

METHODS FOR DATING HISTORICAL BUILDINGS AND VERTICALITY CONTROL OF THE BARONALE PALACE AT AVIO'S CASTLE (TN)

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ABSTRACT

The Laboratorio di Diagnostica per la Conservazione e il Riuso del Costruito, Dipartimento di Progettazione dell'Architettura, at the Politecnico di Milano, has cooperated with F.A.I. (Fondo per l'Ambiente Italiano) on the diagnostic analysis for the conservation project of the Baronale Palace at Avio's Castle (TN). Professional advice was part of a wider preliminary survey that involved all the preventive analysis' various aspects; this analysis, aiming at the conservation and re-use project of the Baronale Palace, was carried out by Architects Campanella and Tessoni's Study. The survey of Avio's Castle was based on the analysis of direct and indirect sources, useful tools for the comprehension of the building itself, taken within its historical evolution, as well as its structure and materials' consistency. Thanks to the archive research carried out, and to the method used for dating historical buildings (stratigraphy, mapping and identifying the different wall construction techniques, chronotypology of apertures) we were able to understand the composition of the building's construction in all its complexity.

The mapping of walls led to the identification of walls' continuity/discontinuity, of tothing/non tothing of partitions and dividing walls, of doors and windows, of eventual holes, pipes and chimney flutes and of stratigraphic facts that suggested the "critical areas" we had to check within the conservation project.

Material data and the geometrical-formal structure aspects we surveyed hold considerable information and attest the building's past history, as well as giving useful hints and indications on the methods to apply for a correct approach to the project.

The survey of structures – showing the out of plumbs - the different construction techniques, walls' discontinuity and the mapping of cracks pointed out the walls that needed monitoring, through a verticality control carried out using the total station. This control was carried out on Baronale Palace's south and east elevations, with the installation of five survey stations. Seven sets of readings have been done, throughout a period of eighteen months, one every three months; this way we achieved all the partial, total, and annual variations necessary to monitor the analysed walls' shifting.

1. INTRODUCTION

F.A.I. (Fondo per l'Ambiente Italiano) – a private non profit Foundation which aims at Italian artistic and environmental heritage's conservation, protection and valorization – is involved in the restoration and re-use of Baronale Palace at Avio's Castle; it has therefore charged the "Diagnostic Analysis. Conservation of Baronale Palace at Avio's Castle" to the Laboratorio di Diagnostica per la Conservazione e il Riuso del Costruito*. The task strictly aimed at the conservation and re-functioning project of the building, carried out by the C. Campanella and M. Tessoni Associated Architects' Study in Crema (CR).

The study consisted in identifying the various construction phases for both the palace and the castle's fortifications in the whole, and also in the control of the variation in the inclination of the palace's walls on the south and east elevations, carried out through the use of a topographic station. The controls were necessary due to the visible problems regarding the building's walls' swelling convexity, the presence of many holes and the lack of tothing between external walls and internal dividing walls.

The whole work was "based" on the geometric survey and on the color photographic draughting of Baronale Palace's external and internal fronts, both carried out some years ago by the same Study of Architects. The photographic survey has been planned so as to assure an optimal survey of fronts (despite the not easy positioning of shooting spots) and also so as to work with the digital images at the same time, at a minimum resolution of 240 dpi; the digital images have been later realigned using the

realignment software.

2. MAPPING OF CONSTRUCTION PHASES: BUILDING'S STRATIGRAPHY, CHRONOTYPOLOGY

The research* carried out at Avio's Castle was based on the analysis of *direct sources* which were used to comprehend the building's historical evolution and consistency of the construction materials used throughout the years. Thanks to the direct dating methods - stratigraphy, typology of wall construction, chronotypology – and to the non-destructive visual analysis carried out, the composition of the construction has been identified, in all its complexity: material data and the geometrical-formal aspects of the structure attest its past history and hold considerable information. Comparing the results of the direct reading with the analysis of *indirect sources* (documentation, cartography, iconography and bibliography), allowed us to attest the matching of results and to identify new aspects to survey. The methodology adopted was carried out in a peculiar way: the investigations went from the detailed phase (Baronale Palace) to the general one (the fortifications around the castle).

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Fig. 1. Example of table showing analysis of internal walls' stratification; south wall, upper floor.

