Labouring with large stones: A study into the investment and impact of construction projects on Mycenaean communities in Late Bronze Age Greece

Boswinkel, Y.

Author: Boswinkel, Y.
Title: Labouring with large stones: A study into the investment and impact of construction projects on Mycenaean communities in Late Bronze Age Greece
Issue date: 2021-02-17

6 The data: measurements of blocks, fortifications and houses

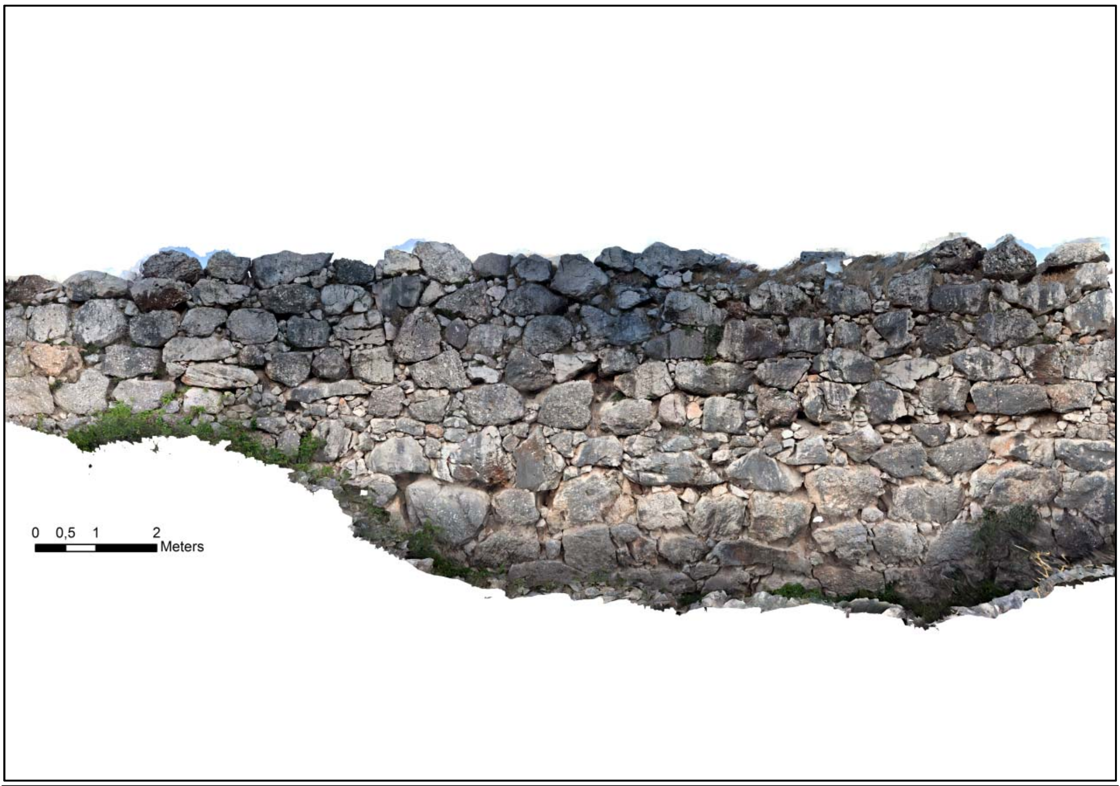
This chapter provides an overview of the acquired data regarding the researched fortifications and domestic structures. The acquired data form the basis for the labour cost calculations of these structures (chapter 7). As shown in the previous chapter, for the fortifications it is the data acquired through photogrammetry that is being used to obtain the volume of the walls and blocks. It is the volume, after all, that is being used to calculate the labour costs (see also chapter 4). In the sections below (6.1 and 6.2) it will be shown what kind of results the used methodology yielded and how these are subsequently used to gain the required information for the fortifications at Mycenae and Teichos Dymaion. For the domestic structures, volumetric data was acquired through literature study, these data are presented in section 6.3. The use of the different types of structures will aid in providing a scale on which to place the calculated labour costs, which in turn will help to understand the potential impact the construction of the fortifications may have had on communities.

6.1 Surface area analysis

The data recording, as described in chapter 5.2, resulted in a number of 3D models of sections of the fortifications at Teichos Dymaion and Mycenae. One of the main issues with these data is how to extract the required data (the volume of the stone material) from these models (see chapter 5). As will be demonstrated, these data show interesting results in comparison to earlier studies (Harper, 2016; Loader, 1998; e.g. J. C. Wright, 1978) concerning the fortifications.

