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Partial Collapse of a XII Century Church due to a Wrong Retrofit

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ABSTRACT: The "Santa Maria del Plesco" Church was founded in Nola, in the surroundings of Naples, between 1136 and 1158, joined to a monastery. Because of the campano-lucano earthquake in 1980, some interventions were made in order to retrofit the structure. On the 30th of January in 2001, around 5 a.m., the spontaneous collapse of the whole right masonry wall occurred. The paper describes the Church of great historical monumental importance, analyzes the collapse causes (due to human error) and illustrates the safety and rebuilding interventions.

1 INTRODUCTION

Historical constructions are usually subjected to strengthening interventions sometimes because of the time degradation and other times because of accidental events (earthquakes, foundation settlements and etc). Retrofit techniques are not always subsequent to a structural analysis and supported by an executive design. In these cases, retrofit interventions may apparently adjust some damage situations but may create other ones. In the Church object of this study, the rebuilding of the roof and the strengthening techniques that should have increased the statics of the structure have produced, on the contrary, the collapse.

2 HISTORICAL OUTLINE OF THE CHURCH

The "Santa Maria del Plesco" Church was founded in Nola, in the surroundings of Naples, between 1136 and 1158, joined to a monastery (see Fig.1).

Figure 1 : A view of the Casamarciano Castle and "Santa Maria del Plesco" Church.

During the XVI and XVII century, both the Church and the monastery were enlarged and transformed. At the beginning of the XVIII century, some restorations were carried out by the Neapolitan artist Domenico Antonio Vaccaro. In 1807, the religious order, which lived there, was abolished and the monastery was transformed in a noble building, looking like to a castle with a chapel.

The Church, made of a single nave 30 m long and 10 m wide, ends with an apse. In Figs. 2 and 3 the plan and the longitudinal section of the Church are schematically represented.

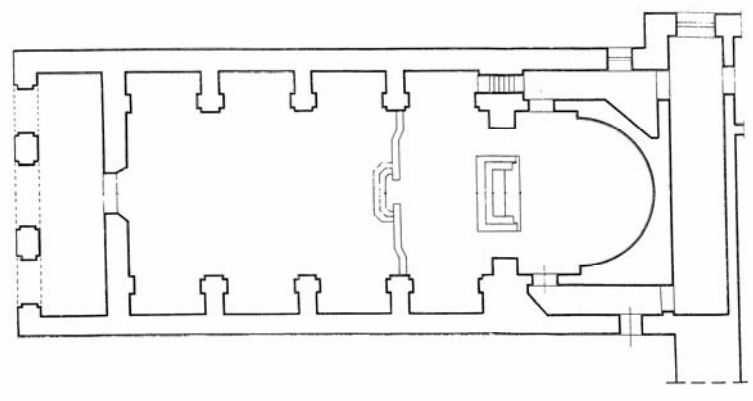

Figure 2 : Plan of the Church.

The structure was in tufa masonry and a saddle roof was sustained by a wooden truss.

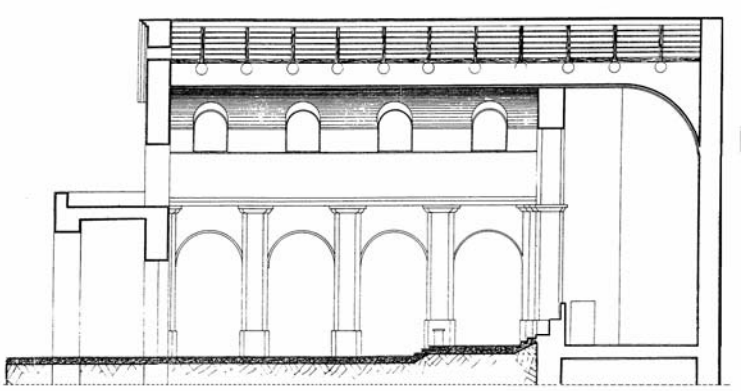

Figure 3 : Longitudinal section of the Church.

The main façade had a galilee with three big arcades and a magnificent baroque stair in the rococò style, see Fig.4.

Inside, many valuable paints in the lateral chapels, a precious wooden chore in the apse, a pulpit and a pipe organ were posed. The inlaid marble floor covered the below crypt level.

Because of the campano-lucano earthquake in 1980, on the 23rd of November, the structure of the Church had some static damages: deep cracks in correspondence of the galilee, the triumphal arch and the apse vaults occurred.

In recent years, due to the seepage of the rain, the ceiling lathwork suspended to the truss partially collapsed and the wooden beams were damaged as well.

Then, the cracking of the waterproofing layer determined some pages in the bearing walls of the nave and of the sacristy; the weakening of the masonry walls followed.

In order to retrofit the structure, the following interventions were provided:

- armed grouting in the corner sections of the walls;
- reinforced concrete beams on the top of the longitudinal walls, anchored to the masonry below through reinforced grouting;
- complete substitution of the wooden roof of the naive and the apse with new steel trusses;
- waterproofing remaking.

