Chapter 5
The Phase 1 Slipways

5.1. Introduction

This chapter presents and discusses the evidence of the earliest identifiable building phase (Phase 1) in the naval installations in Zea Harbour, which is also the earliest found among all three Piraean harbours thus far. Submerged remains of five rock-cut slipways, including both identified and possible elements of their ramps and open-passages, were found in Area 1 (Fig. 2). They are labelled collectively as Slipways 1–3 and 5–6 (Pl. 3).[1]

These slipways are each constructed of a ramp cut into the bedrock with rock-cut slots that held transverse timber sleepers; open-passages are present between the ramps (Figs. 193, 198c, 198e; Pl. 11). The rock-cut slots and timber sleepers they once housed may have served as the foundations of a more sophisticated ramp structure now lost. If such structures were built above these timber sleepers, their design can only be speculation, however. As a result, the slipways at present can only be interpreted as ramps incorporating transverse timber sleepers.

Relative Chronology

It is first necessary to summarise the key evidence of the relative chronology of Phase 1 and its relation to the later building phases in order to present the main arguments for identifying these structures as Phase 1 slipways.

The slipways were constructed with the same design, inclination and position relative to the 87DZ (Pls. 12, 36b). Two later shipshed phases, demarcated by their colonnades and ramps, were identified in the same area as these slipways (Pls. 13, 15–16), but the following direct evidence (1–4) and supporting evidence (5–7) demonstrate that the slipways are earlier than these shipshed structures.

Direct Evidence:

1) The construction of the identified Phase 2 column base foundation trench C13/14:2 in the colonnade di-

1. Slipway 4, found during rescue excavations conducted by the 26th Ephorate of Prehistoric and Classical Antiquities in 2004, is not included in this study.

viding Shipsheds 13 and 14 removed the southern part of a well-defined ramp feature (SW5:R6) in Slipway 5 (Figs. 170, 200–201).[2]

2) Just to the east of C13/14:2 the construction of the identified Phase 3 colonnade foundation trench C22/23:5 dividing Shipsheds 22(N) and 23(Π) removed the southern part of ramp feature SW5:R5 (Figs. 170, 200, 202).

3) The construction of the identified Phase 2 ramps cuts through the ramp features of the Phase 1 slipways.[3] For example, the ramp foundations of Phase 2 Shipshed 10 (S10:R1–R2) have removed parts of Phase 1 Slipway 3 (Figs. 169, 226).

4) The upper, landward ends of the Phase 1 slipways most probably terminated 11.45 m west of the eastern-most identified Phase 2 colonnade feature (Pl. 43; see pp. 158–159) and 31.22 m west of the back-wall of the Phase 3 shipsheds (Pl. 43).[4] The fact that no traces of the Phase 1 slipways have been found in the eastern areas of the Phases 2 and 3 shipsheds also strongly indicates that Phase 1 was not related to the later building phases.

Supporting Evidence:
5) In support of points (1) and (2) above, it is clear that the areas between the preserved parts of all Phase 1 slipways have been cut to a lower elevation by later features (see for example Figs. 224b, 226, 227b; Pl. 40). Unfortunately it is not possible to determine if the ramps of Slipways 2 and 3 extended into the nearby colonnade areas of the later shipsheds, but this is likely, in particular because the construction of the Phase 3 colonnades have shaved down evidence of earlier building phases in several areas. The 6.18 m-long colonnade foundation trench C17/18:14 was clearly constructed to even out earlier features, and it is very likely that Slipway 2 was affected by its construction (Pls. 11–12, 15).

6) The difference in orientation (seen in plan view) between the ramp structure of Slipway 2 and the identified colonnades of Phases 2 and 3 shipsheds is 3.8° (Pl. 11). Such a marked difference in the construction alignment of these very long ramps and superstructures makes it very unlikely that they belong to the same building phase. For example, if the ramp of Slipway 2 and the colonnades are extrapolated west in plan view, towards their lower ends, the southern side of the ramp structure would cut the colonnade dividing Shipsheds 9 and 10 (Phase 2) and Shipshed 18(χ)/19(φ) (Phase 3) *ca* 18 m to the west of ramp feature SW2:R7 (Pl. 11). It should be emphasised that this conflict in alignment is located within the Phase 1–3 harbour-front area that can be securely reconstructed based on the established *minimum* relative sea level change of *ca* -1.90 m (see Chapter 8.1.1).

7) Further, at most shipshed sites the top surfaces of the column bases and other colonnade features are constructed at about the same elevation as the main section of the ramp structure supporting the keel of the warship and the side-passages (see p. 134). The Phases 2 and 3 colonnades at Zea were constructed at an elevation well above the ramps of the Phase 1 slipways (Pl. 43; see pp. 117–118, 132).