The method of classifying the blocks in the wall by size (see 5.3.1), shows known and unknown features of the walls. As described in chapter 3, the fortification walls are built with large blocks, with smaller stones in between to create a balanced whole. The surface area analysis shows that there is a huge differentiation in size, from tiny -less than fist sized- stones to large blocks over a square meter big.[61] Yet, the amount of smaller material seems to have a larger presence than the earlier description would suggest. In some of the analysed sections the largest category of stones only provides 43% of the total wall surface (or rather the surface area of the wall that is actually covered by stone). This is important for a number of reasons: first, the large variety in size of the material should be taken into account in the labour cost calculations as the weight of the material impacts the labour cost greatly (see also chapter 7). Second, it changes the way one should evaluate the necessary material as the large variety shows that the build-up is not simply one category of (extremely) large blocks and one category of small, easily obtainable, filler stones. This can thus potentially impact the organisation of the building processes as well. Finally, the large variety that seemed to have been overlooked by earlier researchers, could also have an influence on the average stone size employed in the walls, something other labour cost studies of cyclopean walls have often used in calculations (e.g. Loader 1998; Harper 2016). Figure 6.1 below shows the original orthophoto and the digitized overlay in which the stones are coloured according to surface area size. In this particular image the four groups represented by colour are based on a Natural Breaks classification (see 5.3).

[61] This is observed in sections that, as far as known, are *not* modern reconstructions. However, also at those sections where reconstructions have taken place, this variety in size has been documented.



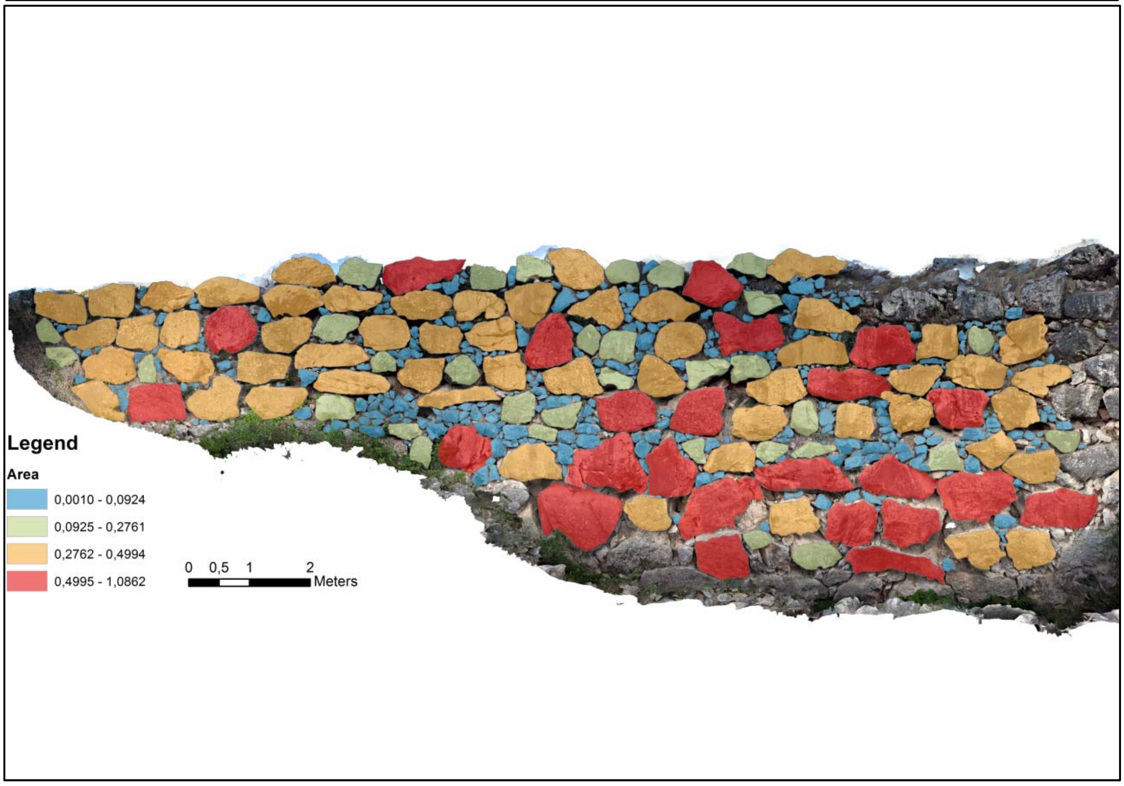


Figure 6.1 Section of the inner face of the Western fortification wall at Mycenae. The top image is the original orthophoto, the bottom image shows the individual stones digitized and coloured according to size. The size groups are determined through Jenks Natural Breaks (see 5.3.1) (images by author).