The mapping of walls led to the identification of walls' continuity/discontinuity, of tooting/non tooting of partitions and dividing walls, of doors and windows, of eventual holes, pipes and chimney flutes. Moreover, this mapping also highlighted the various construction techniques used for the walls and the different levels (floors and roofings) even due to the permanent placing of horizontal structure's beams (presence of sockets).

The first phase of the work led to the compilation of "Tables of stratigraphic analysis" for each external and internal wall, and to the registration of both wall construction techniques and apertures' details (doors and windows) of the Palace.

The detailed analysis of each wall (stratigraphy, wall construction techniques, chronotypology, horizontal structures' levels) has allowed – after a careful elaboration of data – the comprehension of the whole building's general physical relationships. Especially observing the external walls has made the historical-construction phases clear, and has confirmed the detailed mapping's results on each single internal recesses most of which are plastered and frescoed.

The construction *phases* have also been represented by defining the *horizontal sections* – representative of the various levels (soffits, covers) carried out through time – and the *plans* which clarify the construction's general use.

Therefore, the final interpretation of the stratigraphy was carried out by comparison, between the external and internal elevations, in order to identify the correspondence of the various *levels*, that are the horizontal structures' heights and the different traces taken in height, which led to the present configuration of the building. The stratigraphic analysis carried out has allowed to identify the *phases* corresponding to the different construction techniques, which can be grouped within seven main *activities*; the latter exhaustively describe the building's historical evolution through time, from its origins to present day, also considering the reinforcing and restoration works carried out in the seventies. After the appraisal of both stratigraphy and wall construction techniques, a chronotypology analysis of the building's apertures followed. A number of tables showing the internal and external elevations of each aperture (doors and windows) were prepared, integrating the typological-formal description with stratigraphic data. Hence the physical relationship between the apertures and the walls onto which

they placed (same period, before or after) have been identified and placed within the stratigraphy.

The analysis carried out with the direct dating method was compared to the selected iconographic and photographic documents. Another source of information which helped to precisely date the recent restoration works of the building consisted in the interpretation of the archived photos. A hypothesis of the fortifications' development phases was done, also based on the direct observing of the fort's perimeter walls; the stratigraphic relationships between the different sections of the walls, the different portal accesses found in the walls, and the physical relationships with the walls, have been identified. The building phases of the whole fortified construction have been compared to the periods of construction of the Palace.



Fig. 2. Example of table showing analysis of perimeter walls' stratification; northern walls.

It is the building itself that gives, through the traces and patina formed during the years, the accurate methodological indications for a correct approach to the project. Identifying the tooting and non tooting, the continuity and discontinuity between the walls allows to physically represent the building's static stability and instability, which need to be consulted for any intervention on structures to be carried out.

The re-use of the spaces within the castle, as foreseen by F.A.I., requires knowing the building's level of planning restrictions and freedoms regarding all the possible changes that could be carried out on the building itself; especially in case of new openings of doors and windows or of the positioning of new ceilings, the stratigraphic analysis' results will be used, in order to identify the best areas to be implemented for the re-use, identified through the traces of interventions made (marks, beams' and common joist's positioning holes, etc.). This methodology doesn't aim at resuming the hypothetical original disused asset, but expresses the need to thoroughly understand

the building's static structure and its constituent materials, and to protect the integrity of remains and events that took place through time within all their complexity.



Fig. 3. Example of table showing analysis of perimeter walls' stratification; northern and southern walls.

3. VERTICALITY CONTROL: MEASUREMENT METHODOLOGY, INSTRUMENTS USED, RESULTS ACHIEVED.

The survey of structures – showing the out of plumbs - the different construction techniques, walls' discontinuity and the mapping of cracks pointed out the "critical areas" that needed monitoring, through a specific verticality control project carried out using the *total station*. This control was carried out on Avio's Baronale Palace's south and east elevations. For this purpose, five stations in reinforced concrete have been installed (four on the south front and one on the east one) – using the adequate slabs – to make sure the topographic tool is centered. Fixed markings (small centers) have been set up onto each stations' verticality, mounted on small supports, displaced by a few centimeters so as to match with the corresponding station on ground, and so as to determine the zenith angle and distance, using the topographic instrument.

