LASER SCANNING IN OSTIA
A COMPARATIVE STUDY OF ACCURACY OF THE DRAWINGS IN 1950S AND FIELD SURVEY ON TALL STRUCTURES

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ABSTRACT:
In 2008, the field survey applying the laser scanning technology has been carried out at Ostia. The evidence for following results is based on the preliminary analysis of more than 150 stations, which is now being subjected to detailed analysis of the structure. The first part deal with a comparison between the drawings in 1950s and the result of our laser scanning in 2008 and analyze the causes of their failures. Calza, who applied the aerial survey in 1940s to create the first general map of Ostia, may draw the map by the simple way in which the street line may perhaps be traced from an aerial photograph. Consequentially his map includes considerable divergence. However the Decumanus Maximus in Calza's map was almost exact to the distance with a possible error 3 m (This is less than 0.1% errors). The second part deals with a continuing tilt that has brought the top of the walls 5cm out of true vertical in Capitorium and buildings facing Via di Diana and Via dei Balconi. Below the podium of Capitorium, large movement may be taking place in very slow motion, however there is no evidence of sinking at present. Where the cracks are observed on the surface, the high walls without openings do not support the weight of the roof, but is still resisting against wind loadings. In the front walls of buildings facing Via di Diana and Via dei Balconi tilting inward to the block, large movement also may be taking place. On the other hand a front wall of Casa di Diana standing on the true vertical is reinforced on the exterior by a wall buttress at the corner tilting inwards. The fact that there is no crack between the front wall and the buttress at the corner means that that buttress belongs to the later reinforcement.

1. INSTRUCTION

In Ostia many researchers share the sense of disorientation, which was aggravated by the general lack of plans and maps in the text. Extracts from Calza's maps in 1953 (1:1000 in scale) are available at the back of his book published in 1996 (Calza 1996) (Fig. 1), but they are hardly referred to in the text and they are not made easily accessible. And sadly detailed elevations are largely absent.

In 2008, the field survey applying the laser scanning technology has been carried out at Ostia. We introduce an advanced measuring method: 3D scanning system, in which the object can be described as the aggregation of dots having three dimensional coordinates. The measuring of whole of Foro area has been completed within this season, and of east side of the Decumanus Maximus from Via Epagathiana. The Casa di Diana and Capitorium has also been measured in order to detect the movement of high-rise buildings' wall. The evidence for following results is based on the preliminary analysis of more than 150 stations (Fig. 2), which is now being subjected to detailed analysis of the structure.

With the general map drawn by Calza, this article offers interim but useful comparisons across Ostia in the middle of the last century: in the features of errors in measurement.

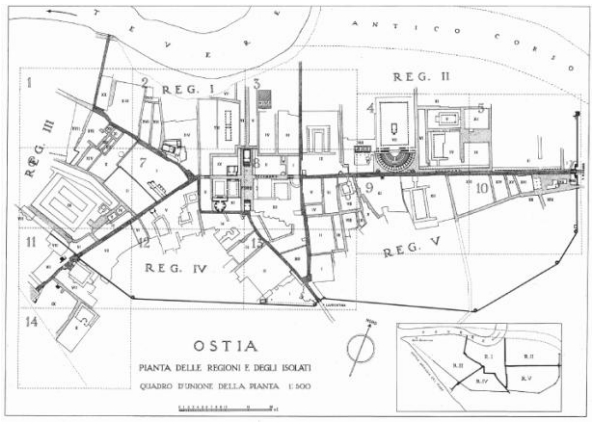

Fig. 1 Map published in 1953 (Calza 1953)

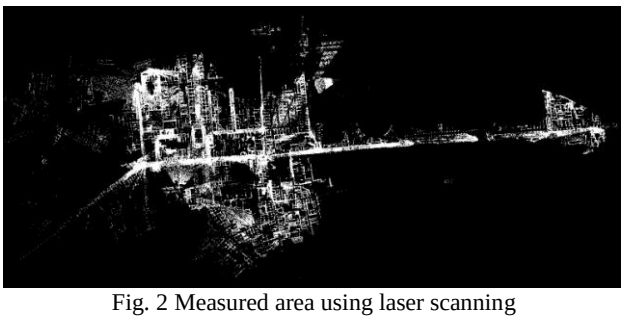

Fig. 2 Measured area using laser scanning

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2. CONPARISON WITH THE MAP OF G. CALZA

"Scavi di Ostia Ⅰ Topografia Generale" was published in 1953. There are 15 maps drew by Calza, which consist of a general map (1:500 in scale) and 14 divided parts of the whole area. Comparing of the general map with our scanning data, some errors are observed as below.