The variation in size of the used material is not only observed within, but also between sections. In other words, the size of the used stone material fluctuates in different sections of the fortifications, even within the same site (see figure 6.2). All documented sections at Mycenae are part of the later phases of the fortification (see chapter 4). At Teichos Dymaion it is assumed that the entire fortification is built in one phase. Therefore, there does not seem to have been chronological differentiation that would account for the differences in size.

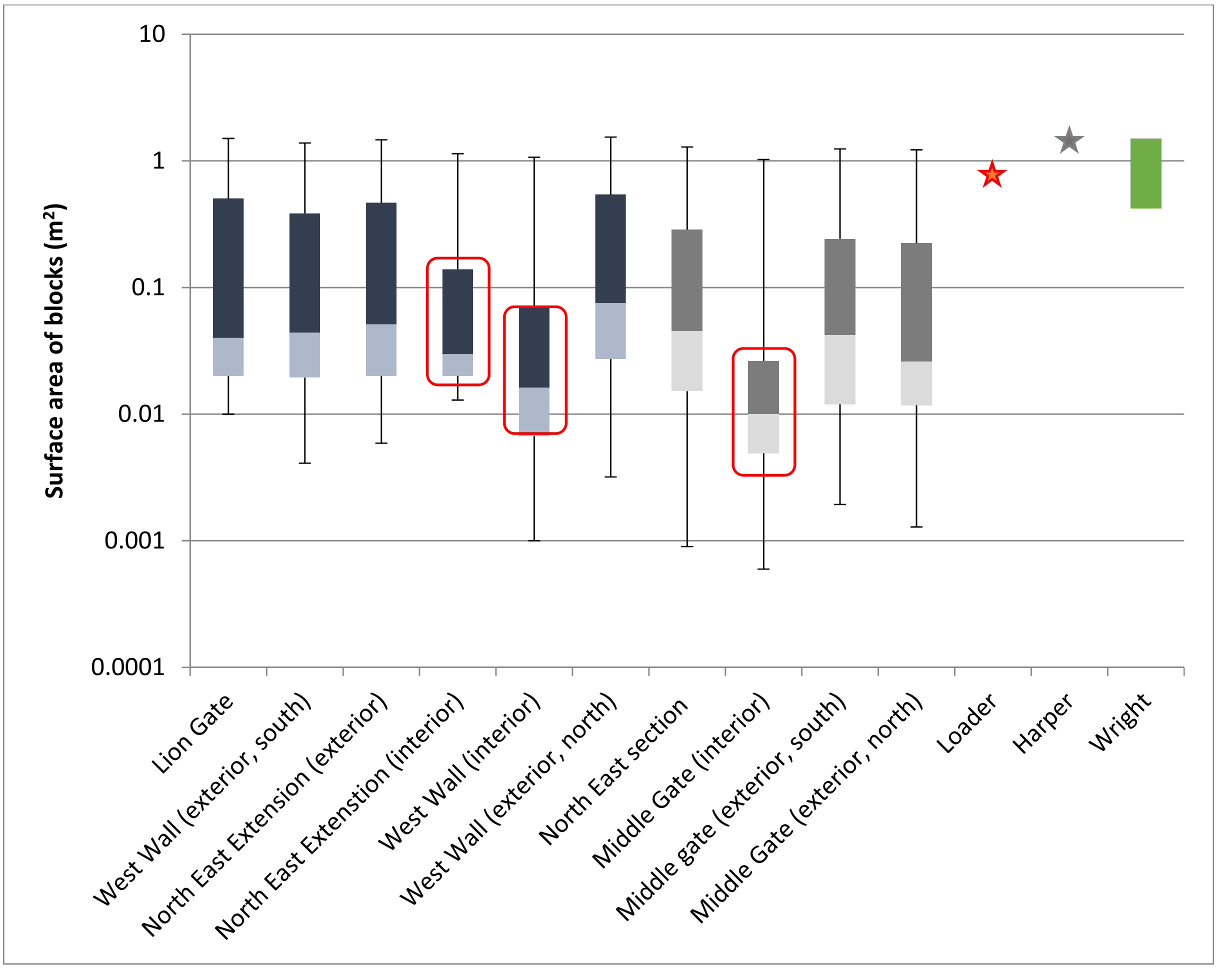


Figure 6.2 Graph showing surface area differentiation in various sections of fortification at Mycenae (blue) and Teichos Dymaion (grey). Indicated sections (red) represent sections of the inner citadel face. Those sections that include the references north *or* south, *indicate that they are part of a longer section and two sub-sections were analysed.*[62] *Also presented here are the average sizes used by Loader (red) and Harper (grey), based on Wright's average range (green). This shows that these averages are all in the top of the ranges as documented at Mycenae and Teichos Dymaion and are thus far too large (graph by author).*