The topographic instrument is a high precision tool, provided with an automatic** verticality indicator and a biaxial compensator, fixed rigidly on the slab; it allowed us to have a stable vertical reference mark necessary for calculating its distance from each fixed marking placed on the support. Calculating the difference between these distances in time – seven sets of readings have been done, throughout a period of eighteen months, one every three months **; this way the partial, total, annual variations necessary to monitor the displacement of the walls, have been achieved. Special attention was paid to the measurement of vertical angles, distances and temperatures, so as to ascertain that variations are calculated at a margin of error of only 0.2-0.3 mm.

Therefore the control has involved 22 points disposed in 5 sections set up with fixed markings (small centers) strictly connected to the walls at different heights. On these points' heights 5 small pillars in reinforced concrete have been built at

ground level, with adequate foundations, where some 5/8" width connection slabs have been placed, purpose-made to rigidly fix the topographic instrument (integrated station).

This way, the topographic instrument is always connected in the same exact place for each different control carried out. Once the instrument has been placed – accurately centering the spherical, toric and electronic bubble, it's possible to measure the inclined distance going from the center of the instrument to each small center, the instrumental height in an accurate way using callipers, and the zenith angles, in left circle CL and right circle CR positions, respectively. These measurements have been repeated at least twice, changing the instrumental height by working on screws so as to get a series of independent measures. With simple trigonometric formulas, the D_0 distance between the instrumental vertical and each small center was calculated. Measuring this distance every three months for each small center, we got the partial, total and annual variations. These variations, through time, give the size of the analysed walls' displacement.

To define zenith angles and distances, we used a Laser TOPCON GPT-6003 Integrated Station, which has a 1,0 mgon total angular precision (s.q.m. based on DIN 18723) with minimum reading of 1 cc (0,1 mgon), 2 mm + 2ppm D distance precision, provided with a biaxial compensator and an automatic zenith indicator, 30 enlargements, 2,5" resolving power. To carry out almost-vertical zenith mappings, the instrument was provided with a "zenith" eyepiece.

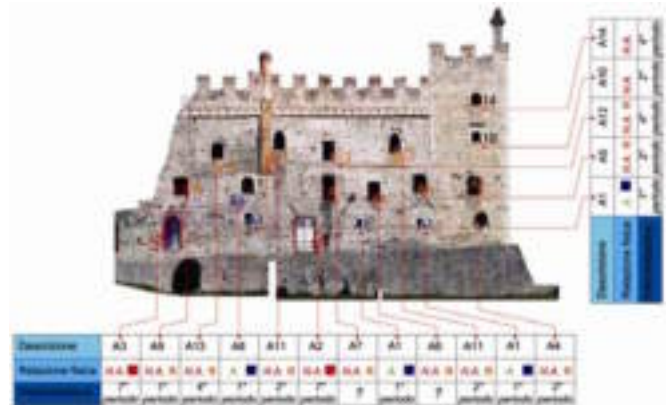


Fig. 4. Legibility of stratification and chronology; southern external elevations.

The measurement methodology adopted, the special attention paid to it, as repeating measurements in conjugated positions, and as the topographic instrument's "forced" centering, allow to minimize measurement errors and to consider their estimates around 1-2 tenths of a mm. It must also be pointed out how both internal and external temperatures to the building have been taken for each station, estimating a +/- 0.1 C°.

The results of the seven measurement controls regarding the five stations, carried out every three months, have been reported in charts. In particular, the first control's results, dating 12/19/2002, have been considered as a reference for the following variations' calculation.

** The controls carried out throughout a period of 18 months every three months have been performed on the following dates: 12/19/2002, 03/12/2003, 06/18/2003, 9/16/2003, 12/15/2003, 03/10/2004 and 06/29/2004.