The structures assigned to Phase 1 are identified as unroofed slipways, since none of the superstructure features found in Area 1 can be related to this phase. It should be noted that none of these slipways or their individual features are preserved in their entirety (Pl. 3); their lengths and widths, including both ramps and open-passages, are estimated based on the surviving evidence. Their total reconstructed lengths, deduced from extrapolation, are based on the position of the slipways, their inclination, an analysis of the established *minimum ca* -1.90 m and hypothetical *maximum ca* -2.90 m relative sea level change that has occurred since the Classical period, and on later shipshed features delineating the Phase 1 slipways on their landward, upper ends (Pls. 11–12). Since these extrapolations require

2. For a full list of feature abbreviations see Vol. I.2, Chapter 3: pp. 73–74. See Chapter 6.4 for a discussion of the Phase 2 colonnade identification.
3. See Chapter 7.4 for a discussion of the Phase 2 ramp identification. It must be noted that there is no evidence of a later ramp structure in the preserved area of Slipway 5 (Figs. 170, 200).
4. All measurements *MoP*: 0.04 m (see pp: 76–79).

processing and interpretation of archaeological data, they do not achieve the same epistemological level as the directly-observable archaeological data reserved for this chapter. All length and height extrapolations, including those of the Phases 2 and 3 shipsheds, are presented and discussed more fully in Chapter 8.2.

Comparanda
Comparable construction features found in other areas of the Piraeus and at sites around the Mediterranean are compared and analysed in the discussion below. It should be stressed here that only sites with evidence of ramps with transverse timber sleepers are included in this chapter, and that other relevant construction designs are included in the analysis of the Phase 2 and Phase 3 shipshed ramps and side-passages presented in Chapter 7. In addition to the slipway sites at Marseille and Sitea, these comparative data derive from shipshed sites at Kos, Mandraki (Rhodes) and Carthage. Also to be explored in this chapter is whether there existed any differences in the ramp construction of unroofed slipways and shipsheds.

5.2. Analysis of Slipways 1–3 & 5–6

Gradients
In this study, the gradients of the slipways (and later shipsheds) were calculated using a combination of methods, as demonstrated here using the Phase 1 ramps and open-passages:

G1-HB. *Average gradient of* ***highest*** *preserved* ***bottom*** *surfaces*: In the ramps of Slipways 2 and 3, the bottom surfaces of the individual rock-cut slots for transverse timber sleepers (SW2:R4–R5; SW3:R4–R7) slope down by 0.01–0.02 m to the north along their respective axes. In Slipway 5, there is a southward down slope along the axes in the rock-cut slots SW5:R4, R6–R8 of 0.05–0.06 m. This evidence, and particularly in Slipway 5, clearly indicates that the builders would rather have utilised additional timber to create an even ramp surface rather than create a level, rock-cut sleeper slot; it certainly would have been no easy task to drill and carve a slot with a perfectly level bottom surface in bedrock.[5]

The ramp G1-HB gradient is calculated here between the highest bottom surfaces of each rock-cut slot, based on the assumption that the rock-cut slots were constructed to a minimum depth (probably averaging 0.10 m; see below) determined by the load and stress levels they were designed to withstand. The areas close to the ends of the slots are excluded from measurements, as they are often unevenly cut and do not represent the intended bottom surface (Fig. 117).

The timber sleepers were probably planed level, and the ramps may not have had perfect, evenly inclined surfaces, at least originally, but the areas in contact with the keel would probably have been worn smooth with use.

G2-T. *Linear regression through points representing the best-preserved* ***top*** *surfaces on a given section*: The top surface of the original rock-cut part of the ramp (the inclined bedrock surface into which the slots were carved) is well preserved in Slipway 3. The G2-T gradient was calculated based on the points representing the best preserved top surface on the surveyed longitudinal-section of this ramp structure using linear regression (Fig. 217a).[6] This method has shown that parts of the top surface are in all probability also intact in Slipway 5 (Fig. 218a).

It is less difficult to carve a relatively smooth inclined surface than it is to cut a large number of rock-cut slots on a linear gradient; the use of wooden elements as sleepers in the ramp structure would have permitted further adjustments to the inclination. The inclination of the two fairly well-preserved Phase 1 open passages (OP/SWR3(S):1 and OP/SWR6(S):2) is also calculated in this manner (Figs. 219a–219b), whereas the ramp of Slipway 2 was excluded, as its rock-cut top surface has been destroyed (Figs. 107, 186, 192a).

G3-B. *Linear regression through points representing the best preserved* ***bottom*** *surfaces on a given section*: The linear regression is calculated through the bottom surfaces of

5. See below, p. 67, for a description of the Phase 1 construction methods.
6. The linear regression was calculated using the software program Rhinoceros® 4.0.

the rock-cut sleeper slots in a given ramp section using the same method described in G2-T (see for example the ramp of Slipway 3; Fig. 217b). The bottom surfaces used in the G3-B calculation have suffered less erosion than the top surfaces used in G2-T, and as a result G3-B is considered more accurate.