1) There is 0.1% errors of distance on the Decumanus Maximus .
2) In the middle of the map; the Terme del Foro in his map deviates increasingly westwards and northwards, and Via di Diana deviates northwards (Fig. 2).
3) In detailed comparison with scanning data, Via di Diana in his map deviates westwards (Fig. 3).
4) Regione around the Bibio di Castrum, where the Decumanus Maximus is at an angle of 23 degree to east, deviates south-eastwards (Fig. 4).

Taking 0.1% errors of the whole general map in consideration, divergences of 2)the Terme del Foro and Via dei Diana are not negligible quantity probably because of methods of measuring in 1950s. In 1950s, there were generally 2 methods of measuring; using cordage and aerial survey.

2.1 Aerial survey

When a map is traced from an aerial survey, there could not be any divergences generally. However surveyors had to pay attention to trace it to draw map. We showed that there is divergence between our scanning data and Pompeii map drew by Eschebach in 1950s (Fig. 6). The wrong street line may perhaps be traced by tracer's hand from an aerial photograph and he may follow the long shadows of the high remained walls (3D-ARCH2007). Because there are many high-rise buildings in Ostia, such as 2) the Terme del Foro and 3) buildings along Via di Diana, Calza may trace shadow line in the same way.
"Atlante di Ostia antica" includes a map, which is traced from an aerial photograph by Manucci. This map is traced from aerial photograph taken in 1995, which has good resolution, so surveyors traced correctly (Fig. 7). On the aerial photograph in low resolution in 1944 (Fig. 8), so it is difficult to distinguish high remained walls from its shadow. Therefore Calza may trace the wrong line. For example, 2) the Terme del Foro in his map deviates north-westwards and this line coincide with a location where the shadow of the high building lay across. As well as this, 3) walls along Via di Diana in Calza's map deviates north-westwards because of shadow. Around Via di Diana, north buildings is higher than south ones, and the shadow of the buildings may lay across longer than south one (Fig. 9). Therefore there is considerable divergence in Via di Diana.

Fig. 3 Divergence between Calza's map and scanning data (in red) on the Terme del Foro (a present vegetation map in yellow green)

Fig. 4 Divergence between Calza's map and scanning data (in red) on Via di Diana (a present vegetation map in yellow green)

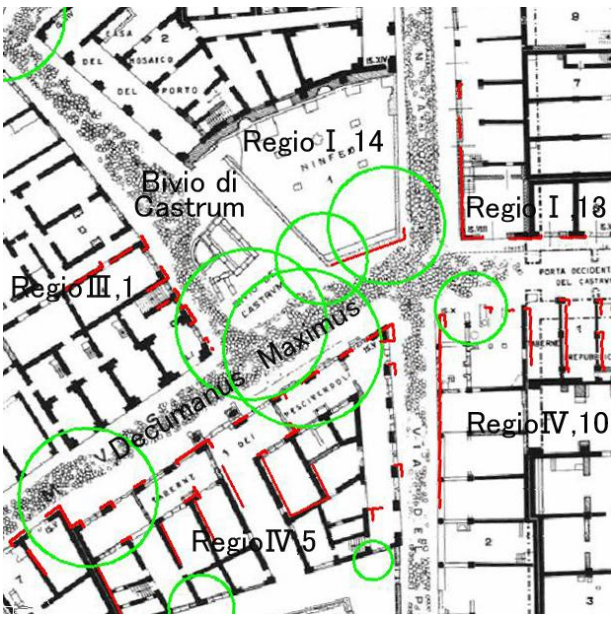

Fig. 5 Devergence between Calza's map and scanning data (in red) on the Decumanus Maximus (a present vegetation map in yellow green)