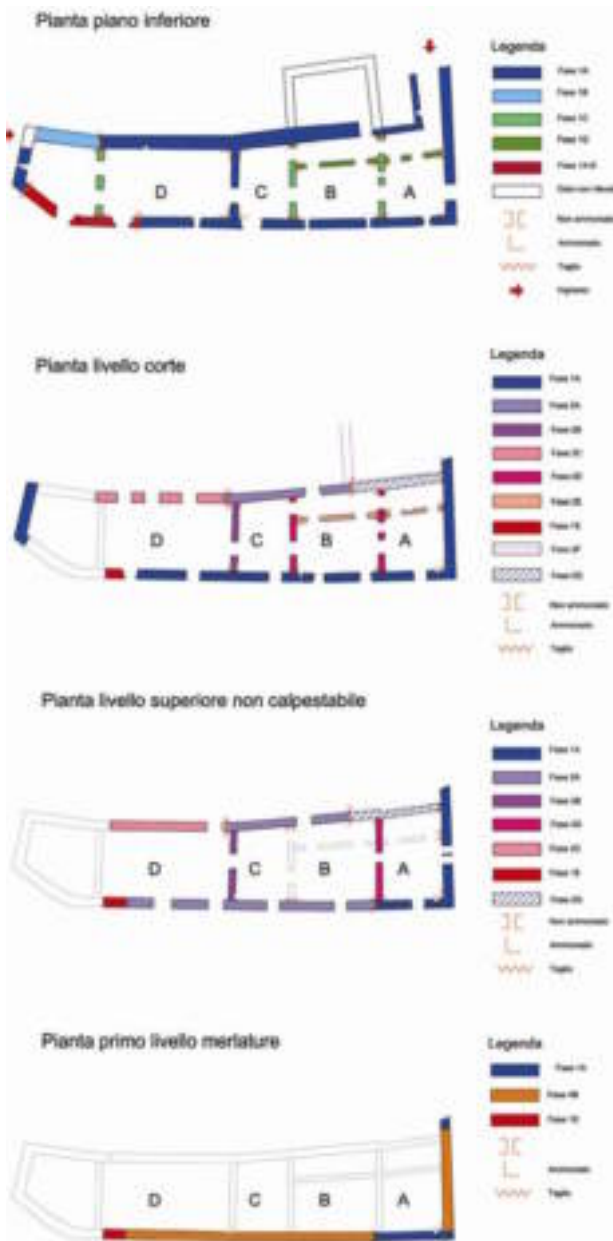


Fig.5. Legibility of stratification of walls; plans for different levels.

In the various columns of the charts, all essential elements have been reported: point's name, height from the ground to the small center (H seight), CL and CR readings and average, calculation of the horizontal distance between the instrumental vertical and the small center (reading), and at last, the two readings' average. The latter is considered within the various controls for the variations' calculation. In general, on the basis of the survey scheme, for each zenith angular reading greater than the one taken on a different day, there's a corresponding shifting of walls towards the outside, while it's exactly the opposite for smaller zenith readings. The size of the partial, total and annual variations are also analytically reported within charts.

Partial Variations (P.V.)

The P.V. value determines the shifting of each small center from its previous position, that is, resulting from the previous

control. From the analytic charts' analysis and, most of all, from the graphic charts, it's easy to see the effect of cyclic phenomena connected to thermic factors. In fact, the greater the temperature variation, the more evident is the corresponding shifting. This phenomena appears greater in station n.3 and even greater in station n.1, due to the fact that the wall lacks of limits on the top. The size of the P.V.'s shiftings are in general very significant.

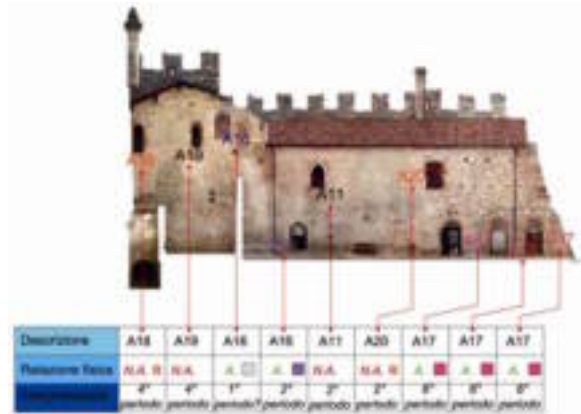


Fig.6. Legibility of stratification and chronology; northern external elevations.

Total Variations (T.V.)

T.V.s result from the algebraic sum of the previously said P.V.s, therefore, the previously mentioned cyclic phenomena can still be found but is less evident.

Annual Variations (A.V.)

