Transactions on the Built Environment vol 4, © 1993 WIT Press, www.witpress.com, ISSN 1743-3509

Static restoration of San Domenico's church at Ruvo di Puglia (BA)

C. Cherubini,[a] T. Apicella[b]

[a] *Institute of Engineering Geology and Geotechnics, Tehcnical University, Bari, Italy*

[b] *Puglia Region, Corp of Civil Engineers, Bari, Italy*

SUMMARY

The construction of San Domenico's Church at Ruvo di Puglia-a town in the province of Bari, (Italy)-was begun in 1560 and continued intermittently until the 19th century when it was finally completed.

In recent years many lines of cracks have appeared at several points in the Church, mainly on the arches and along the central vault, possibly, amongst other things, due to seismic stresses.

To investigate causes of the discontinuities, the site was excavated and drilled, special interventions were planned, some of which have already been completed while others are still in progress or are nearing completion. Essentially the work involves in consolidating the whole structure starting from the foundations on calcareous rock strengthened with cement-water injections and micropiles.

INTRODUCTION

San Domenico's Church in Ruvo di Puglia (Province of Bari,Italy), with latin cross in the single aisled nave, dates from approximately 1560, was re-modelled on several occasions over successive centuries and was subjected to major restoration between 1854 and 1875 since which time it has remained essentially unchanged.

The building is marked by a complex systems of cracking and resettling that conspicuous affects the locally-cut limestone arches , the cupola and the brickwork of the internal vaults. Damage is also beginning to show outside the Church, to the sounding walls which are of irregular shaped blocks of limestone.

The Ruvo di Puglia area is in a grade 6 seismic zone as defined by Italian Law n. 64 of 6 February 1974 and the Ministerial Decree of 24 January 1986.

A consideration that led to a preliminary survey of all the building's load bearing structures being carried out, from the foundations upwards.

DESCRIPTION OF CRACKING FISSURES

The cracking of greatest concern inside the Church is that to the four arches that support the dome, positioned at the intersection of the central nave and the transept have become visibly damaged, particularly the keystones, with gaps of the order of several centimetres. With time this has brought a variation in the static functions of the load bearing structures of the building from the original pillar-arch system with the load being transmitted to the foundations to one of semiarches and pillars acting as brackets (fig.1).

The cracking seems to be basically symmetrical, with reference to the four pillars examined, even though the external plumb line of the first pillar on the right is more marked than the other three.

The section of the exterior of the Church relative to the above-mentioned right pillar shows not only damage to the interstitial mortar but also to the stonework itself.

Cracks and discontinuities have also been found in the masonry of the foundations that were constructed from irregular shaped limestone blocks and extend to a depths of four to five metres.

GEOLOGY AND GEOTECHNICS

The foundation rocks under the area covered by the Church, as sampled both by digging and drilling, are lastriform detritic limestone from the Cretaceous (Bari Limestone) and,subordinately Pleistocenic alluvial deposits.

Red soil levels and/or lenses are often found in the limestone formation .

Excavations have uncovered the structure of the foundations of the four pillars that support the dome and also the corresponding underlying rocks.

Four other geognostic investigations were carried out to take samples for visual examinations and laboratory tests

The following is a summary of some of the results obtained from samples extracted:

-Average rugosity profile of the rock between 5° and 6°with J.R.C. purameter values of 8-12.(Barton 1977)

-Average specific weight of the rocks mass equal to - 2.5 KN/mc.
-Simple compression strength of the rock, evaluated using a Schmidt hammer in contact with the foundation level, varying from 27 to 63 MPa.
-RQD varying from 27 to 44 % .

The laboratory tests on the 4 cylindrical samples extracted during the investigations, though not necessarily representative of the rock mass , have given values varying from approximately 31.5 to 97 MPa, with deformability coefficient between 17.8 and 36.2 GPa.

The total percentage recovery was high and varied from 85 to 93 % .

The geomechanic scheme of reference adopted was that of Bieniawski (1976).

Without going into a detailed explanation of methods used,the following values of the various indexes were obtained:

1-Intact Rock Strength	4 - 7
2-RQD	8
3-Joint spacing	15 - 20
4-Joint conditions	10 - 20
5-Hydraulic conditions	10

Giving a total maximum point score of 65 (good rock)
Giving a total minimum point score of 47 (fair rock)

Corresponding to this point score it has been possible to obtain a measure of cohesion value and the friction angle of the mass, as well as the relative deformability coefficients that, obviously, differ from those found from samples in the laboratory.