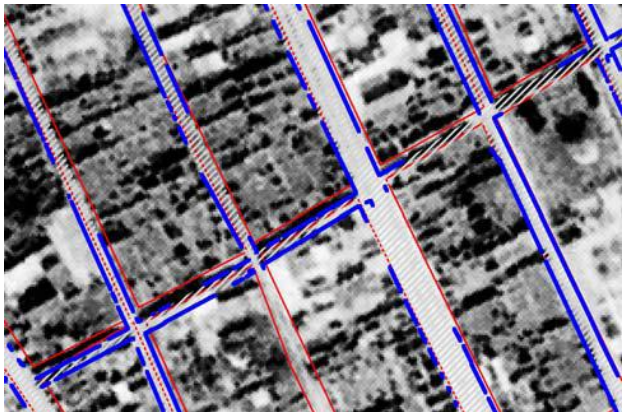

Fig. 6 Superimposed scanned data (in blue) and Eschebach's plan of blocks (in red) on an aerial photograph of Vico di Mercurio

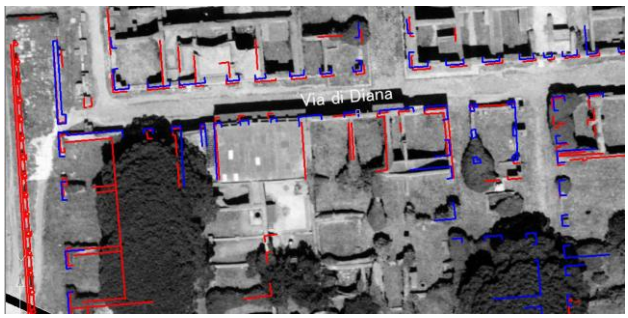

Fig. 7 Superimposed scanning data (in red) and Calza's plan of frontages (in blue) on an aerial photograph in 1995

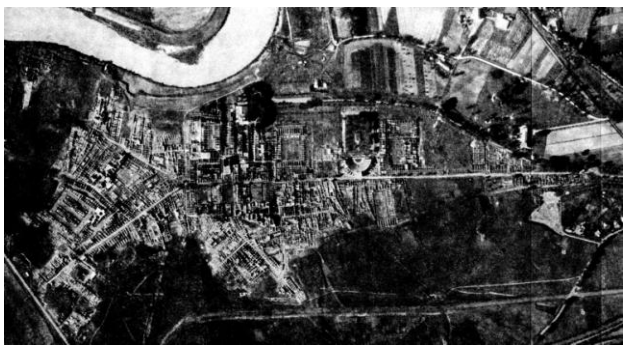

Fig. 8 Aerial photograph in 1944

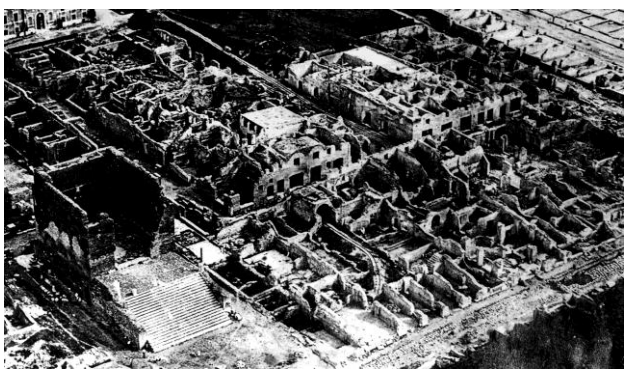

Fig. 9 Aerial photograph around Via di Diana

2.2 Measuring using cordage

When the map was traced from an aerial photograph, high remained buildings were obstacle because of poor visibility. Furthermore there were invisible areas from an aerial photograph because of trees, and then surveyors may measure on the ground by using cordage. It was difficult for them to stretch cordage straight on the high-rise building area so they tend to make man-made mistakes.

Now there are many trees in Ostia, so there should be smaller trees in 1944 when the aerial photograph was taken. In comparison with a present vegetation map, locations of trees coincide with divergences in the map of Calza; 2) east of octagonal plan of the Terme del Foro, 3) Regio Ⅰ,2 which is located on south of Via di Diana and 4) the Bivio di Castrum,.

In detailed comparison of scanning data and no.8 divided part of the general map, there is considerable divergence of the area around 2) the Palestre (Fig. 3). Surveyors could view far away from the Decumanus Maximus, so they may start measuring from there. However they could not view the Palestre from the Decumanus Maximus and Foro because there is high remained building; the Terme del Foro (Fig. 10). Therefore they may not stretch cordage in a straight and could not measure correctly. As well as this case, 3) walls located west of Regio Ⅰ,2, where trees stand, deviates southwards probably because of using cordage(Fig. 4).