The A.V. value determines the shifting of each small center from its previous position, that is, resulting from the previous year's control. Since both the environment and temperature conditions (variations in the range of 2 or 3 C°) result from these measures, the corresponding A.V.s can be considered as practically purified of the effect of the previously mentioned cyclic phenomena. This is also strengthened by the residual values found, which are quite low, especially for each station's lowest points, except for station n.1, where the highest point had a significant residual value. Moreover, comparing positions n. 1,2,3 's shifting lengthwise, at the highest points (south side of the castle), A.V.s' residual values of opposite sign are found, suggesting that a distorsion is probably taking place (regarding this matter, a distorsion on the upper part of the castle's south wall can be easily seen). In order to confirm this effect, it would be necessary to monitor the walls for a longer period of time.

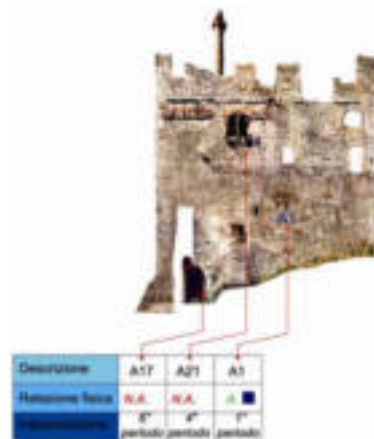


Fig. 7. Eastern external elevations

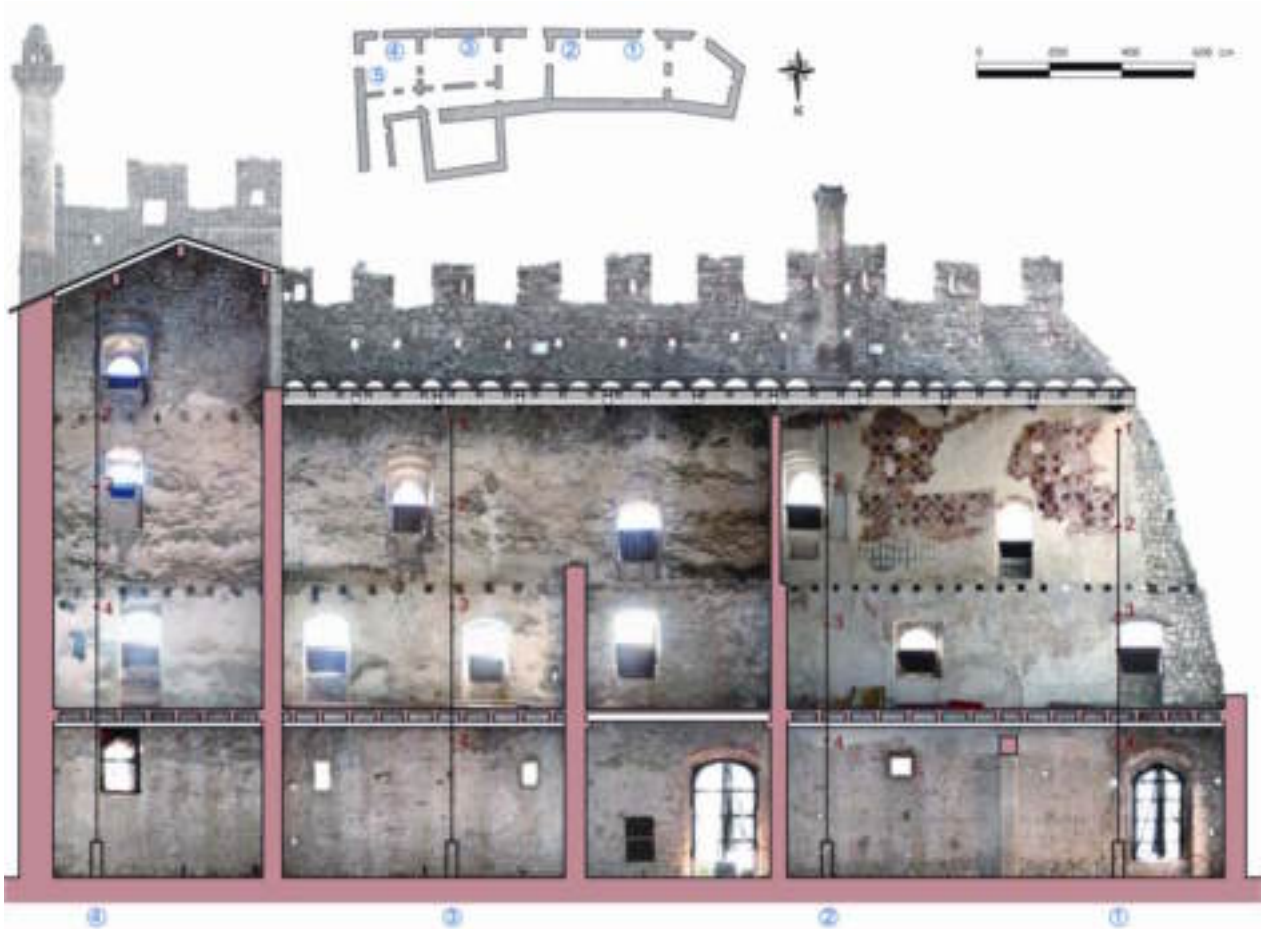


Fig 8. South wall's section: setting of stations 1,2,3,4



Fig.9. East wall's section: setting of station 5.

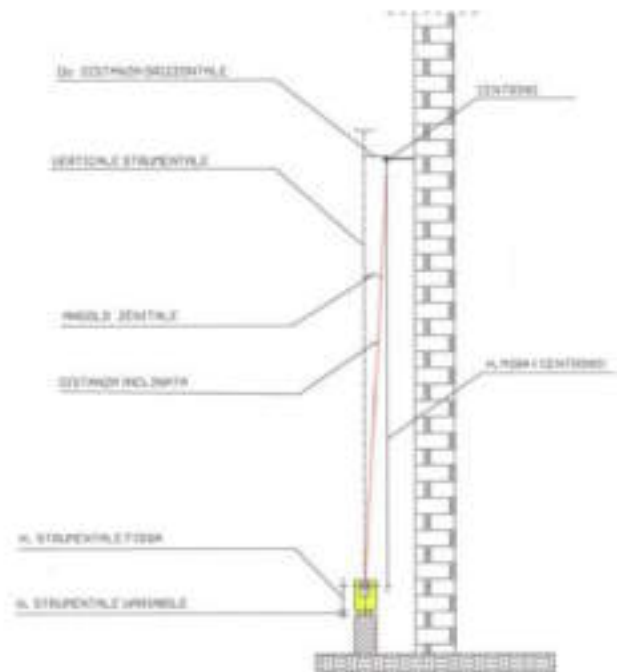


Fig.10. Verticality control survey's outline.

4. CONCLUSION