The characteristics of the walls' style, built with mostly unshaped blocks, would always result in sections in which stone size varies. This is partly reflected in the graph above. However, what is interesting to notice is that there are three sections in this graph that are clearly built with, on average, smaller blocks than the other sections. These bars reflect sections that are located on the inside of the fortified area, the side of the wall that is facing the citadel, rather than the outside world. The differentiation in size between the two faces was also noted by, amongst others, Küpper

[62] It is important to note that the scale in the graph is a logarithmic (log) scale. Using a log scale shows very clearly the differentiation in size, particularly for the lower figures. Because the variation in size is so large, a linear scale would only show the top box and whisker. By using the log scale, it can show the differentiation in each group of stones, with the groups each representing 25% of the stones. This also means that some of the smaller groups might seem to have a large size differentiation, but this variation might not be more than 0.0009m^2 (e.g. the North East section at Teichos Dymaion). Whereas the variation in the top group, represented by a slightly shorter whisker, might be as much as 0.97m^2 (same section).

(1996: 33), although he never quantified it. Considering the consistency with which this is done, it would imply a conscious decision to use larger material on the outer face. This gives rise to the question whether this is due to a constructional necessity, if it is a matter of displaying the larger material to outsiders, or a combination of these. Having larger material in the outer walls is not a localised or era-specific phenomenon.[63] However, since the fortification comprises a free-standing wall, it seems more likely to be an aesthetic measure than a structural need.

Finally, the analysis of the wall surfaces has shown that for the various sections being studied, on average 17% of the surface is not covered by stone. These cavities, which are common, if not inherently present, in rubble style walls influence the amount of material that is needed. While it is possible that stones have fallen out of the wall, Mundell et al. (2009: 205) found that tightly built rubble walls have about 20% 'voidage', while 40% is possible in poorly built walls. The 17% found in the surface is thus to be considered an absolute minimum. Furthermore, it needs to be taken into account that this space could have been left empty, or was filled with a clay, as suggested by Wright (1978: 160) and recorded at Tiryns (Küpper 1996: 33) and Mycenae (Mylonas, 1962) (see also chapter 3). Within the used scenarios 17% of the volume is taken into account as possibly not filled with stone. However, due to the large variety in possible volume as well as the lack of knowledge about how and when a form of clay was used in these walls, the clay itself is not taken into account in this study.

6.2 From surface to volume

Surface area might provide a good first step in the analysis of the build-up of the wall, but ultimately the volume is what determines the weight (in combination with the specific weight of a given material), which in turn impacts the various steps of construction. Here new challenges arise, as it was impossible to assess the depth of the blocks with the available equipment. In section 5.3 it was explained how this was dealt with, first on the level of individual blocks, secondly on the level of entire walls. Below the resulting data are presented.

The façades built in conglomerate at the Lion and North Gates at Mycenae, are only that, a façade. Except for the gate itself, the façade is encapsulating a cyclopean-style wall. It is visible in multiple places that this conglomerate façade is only a single block wide. Obviously, there is some variation based on individual blocks, but this is minimal and on average this is a depth of about 0.80m at both gate façades.

The recorded sections at Mycenae show that the wall itself is between 6 and 7.5 metres wide and preserved up to 9.5 metres high. The height is varying and this obviously influences the calculated

[63] Not only is it visible at both Mycenae and Teichos Dymaion, similar observations have been made at Koroneia from the late Archaic period (Boswinkel, 2018) as well as Hellenistic Halos (Haagsma, 2003), both sites located in Greece. Both examples represent much smaller constructions, with the first being a possible temple-like structure and the second a domestic structure and in both cases the walls are less than a meter high. Haagsma, nevertheless argues that for the structures at Halos there is a constructional reason for the difference in size between the inner and outer face of the walls. This is visible in the fact that the outer walls had to bear more pressure and weight than internal walls and if there was no structure immediately attached to a wall, it had nothing to lean against and, therefore, these outer faces were built with larger stones (Haagsma 2003: 40). This seems unlikely to be applicable to a fortification as this comprises a free-standing wall. However, the difference in size of the material is certainly present.

volume greatly. Nevertheless, the volume of the studied sections provides a good sample for the later parts of the fortification (see chapter 4): the western wall, both gates and the North Eastern extension. It is possible to extrapolate the data from the documented sections and use that to calculate the volume and subsequently the labour costs for these final additions. In the table below (table 6.1) an overview of the volumes is provided. Figure 6.3 shows the location of the mentioned sections. Note that the *analysed* sections below are smaller than the *documented* sections as presented in figures 5.5 – 5.6. As explained in section 5.3.2, this is to ensure the most reliable data.