Fig. 10 Poor visibility from Palestre to Foro

The Decumanus Maximus curves at an angle of 23 degrees rear 4) the Bivio di Castrum, so this point is very important to draw map. In detailed comparison of no.7 divided part of the general map and scanning data, there is divergence at the intersection; Regio Ⅲ,1 deviates 340mm north-eastwards, Regio Ⅰ,14 deviates 420mm northwards, RegioⅣ,5 deviates 590mm north-westwards and Regio Ⅳ,10 690mm westwards (Fig. 5). Surveyors may take mistakes in attaching a survey map by using cordage to the map traced from the aerial photograph. This may effect 600mm eastwards divergences of Via Epagathiana. Furthermore in comparison with the aerial photograph in 1995, the westside Decumanus Maximus deviates north-westwards 1000mm. However we could not scan there this time, so it needs further consideration.

3. LASER SCANNING FOR TALL STRUCTURES

This part of the survey article on the Ostian buildings in the Roman period, based on laser scanning technology, provides a contrast to the other more archaeological contributions. The tall structures can be described as the aggregation of dots having three dimensional coordinates, which can be used as plans and elevations directly without any tracing those pictures. The dots from 60cm above ground level to 60cm below the top of

structures can be erased easily from the whole model leaving two groups of dots, which make visible the degree of tilt (Fig. 11).

In places restoration went hand in hand with excavation, as can be seen in the entire area, but there were also problems; many closed rooms to visitors and the mosaic floors re-covered with grasses, and the tall structures, such as Capitolium and buildings facing Via di Diana and Via dei Balconi, may begin to tilt. This includes many of the best-known and tall monuments of early second-century Ostia: the Capitolium and the buildings to the north and east of it. The following major changes were the realignment of the northern section of the cardo maximus between the forum and the Tiber, and the displacement of part of the inner pomerial road (Via delle Casette Repubblicane and the Via di Diana) to accommodate the new Capitolium. The variety of structural choices can be seen most clearly in the multi-storey residential and commercial buildings, such as the Casa di Diana, the Caseggiato del Mitreo di Lucrezio Menandro, the Thermopolium and the Insula di Giove e Ganimede (Fig. 12), constructed of brick- and reticulate-faced concrete which form the majority of the urban fabric. However, the result of laser scanning suggest that structurally, despite their variety, a continuing tilt that has brought the top of the walls 5cm out of true vertical against the streets has been detected in those buildings (Fig. 13). The only clear exception is the Casa di Diana, of which a front wall is still standing on true vertical. The front wall of Casa di Diana is reinforced on the exterior by a wall buttress at the corner tilting inwards (Fig. 14). The fact that there is no crack between the front wall and the buttress at the corner means that this buttress belongs to the later reinforcement

