaque groundmass and almost absence of framework (b).

### *Forte delle Marze*

As reported in the description of the Forte delle Marze, the masonry is made of sandstone ashlars referable to Pietra Serena and Pietra Bigia, extensively studied materials [12]. Therefore, only the bedding mortars were studied. The mortars consist of a scarce binder (aggregate binder ratio ~1/3) of aerial lime of micritic appearance. The aggregate is homogeneously distributed with unimodal

grain size (300÷400 μm) and consists of subrounded granules of sparitic calcite, organonogenic and micritic limestones, quartz, and arenaceous fragments (Fig. 8). Lumps of lime putty are present. Macroporosity is scarce and regular in shape.

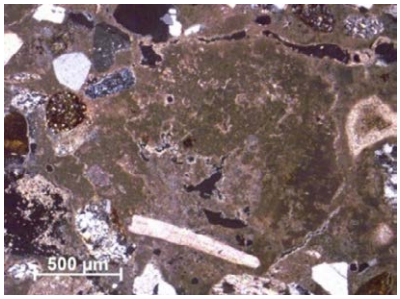
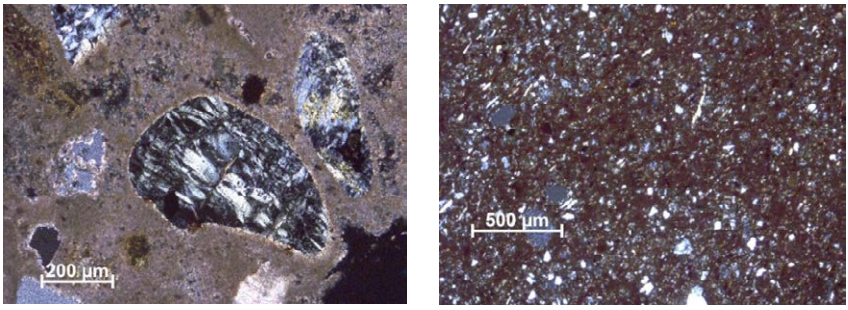



Figure 8 – Images at the optical microscope in thin section, crossed polarized light of the bedding mortar with a lump of lime putty.

***Forte di Marina di Bibbona***

The bastion bedding mortars have a medium to abundant binder (binder/aggregate ratio ~ 1/2-1/3) of aerial lime of micritic appearance. The aggregate is homogeneously distributed with unimodal grain size (300÷500 μm), and consists of subangular to subrounded grains of quartz, serpentinites, sparitic calcite, and micritic carbonate rocks. Numerous lumps of lime putty and under-burnt remnants of organogenic limestones are present (Fig. 9a). Macroporosity is scarce and consists of irregularly shaped pores. The bricks of the rampart are similar to those of Forte San Rocco and were obtained by firing an almost pure clay. The framework is almost absent (rare quartz grains of size 200÷300 μm). The groundmass is opaque, indicating a firing temperature above 800 °C (Fig. 9b). Macroprosity is scarce and irregular in shape.



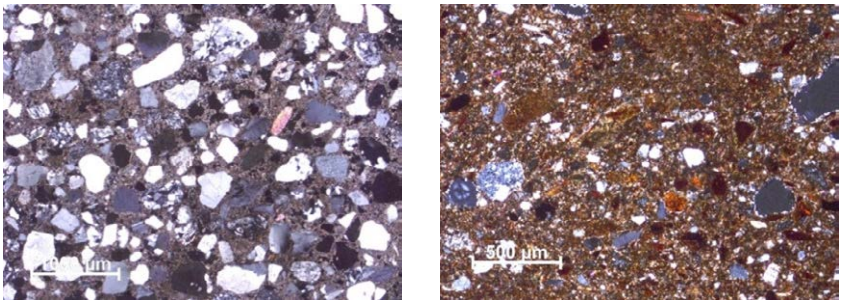

a b

Figure 9 – Images at the optical microscope in thin section, crossed polarized light: bedding mortar with presence of serpentinite in the aggregate (a); brick with opaque groundmass and the almost absence of the framework (b).

*Forte di Marina di Castagneto*

The bastion bedding mortars have a scarce binder (ratio binder/aggregate ~ 1/3-1/4) of aerial lime of micritic appearance. The aggregate is homogeneously distributed, with unimodal grain size (300÷500 μm) and consists of subangular-shaped grains of quartz, feldspars, quartzites, rare pyroxenes (Fig. 10a). Lumps are absent. Macroporosity is poor and consists in irregularly shaped pores.

The bastion bricks were obtained by firing a silty clay as indicated by a framework made of an abundant fraction of quartz and feldspars with a size of 20-40μm. The groundmass is weakly birefringent, suggesting a firing temperature below 700°C (Fig. 10b). Macroporosity is scarce and irregular in shape.




a b

Figure 10 – Images at the optical microscope in thin section, crossed polarized light: bedding mortar with an abundant aggregate (a); brick with a weakly birefringent groundmass and abundant framework consisting of quartz and feldspars (b).

## Conclusions

The study of the building materials makes it possible to relate the resources of individual territories to their use over the centuries. Indeed, buildings constructed in times when a standardised production of building materials was not yet present reveal their local identity. The Pietra Panchina, a material characteristic of the Tuscan Maremma, is present in the architectural elements of the forts of Bibbona, San Rocco and Castagneto, while in Forte dei Marmi the same architectural elements are made of white veined marble from Carrara. Also, with regard to the bedding mortars, the study of the aggregate made it possible to verify the local supply (e.g. ophiolitic grains in the mortars of the forts of Castagneto and Bibbona). As for the bricks, those from Forte di Bibbona and Forte San Rocco appear to have been made in the same production centre both because of their similar texture (almost absence of the framework) and because of their similar dimensions. while a different clay raw material appears to have been used for the bricks of forte di Castagneto.

Excluding the recently renovated forts, the others show signs of decay caused by their interaction with the marine environment. This includes the combined effects of marine aerosol and sand erosion, which can be seen in the alveolisation phenomena on the bricks. Additionally, there are other forms of decay that are a

result of the forts' new environment, brought about by the retreat of the coastline. These include biological growth. Some forms of decay are also due to human activity, such as the improper installation of stone ashlars or the destructive actions of vandals who have defaced the masonry with graffiti.

It is worth noting that some recovery interventions have successfully revitalized the forts, transforming them into public spaces. This type of approach should also be applied to the abandoned forts in order to halt the process of decay caused by the lack of necessary maintenance. This would ensure the recovery, safety, and usability of the site.

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