Table 6.1 Volume of recorded sections of the fortification wall at Mycenae.

Section		**Volume m^3**
1	Lion Gate *Façade*	237.4
2	North Gate *Façade*	48.2
3	West Wall	1197
4	North East extension	246.5

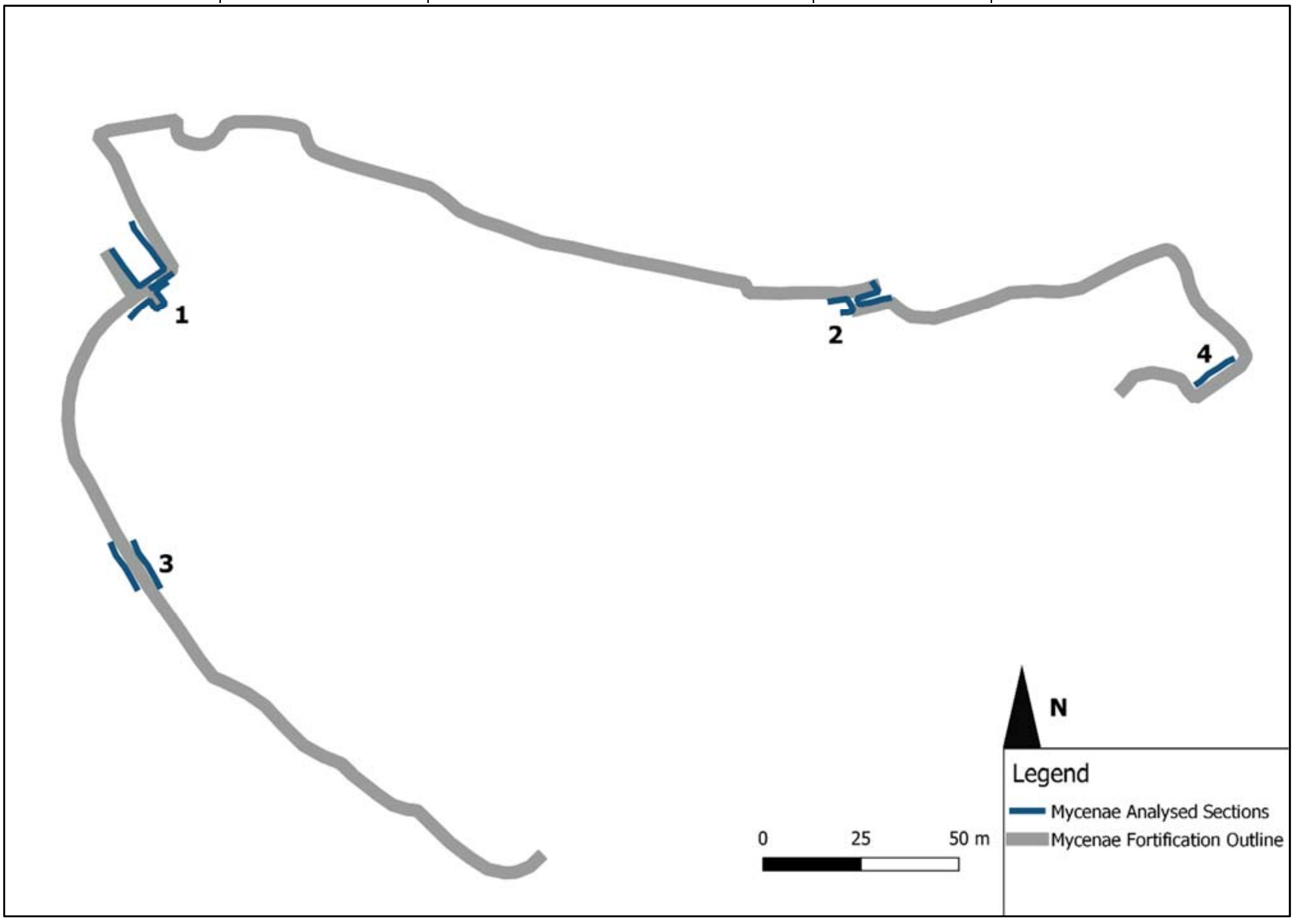


Figure 6.3 An overview of the analysed sections at Mycenae (map by author).