These works were made between the months of May in 1990 and November in 1991. The interventions were suspended before the completion of the counter ceiling of which only the bearing frames, made of light steel sections, had been installed. Neither the regulation and the protection of masonry walls from the storm water seepage was completed

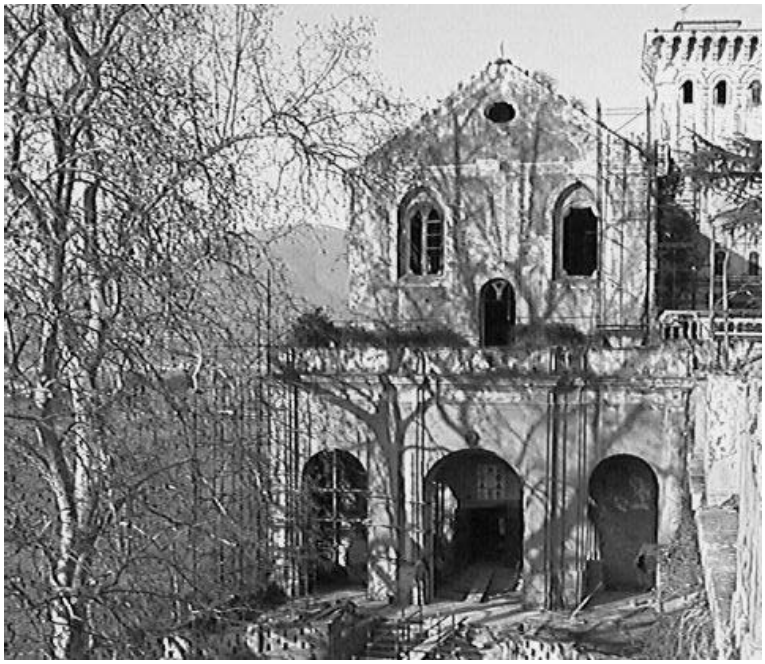

Figure 4 : Church's main façade.

3 THE COLLAPSE

On the 30th of January in 2001, around 5 a.m., the spontaneous collapse of the whole right masonry wall inside the Church occurred. (see Figs. 5 and 6).

Figure 5 : Right collapsed masonry wall

In consequence of the collapse the steel frame, which should have constituted the false ceiling

provided of fanlights underneath the new roof, remained suspended. The reinforced concrete beam on the top of the wall and the roof, made of steel trusses, were hanging up as well.

Figure 6 : Collapsed right masonry wall

In Figs. 5 and 6 the steel riveting which anchored the r.c. beam to the collapsed masonry can be noticed.

In the plan of Fig. 7, the longitudinal right part of the fallen down masonry is hatched in grey.

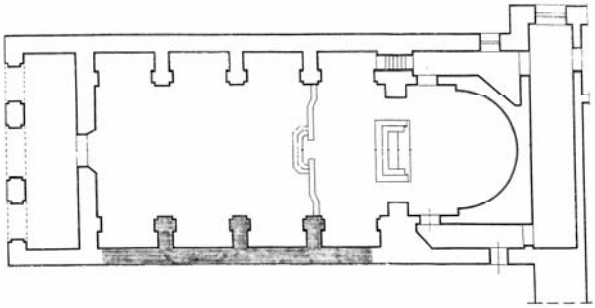

Figure 7 : Collapsed right masonry wall

Fig. 8, shot inside the roof system, shows the new steel roof truss that sustained the roof and the new r.c. beam on which it leaned on. Furthermore it can be noticed that, beneath this beam, the masonry wall was completely collapsed.

In Fig. 9, a view of the collapse from inside the Church can be observed. It is still possible to notice the scaffolds left in order to realize the counter ceiling underneath the new roof, which had not been completed.

The held inquiries have allowed to assure the dynamic of the collapse which occurred because of the falling down of the three buttresses of the right longitudinal walls of the nave which delimited the lateral chapels (see Fig. 7). In the inferior part of the masonry piers some steep sliding surfaces, along which the masonry structure had slipped, formed.

In Fig. 10 one of these surfaces, after the rubble removal, can be observed.

The huge mass of the roof structures, remained suspended after the collapse of the right nave, has determined a situation of instable equilibrium and great danger also for the workers in charge of removing the rubble and going on with the possible cribbing. Because of this risk and the needing of realizing imposing safety works, proportioned to the weight and the height of the structures remained in equilibrium, it has been decided to realize final interventions. In this way,

from one side it has been guaranteed that workers could operate in safety conditions and from the other side a remarkable economy in the costs of rebuilding has been realized.