More specifically the fair rock has a cohesion value of 100 to 150 kpa and a friction angle between 30° and 35° , whereas the good rock can be said to have cohesion values of 150 to 200 KPa and friction angles between 35° and 40° .

For the rock in question, it is possible to assume c = 150 KPa and Ø = 35°, with a deformability coefficient from 10 to 35 GPa. (Serafim and Pereira 1983).

Therefore values were estimated of an allowable bearing capacity greater than 800 KPa (Bowles J. E. 1982).This under centred and vertical load conditions

Even the consideration of a certain eccentricity and inclination of the loads for the foundations, still lead to a satisfatory check of the contact passures of the foundations on the rock mass.

SUMMARY OF OPERATIONS CARRIED OUT

Detailed observations of the foundations, made

Transactions on the Built Environment vol 4, © 1993 WIT Press, www.witpress.com, ISSN 1743-3509

possible by excavations carried out, have shown that the damage to San Domenico's Church is only to a small ascribable to the geological aspect and to the geomechanical characteristics of the base rocks.

The insufficient geometric characteristics as well as the resistance of the same foundations would seem to be much more influential. These foundations, which as primarily mentioned , extended to a depth of 5 m., interact in some cases, in ways that are not always identifiable, with sections of walls and foundations from earlier years.

It therefore proved necessary , prior to working on the arches and vaults, to procede with an effective connection of the pillars , foundations and rocks to be carried out in several phases

The first phase consisted of the stitching of the walled structure of the foundations using 30 mm bores reinforced with 12 mm steel rods of improved adherence and successive injections of water-cement mixture at high pressure. In addition the work was carried out so as to bird the foundations with reinforced concrete walls , in which case the direct observation of their consistency became necessary. (Fig. 2).

A succesive phase involved the sinking of tubfix micropiles (Mascardi 1968) , by means of a boring of Ø 100 mm diameter and a length of 10.00 m. The boring was and followed by the putting in pluce in the bores of reinforced tubes of Ø 73 mm, thickness of 8 mm,(steel Fe 510) equipped in the bulb zone with cuff valves every 0.50 m for the repeated injection of water-cement mixture at high pressure.

In this way an improved connection was obtained between the pillars and the rocks through the foundations as well as the absorbtion of the added load linked to the filling of the cavities in the pillars and relative foundations.

Careful calcolations and executive considerations estimate eight as the right number of micropiles for pillar. (Figg. 3 and 4)

Other operations were planned after reestablishing continuity in damaged load bearing structures , in particular the pillars , vaults and dome, as well as complying with the regulations of the previously cited anti-seismic law.

To date the following additional work hes been carried out:

- Rotational drilling of the foundations of the pillars in the central nave and apse, with successive deployment of extra-adherent steel bars and injection of water-cement mixture at the appropriate pressure to reconstitute the continuity of the foundations.
- Rotational drilling of the pillars that support the dome followed by insertion of inox-steel bars and

subsequent injection of water-cement mixture at the appropriate pressure.

- Stitching of the arches with injection of epoxy resin and relevant reinforcement with inox-steel bolts carried out in such a manner as to constitute a suitable " space-lattice " in thath it gives back continuity to the same and absorb the residual cracking phenomena.

As yet to be carried out is the consolidation on the pillars in the central nave , using the same methodology employed for the four other pillars , and the consolidation of walls and foundations by means of pouring cement, water and sand.

Non-structural work (replastering ,damage repar, painting etc..) have been also carried out to restore the Church to it's original glory.

BIBLIOGRAPHY

- PELLEGRINI V. (1970). La chiesa di San Domenico in Ruvo. Mezzina - Molfetta -
- ZEZZA F. (1975).Le facies carbonatiche della Puglia ed il fenomeno carsico ipogeo. Geologia Applicata ed Idrologia vol. X parte I pp. 1-5 - Bari -
- MASCARDI C. (1968). Micropali di elevata capacità portante. Rivista Italiana di Geotecnica n.4,10-25
- LEGGE n. 64 del 2 Febbraio 1974 .
- DECRETO MINISTERIALE del 24 Gennaio 1986 .
- BARTON N.R. , CHOUBEY V. (1977). The shear of rock joints in theory and practice.Rock Mech 10,1/2,1-54
- BIENIAWSKI Z.T. (1976). Rock mass classification in rock engineering. Proc. Symp." Exploration for Rock Engineering" 1, 97-106. Balkema, Rotterdam.
- SERAFIM J.L. , PEREIRA J.P. (1983). Considerations of the Geomechanics Classification of BIENIAWSKI. Proc. Int. Symp. on Enang. Geol. and Underground Constr., Lnec, Lisbon.
- BOWLES J.E. (1982). Fondation analysis and design. International Student Edition. Mc Graw Hill.