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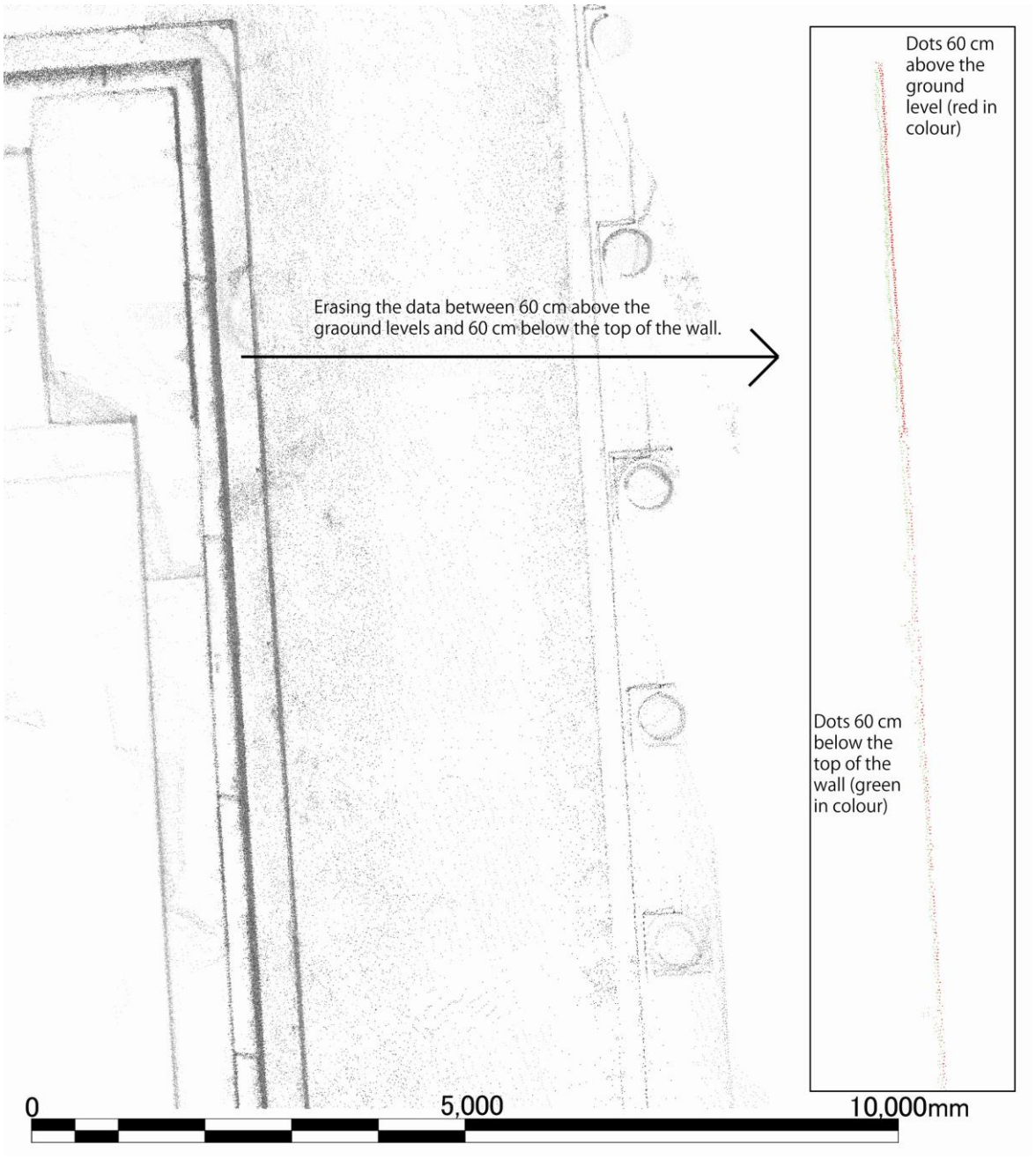