At Teichos Dymaion, no special façades are present like those at the gates of Mycenae. The wall is between 5.6 – 6.4 metres wide, although the bastion at the south gate is only 4.4 metres wide. The highest section recorded still stands 7.5 metres high. At Teichos Dymaion a larger proportion of the wall is documented, at least of the outer face, than at Mycenae, due to the overall smaller size of the site. Height, as is to be expected, differs between sections, but overall, the wall seems to be of a relatively regular height. Table 6.2 shows the volume of the sections at Teichos Dymaion. Figure 6.4 provides the location of these analysed sections.

Table 6.2 Volume of recorded sections of the fortification wall at Teichos Dymaion.

Section		Volume m^3
1	Middle Gate	728
2	South Wall	558.3
3	North East section	549
4	North Gate	219.2

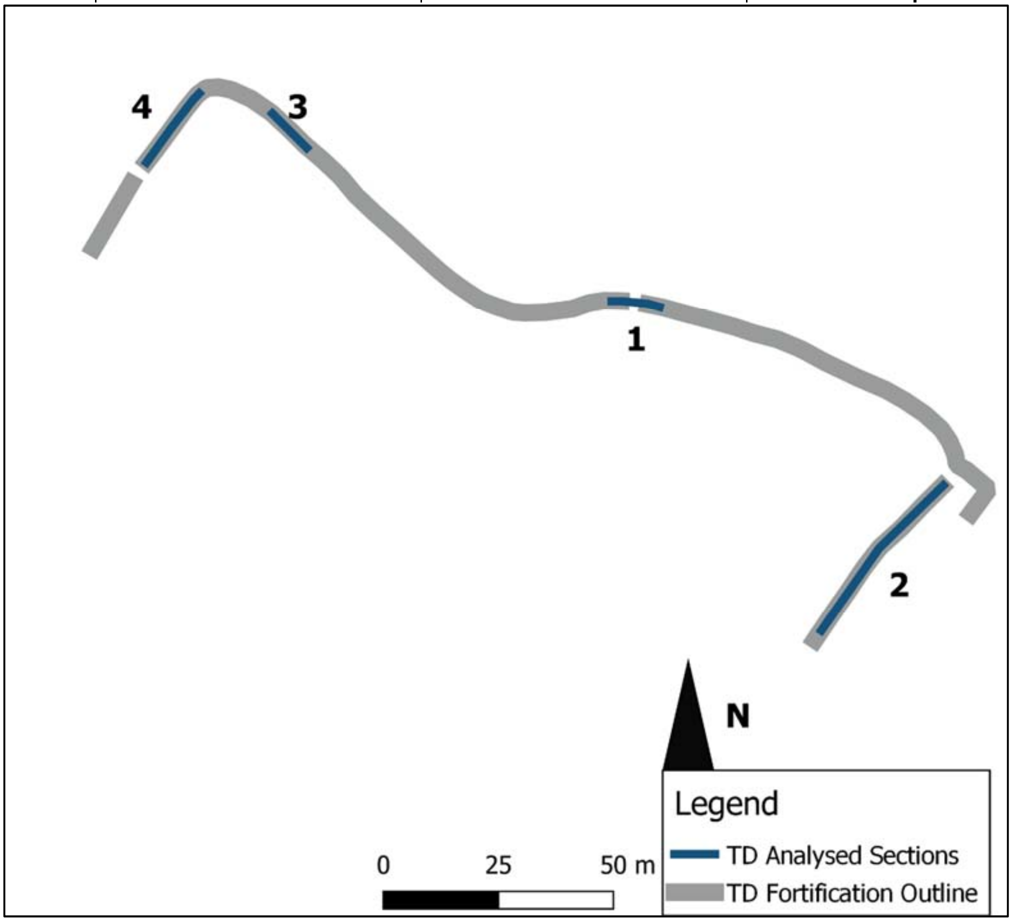


Figure 6.4 Overview of analysed sections at Teichos Dymaion (map by author).

It is important to note for both sites that the volumes are based on the current preservation, visibility and in some cases the completeness of documentation. In figure 6.5 below, this can be observed quite well. The section in the figure corresponds with section 2 at Teichos Dymaion, which is a relatively long section, but only preserved to a low height and not the complete length was digitized. Hence, despite the length, the volume of this particular wall section that is used in the calculations is not very large. This needs to be taken into account when the labour costs are interpreted as the actual wall was far larger than the remains that are visible today. Hence, in chapter 8 the volume and the associated labour costs will thus be extrapolated. The initial calculations are based on the actual remains though.