The complexity of the work carried out doesn't involve only the simple improvement of knowledge and of the building's comprehension; the survey of material data and of the geometrical-formal aspects of the structure attest the building's past history and hold considerable information; they also give useful hints and indications on the methods to apply for a correct approach to the intervention project.

As a matter of fact, all the information resulting from the mapping carried out, correlated with the direct measurements of the cracks, with the monitoring of walls carried out by using a georadar and sonic equipment, let us achieve detailed and exhaustive answers to all the problems present.

The clearness and completeness of the preventive diagnostic outline, further strengthened by chemical-physical analysis of materials, has allowed the correct performing of a specific conservation and structure improvement project, directly working on partitions and setting metal supports (tie beams, rafters, beams, centerings) to protect the building's total statics.

CASTELLO DI ALA-AVIO 1° CONTROLLO 19/12/2002													
POSTAZIONE N° 1													
PUNTO N°	E. MUR		ANGOLO D'INFIACE		ipso		Lattine		E. MUR		ANGOLO D'INFIACE		MEDIA M
	SE	CE	CO	MEDIA	M	M	CE	CO	MEDIA	M	M	M	
1	11,2624	1,262	391,939	1,262	8,1991	11,262	1,262	391,939	1,262	8,1994	11,262	1,262	391,944
2	8,7581	1,2136	391,939	1,2136	8,2082	8,7581	1,2136	391,939	1,2136	8,2077	8,7581	1,2136	391,939
3	8,1991	2,1115	391,939	2,1115	8,2075	8,1991	2,1115	391,939	2,1115	8,2075	8,1991	2,1115	391,939
4	2,7991	8,6798	391,939	8,6798	8,2082	2,7991	8,6798	391,939	8,6798	8,2082	2,7991	8,6798	391,939

Data: 19/12/2002
 Tempo M.C.: 11
 Tempo S.M.C.: 13

Fig. 12. Annual variations' (V.A.) chart.