Fig. 11 Visualization of the tilt in the east wall of Capitolium

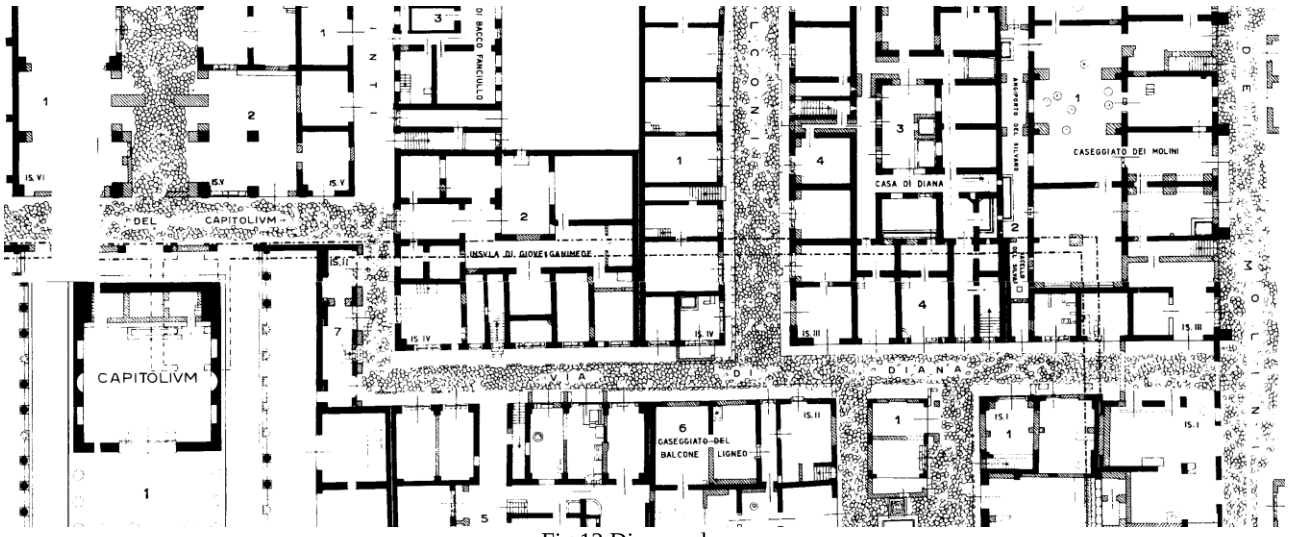

Fig.12 Discussed area

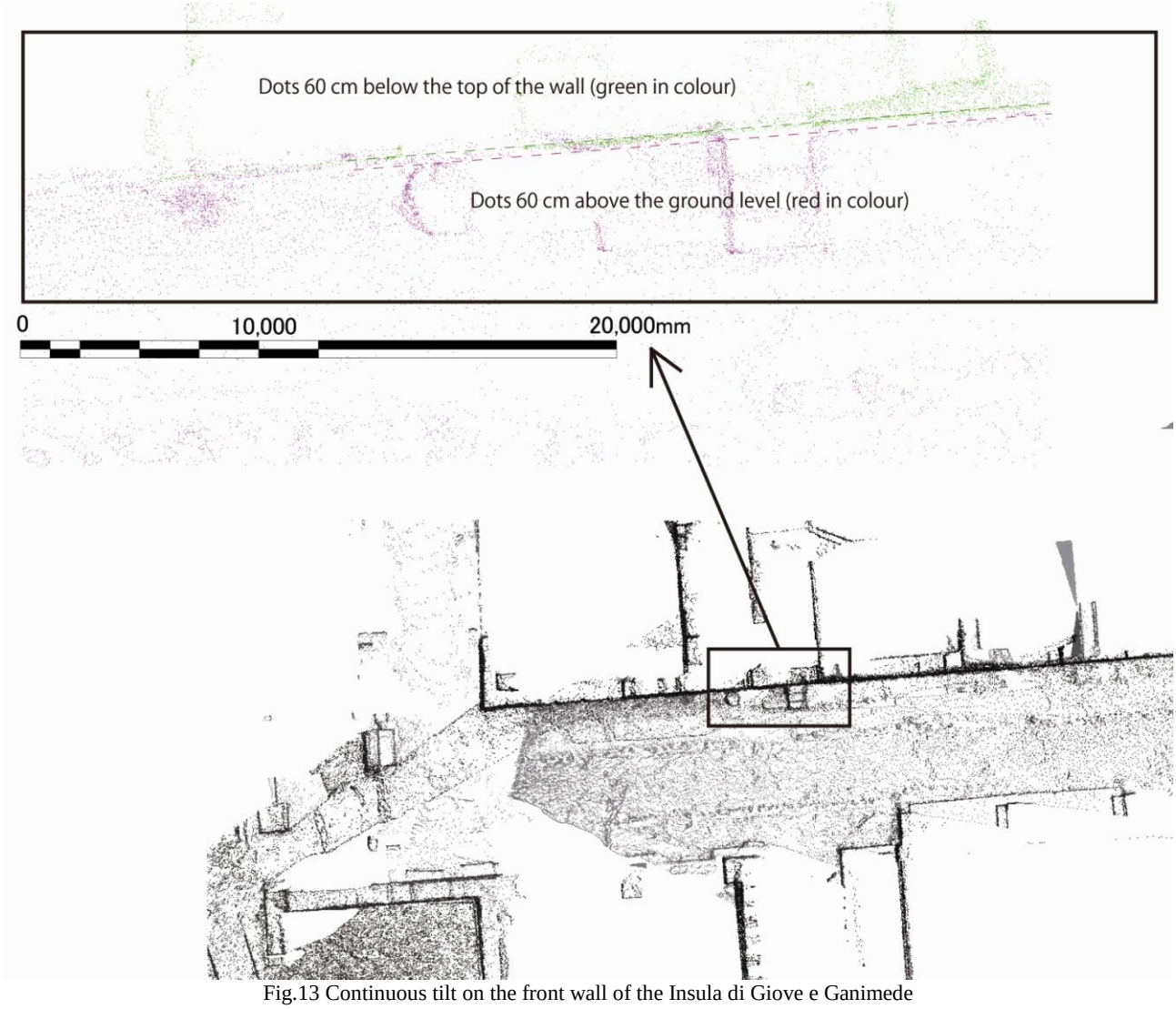

Fig.13 Continuous tilt on the front wall of the Insula di Giove e Ganimede

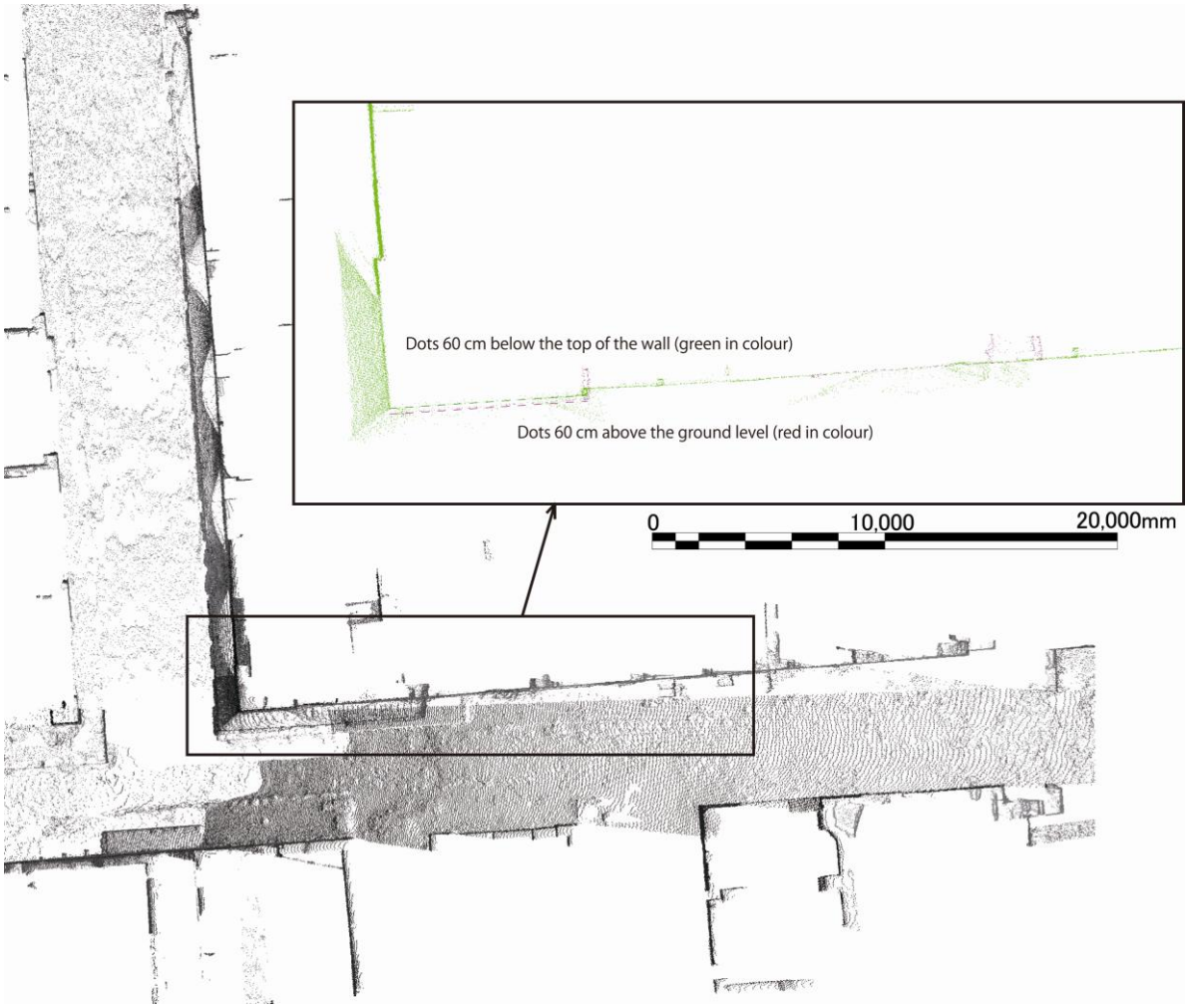

Fig.14 The front wall and the buttress at the corner of the Casa di Diana

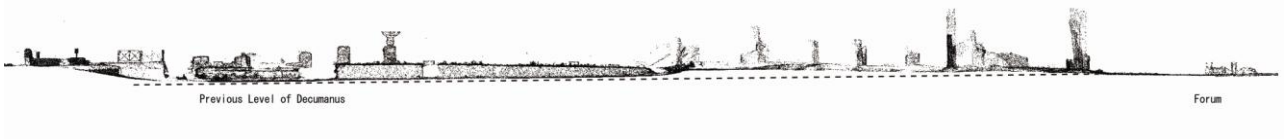

Fig.15 Section of the Decumanus Maximus viewed from the north

A major change in ground level, which can be identified in previous excavations along with Decumanus Maximus, which is one of the characteristics in urban development in Ostia, may causes this movement. A large depression, which remained in the whole area of Forum (Fig. 15), could be close to the original ground level in the Republican period and may also have been deepened in levelling-up of other parts of the city. And a break on the surface in fabric of the Via dei Balconi is also identifiable through a difference in level (see Fig. 16). It is not unlikely that the preparation of the rising the floor level, which is approximately 70 cm higher than the ground level presenting unusual difficulties for entering to those shops (Fig. 17), has begun before the start of the raising of street level, particularly if there was some predictable raising.

That preparation may enhance the possibility of the movement. Walls should be placed over the centre of the footing, and the raised floor should be absolutely level to avoid any slippage or movement, and it was thereby maintained on the same horizontal plane to as great a distance as possible, until the major change in ground level enforced a rise in the whole structure, preferably at some interruption to the wall as seen in the Casa di Diana; when the gradient followed is quite noticeable, which could occur in the buildings facing the streets correspondingly, does the wall buttress at the corner of the Casa di Diana reinforced the front wall in the phase of 5a suggested by Descœudres, which avoided to tilt