Figure 8 : Collapsed left masonry wall

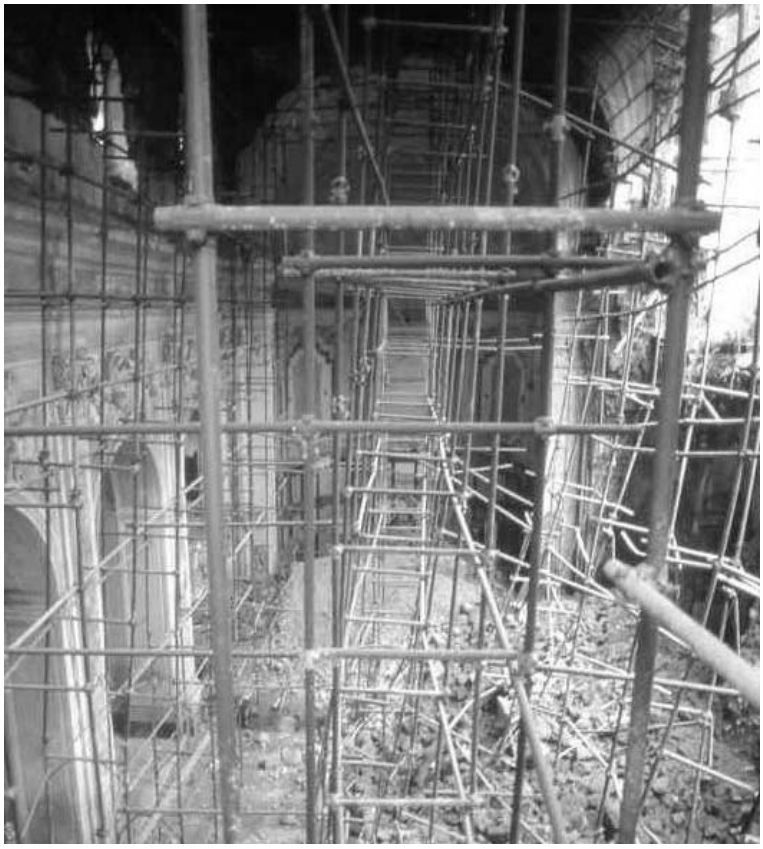

Figure 9 : Inside view of the Church.

After having removed the neighbouring rubble with extreme caution, the central buttress has been demolished until a trustable masonry surface, on which new piers could be built, was individuated. Starting from this section, a new regular masonry in squared tufa stones and cement mortar has been realized.

Figure 10 : Cracking surface of the first pier.

This wall has been erected until the height of the intrados of the roof beam in r.c. was in equilibrium in the empty space. In this way an effective cribbing of the structures in precarious equilibrium, dividing into two parts the length of the beam, has been realized. Successively, in complete safety conditions, it has been possible to rebuild the collapsed parts.

4 THE CAUSES OF THE COLLAPSE

The exam of the acquired documentation and the held inquires on site have allowed to individuate the following collapse causes:

- the restructuring works executed in 1991 had not been preceded by a theoretical and experimental check of the masonry structures of the Church, which mortar was degraded;
- the substitution of the old wooden roof truss with heavy steel truss beams had overloaded the ancient bearing walls (see Fig. 8); This load had been ulterior overburdened by the presence of a big beam in r.c. realized on the top of the masonry walls for the leaning of the new steel truss;
- in order to link up the façade wall and the new r.c. beam with the longitudinal walls, some cement mortar injections, reinforced with steel bars, had been realized inside the masonry. This intervention had determined huge damages to the masonry structures: the drilling, in fact, had induced noxious vibrations whilst the water and cement pressurized injection had caused the washing away of the ancient mortar;
- the strengthening interventions executed with cement mortar injections were absolutely ill-suited to the masonry typology the Church was made of; this masonry, indeed, was constituted of natural shapeless units of big dimensions, immerged in a mixture of lime mortar and small stones;

- the injection of cement mortar has been conducted, however, in a bad manner; after the collapse it has been verified that the steel bars, drawn out of masonry, lacked of the collar in cement mortar (see Fig. 11);
- collecting and removal works of the rainwater from the external wall of the right longitudinal wall of the Church did not exist; waterproofing works able to avoid the water seepage between the embankment and the masonry wall had not been realized as well;
- the incomplete and faulty waterproofing of the new roof had determined huge water seepage also in the internal side of the external walls.

Figure 11 : Particular of the collapsed area.

5 CONCLUSIONS

The analysis of the collapse above described and of the causes that determined it, supplies many teaching.

First of all, when an historical construction is under intervention, an analysis of its static conditions and the state of material preservation is necessary.

The cognitive inquiry on materials has to be executed through an experimental campaign with the aim of determining also the degradation degree of the mortar in the time.

The possible strengthening interventions have to be studied specifically for the structure under exam and current techniques can not been applied indiscreetly.

The eventual substitution of the roof with different and heavier structures than the previous ones need to be preceded by an efficacious design of the existing structures.

Masonry walls, specially the old ones, have to be efficaciously protected by the water seepage that can produce devastating effects on ancient mortars.

All the structural interventions on historical constructions need to be always preceded by effective cribbing.

REFERENCES

Augenti N. 2001. *Il crollo parziale della Chiesa di S. Maria del Plesco*. Napoli.