Transactions on the Built Environment vol 4, © 1993 WIT Press, www.witpress.com, ISSN 1743-3509

FIG. 1 : Damaged arche before intervention.

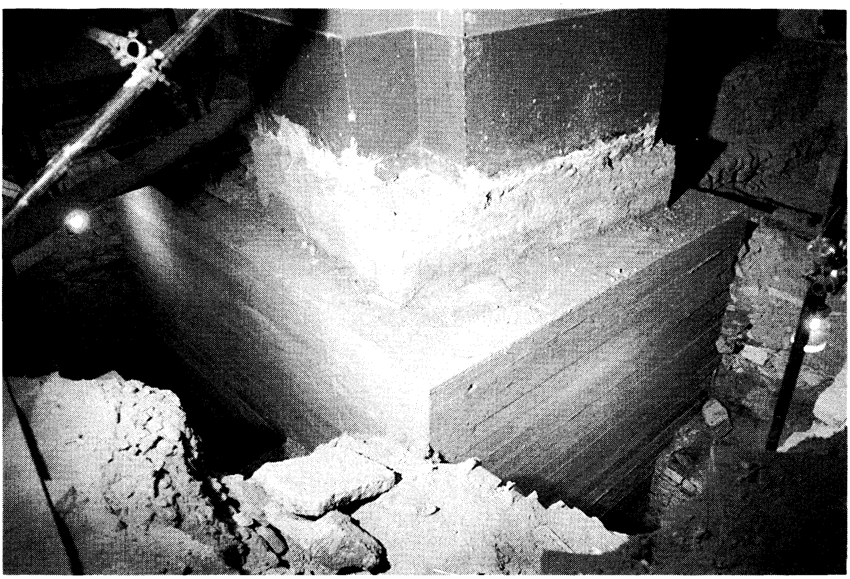

FIG. 2 : Foudation of pillar with a reinforced concrete wall.

Transactions on the Built Environment vol 4, © 1993 WIT Press, www.witpress.com, ISSN 1743-3509