as a consequence of the reinforcement. It will focus primarily on the positive virtues of exceptional construction such as buttress and raising of the ground level, rather than on negative attitudes towards it, and for the main part on the act of construction rather than finished structure, looking not only at what appears on the surface, but also at how and where images of construction were displayed, and at aspects of an actual construction project.

The problems of large movement range from a simple, direct sinking into the ground to more catastrophic failures resulting from the development of slip planes, which cause the building to tilt and overturn. Below the podium of Capitolium, that former phenomenon may be taking place in very slow motion,

however there is no evidence of sinking at present. There are not to a certain extent symptoms of cracks and a tilt in the north elevation. In an orthographic photo of the north elevation of that tall structure, which has been created from 3D data (Fig. 1 8), where the cracks are observed on the east surface, the high walls without openings, which act as a prudent expedient to ward off cracking, do not support the weight of the roof, but is still resisting against wind loadings.

Fig. 16 Break on the surface of the Via di Balconi

Fig. 17 Floor level of the front shops
in the Insula di Giove e Ganimede


Fig. 18 Orthographic photo of the east elevation of Capitolium


Fig. 19 Back side of the front wall of the Casa di Diana

In the front walls of buildings facing Via di Diana and Via dei Balconi tilting inward to the city block, the slow movement and slippage may also be taking place. Even slight level of tension in a masonry wall resulted in cracking, which has been stitched together with cramps from the back side (Fig. 19), many front walls have suffered from and tilting due to shear distortion, which has progressed over the last 1600 years to a point where collapse seems to occur in near future. On the other hand the front wall of Casa di Diana standing on the true vertical is reinforced on the exterior by a wall buttress at the corner tilting inwards as mentioned above. We need to carry more detailed survey on high-raised structures including those buildings in the year following.