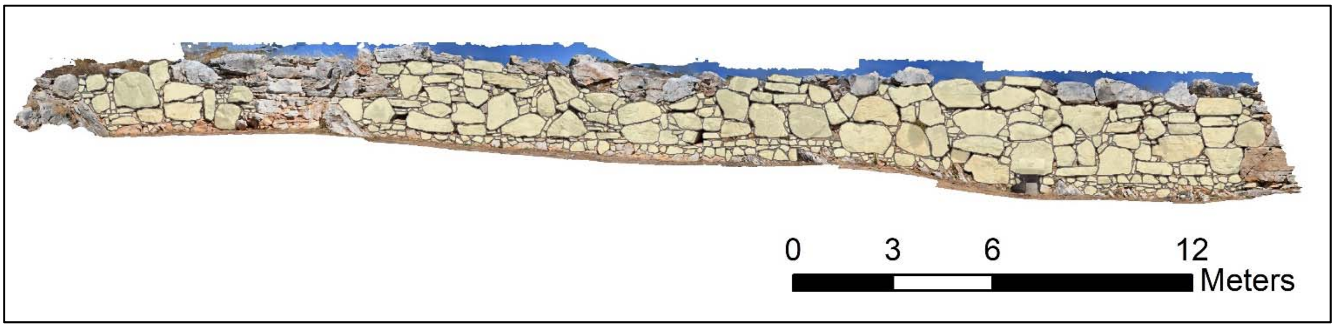


Figure 6.5 Section III of Teichos Dymaion with digitized blocks where possible. Although it comprises a long section, it is quite low and its overall volume is thus relatively small (image by author).

6.3 Measurements from domestic structures

From the various sources (Harper, 2016; Jazwa, 2016; e.g. Palyvou, 2005; Tartaron et al., 2011) it is clear that there is a large variety in Late Helladic houses. Houses measure a few dozen square meters up to over 300 square meters. From Jazwa's (2016) extensive study into domestic structures of prehistoric Greece, a selection of 15 structures is used. These structures were selected due to their location in the Argolid (unfortunately, none of the structures he studied from Achaea, had reliable measurements) and the fact that these are dated to LH IIIA-C. Two are from Midea, four from Mycenae and nine from Tiryns (see table 6.3). Another structure is used from the site of Kalamianos, for which the data come from Tartaron et al. (2011) and Harper (2016), bringing the total to 16 structures. Comparing these figures to those from the study on Kalamianos by Tartaron et al (2011: 589; see table 6.4 below), it is clear that three of the four structures from Mycenae are (far) larger (over 310m^2) than the majority of the domestic buildings from this era. For one of these, the so called West House, Jazwa (2016: 141) points out that its size, the used construction as well as exotic luxury goods indicate an "elite status of the inhabitants of the complex". Most structures are a lot smaller, with a size of 50-100m2 being the most common range (a third) and the majority of domestic buildings being smaller than 200m2 (nearly 75%) (Tartaron et al. 2011: 589). It must be noted that these figures represent the total exterior footprint of the building, including the walls. Tartaron et al. (2011: 589) have shown that for Kalamianos an average of 61.9% of that area is actual room floor surface (their range is 48-70%).

In the appendix of Jazwa's study (2016: 408–694) the variety of the size of the walls, in particular their width, is shown.[64] It does not only differ between buildings, but it also varies within a building.

[64] From what source individual measurements are taken in Jazwa's work is unclear. However, he does provide a bibliography per site and in some cases per house from which data are taken.
Midea: Walberg 1998, 1999, 2007; Demakopoulou 2001, 2007; Demakopoulou and Divari-Valakou 2010
Mycenae:
Mu House: Shear 1968, 235-249; Hiesel 1990, 52-54, 147-149; Darcque 2005
South House: Wace 1925, 1980; Shear 1968; Taylour 1981; Hiesel 1990, 85, 160; Darcque 2005
Tsountas House: Tsountas 1886, 1887, 1964; Mylonas 1966; Shear 1968, 226-235; Hiesel 1990, 125; Darcque 2005
West House: Hiesel 1990; Tournavitou 1995; Shelton 2010
Tiryns: Müller 1930 (Tiryns 3); Gercke and Heisel 1971 (Tiryns 5), 1-19; Grossmann and Schäfer 1971 (Tiryns 5), 41-75; Gercke, Gercke, and Heisel 1975 (Tiryns 8), 7-37; Grossmann and Schäfer 1975 (Tiryns 8), 55-96; Rudolph 1975 (Tiryns 8), 97-117; Avila, Grossman, and Schäfer 1980 (Tiryns 9), 1-88; Grossman, et al. 1980

The width varies between 0.45 and 1.40 meters, but an overall average width for the walls from all 15 buildings is 0.66m for the exterior walls and 0.60m for the interior walls.