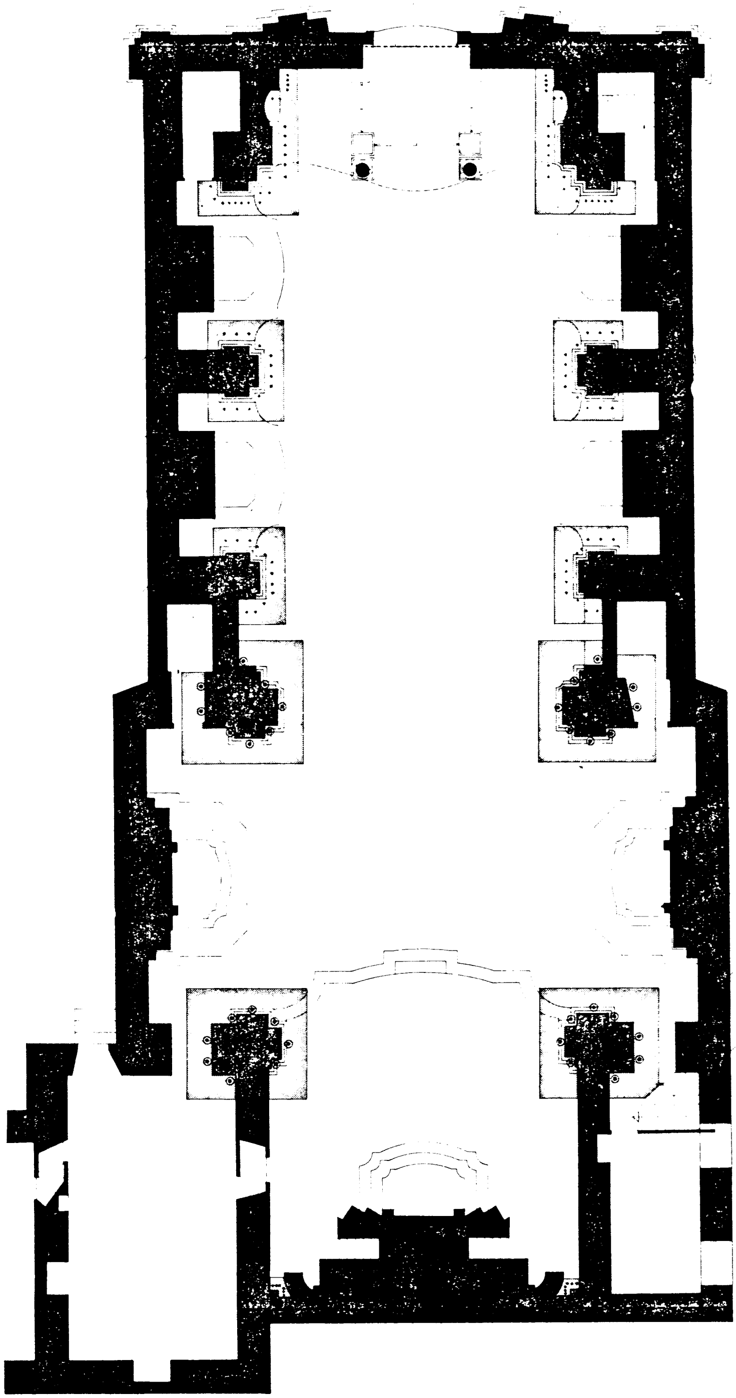

FIG. 3 : Plan of the Church.

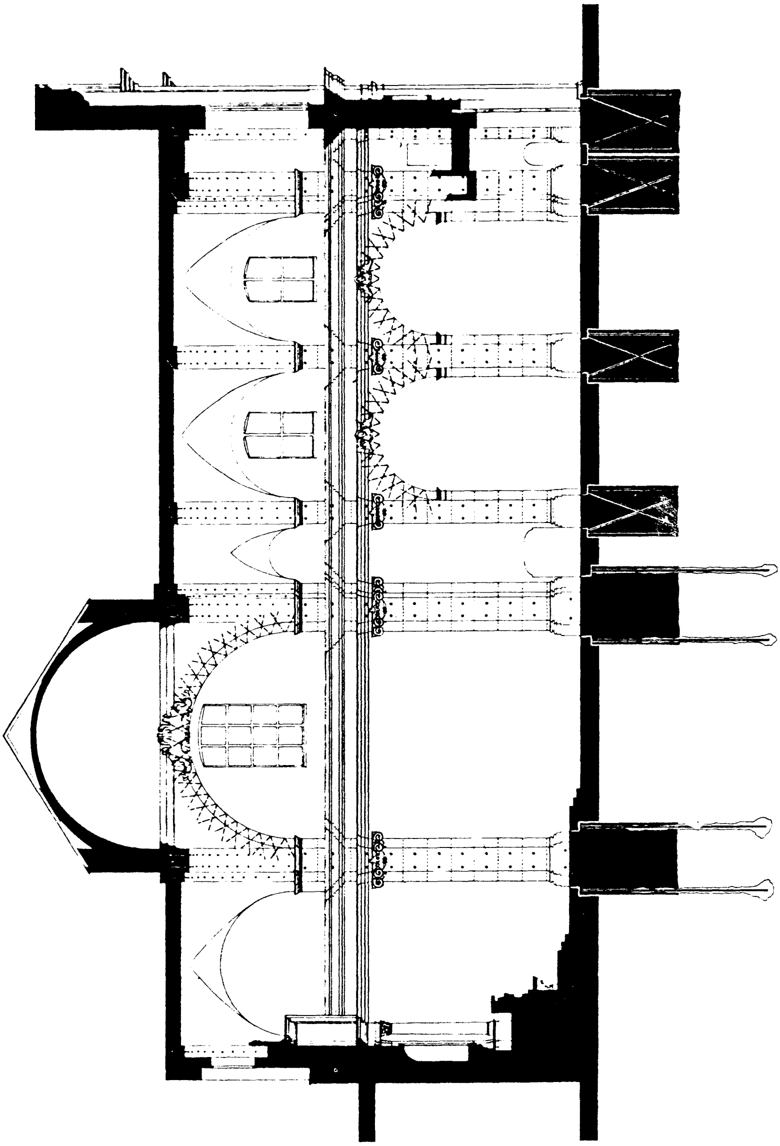

FIG. 4 : Section of the Church.