The control of such a huge area and tall structures in Ostia inevitably brought us into a new reality, where we do not have only to cover the whole area, but to measure the tall structure. Although Ostia has undergone more than a hundred years excavation and conservation, this has had a relatively small impact upon the disciplines of archaeology, due to the unique high-raising structure and the variety of brick- and reticulate-faced concrete. Unencumbered with huge costs for recording and conservation, using laser scanning technology those structure can be studied and published comparatively quickly; moreover, that technology offer considerable potential for constructive aspects of ancient Roman architecture.

4. CONCLUSION

It is very difficult to draw a map in detail by cordage measuring and aerial survey in 1950s because there were many problems such as high remained buildings, trees, resolution of photograph. The laser scanning technology is not effected by such obstacles, and the three dimensional points coming from laser scanning on the ground can be calculated with a considerable degree of accuracy from the over-all measurements comparing the aerial survey.

However The work of Calza is note worthy for its accuracy. There is less than 0.1 % divergence between scanning data and Calza's general map of 1:500 in scale. Furthermore parts of his map, such as Foro, is coincide with scanning data probably because of visibility. Despite the thoroughness of these procedures and the obvious care in mensuration with which many of them were produced, it would have been difficult, if not impossible, to maintain a high degree of accuracy over long distances, because the careless mistakes would exist in the mind of surveyors.

5. REFERENCES

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