Table 6.3 Overview of the used houses (after Jazwa 2016, Tartaron et al. 2011 and Harper 2016).

Site	**Structure**	**Date**	**Surface area (m^2)**
Midea	Megaron 1	LH IIIB	161
	Megaron 2	LH IIIC	100
Mycenae	Mu House	LH IIIB	887
	South House	LH IIIA/B	357
	Tsountas House	LH IIIA/B	194
	West House	LH IIIB	377
Tiryns	A	LH IIIB	266
	II	LH IIIB	25
	VI	LH IIIB	214
	R97	LH IIIC	27
	8786	LH IIIC	46
	127	LH IIIC	90
	110	LH IIIC	10
	W	LH IIIC	177
	O	LH IIIC	24
Kalamianos	7 – X	LH IIIB	105

Table 6.4 Overview of occurrence (in percentage) of houses in a certain size class (after Tartaron et al. 2011 and Darcque 2005) (please note that rounded numbers are used).

Building size (m^2)	Kalamianos (%)	Cumulative (%)	Other Mycenaean sites (%)	Cumulative (%)
20 - 50	0	0	18	18
50 - 100	47	47	33	52
100 - 120	5	53	9	61
120 - 200	26	79	14	74
200 - 310	16	95	9	83
>310	5	100	17	100

The height of the walls is kept consistent at 2.5m per floor. There are only limited Mycenaean domestic structures that show a second storey to extract a reliable height from, yet from Akrotiri it seems that the height varies roughly between 2.3 and 3.3m for the West House (Palyvou 2005: 46).[65]

(Tiryns 9), 89-180; Hiesel 1990, 22-23, 197; Müllenbruch 2013 (Tiryns 17); Wiersma 2013, 146-149. See for full bibliography Jazwa 2016.

[65] Akrotiri is a site on the Greek island Thera and was covered by a volcanic ash in the 17th century B.C.E. (e.g. Palyvou 2005). Although it is thus older than the other studied structures, it is one of the very few locations where domestic structures from the Late Bronze Age are preserved in such a state that these kind of data can be documented.

This is the effect of a large discrepancy of the floor level (variations of up to 1.80m) and so the ceiling had to be at least on the height of the lower value. A height between 1.90-3.00m is average when considering the Beta and Delta houses as well (Palyvou 2005: 128, table 1). Thus, taking into account some of the thickness of the second floor/roof, 2.5m seems a solid figure. In table 6.5 below is a summary of the data, using average values based on the size of the structures.

Table 6.5 Summary values of the various scenarios for the required materials for domestic structures. All values are averages and are in cubic meters (m3). The size (surface area) of the structures is taken as 75, 110, 160, 200, 250, 300 and 370m^2 respectively. The averages for mudbricks include 0-values (left column) and exclude 0-values (right column) in the scenarios with walls built completely in stone. The averages also include the scenarios with and without a second floor.

House size category (m^2)	Stone	Mudbrick		Wall plaster	Floor plaster (5cm)	Floor plaster (20cm)	Roof clay	Wood (per floor)	Small wood (per floor)
75	63.25	47.38	8.69	3.41	13.65	15.00	2.27	3.75	63.25
110	92.77	69.48	12.74	5.01	20.02	22.00	3.63	5.50	92.77
160	134.93	101.07	18.53	7.28	29.12	32.00	4.99	8.00	134.93
200	168.67	126.33	23.17	9.10	36.40	40.00	6.35	10.00	168.67
250	210.83	157.92	28.96	11.38	45.50	50.00	7.71	12.50	210.83
300	253.00	189.50	34.75	13.65	54.60	60.00	9.07	15.00	253.00
370	312.03	233.72	42.86	16.84	67.34	74.00	9.07	18.50	312.03

6.4 Concluding remarks

In this chapter the volumetric data have been presented that derive from fieldwork in Greece (the fortification walls) or from literature on the domestic structures. The data show, first, that on average the blocks used in cyclopean constructions are (far) smaller than previously envisioned (as shown in figure 6.2), and, second, that there is a large variety in size of the blocks within the structures. Besides any influence these observations may have on the labour cost (see chapter 7), this detailed size analysis, at least provides a more comprehensive insight into the actual build-up of the fortification walls. The presented data in this chapter will be used in the following chapter (7) for the calculation of the labour costs of each of the studied sections. The interpretation of these costs will be presented in chapter 8.