The calculations resulting from these three methods to determine gradient do not necessarily represent the actual gradient of the wooden ramp structures, especially if the transverse timber sleepers acted as the foundations of more sophisticated ramp structures that have not survived; however, it can be assumed that the actual gradient was probably close to that of the rock-cut slots holding the transverse timber sleepers. (For a discussion on the methodology and accuracy of calculating inclinations, see also p. 6.)

Measurements

The condition of the top edges of the rock-cut features varies from good (Fig. 113) to severely eroded to completely destroyed (Fig. 107). Hence, in the descriptions below, the distance between two rock-cut slots in a ramp is measured side-to-side, that is, between the nearest bottom edges of two adjacent slots. Because the rock-cut slots are not precisely parallel to each other, centre-to-centre average measurements between two adjacent slots are comprised of the recorded width of each ramp feature, divided by two, plus their average side-to-side measurement (see Table 5.1 below). Features not preserved to their original bottom width or depth, listed in *italics* in tables, are not included in the average calculations. Features not securely identified will not be included in the discussion.

5.2.1. Slipway 1

Cat. nos: SW1:R1, OP/SWR1&2:1–2

Ramp and Open-passage

One feature, a rock-cut slot (SW1:R1), defines Slipway 1 (Pl. 3; Figs. 167, 179, 185b). The construction of the Phases 2 and 3 shipshed colonnades (C8/9:6–7, C17/18:15B) and U:19 have removed any traces of Slipway 1 on its southern side, and dredging has destroyed the structure at its western end.[7] The construction of ramp foundations for Shipshed 8 (S8:R2) resulted in the removal of the northern side of the rock-cut slot SW1:R1 and the open-passage, and the construction of U:14A destroyed parts of it to the east (Fig. 167).[8]

The rock-cut slot SW1:R1 in Slipway 1 (bottom elevation: -0.68 to -0.69 m) has the same longitudinal position as the following rock-cut slots: Slipway 2 (SW2:R1; -0.71 m), Slipway 3 (SW3:R1; -0.68 to -0.69 m) and Slipway 5 (SW5:R7; -0.69 to -0.74 m) (Pl. 3, from top to bottom); all four ramps' features were constructed at nearly the same elevation and are therefore clearly associated with a single phase of slipway construction.

When compared to the ramp and open-passage of Slipway 3, the presence of the slot in Slipway 1 (SW1:R1) and the top surface directly east and west of it (gradient 1:21.3/2.7°) provide a solid indication that these features are related to Phase 1 (Figs. 183, 197, 223a). However, applying the average, side-to-side distance between slots from the other slipways, the next slot on Slipway 1 would be expected at about 0.69 m (see pp. 61–62) to the west of SW1:R1. This is not the case, but it is very likely that the missing ramp features in Slipway 1 may have begun farther north, especially since the ends of similar ramp features in Slipways 2, 3 and 5 are not aligned (see for example Fig. 193). This area is thus interpreted as an open-passage (OP/SWR1&2:2). Directly to the east of this feature, beyond U:14A, a small section of the Phase 1 open-passage (OP/SWR1&2:1) is located along the southern side of Shipshed 17(η)'s ramp foundations (S17:R7; Figs. 167, 179, 185b, 223a).

5.2.2. Slipway 2

Cat. nos.: SW2:R1–R7, R8(?); OP/SWR2&3:1–2

Ramp

PL: 5.05 m (5.92 m); PW: 1.38 m (SW2:R4); G1-HB: 1:20.5 (2.8°)

The ramp of Slipway 2 is preserved for a total length of 5.05 m (Pl. 3). Seven, or perhaps eight, rock-cut slots for transverse timber sleepers were identified

7. A number of structures in Area 1 at Zea have not been identified. U:19 refers to Unidentified feature 19, which will be discussed in a future study.

8. U:14A–U14E is a 45.38 m-long and *ca* 1 m-wide unidentified feature that cuts through slipway and shipshed features from the northern to the southern parts of Area 1; see Pl. 40.

a. Average bottom width		
Feature	**Width (m)**	**Average (m)**
R1	*ca* 0.10	-
R2	0.11	-
R3	0.10	-
R4	0.09–0.10	0.10
R5	0.11	-
R6	0.10	-
R7	0.10–0.14	0.12
R*8(?)*	*0.10*	-
Average bottom width of R1–R7: **0.11 m**		

b. Average depth	
Feature	**Depth (m)**
R1	*ca* 0.10
R2	0.07*
R3	0.03*
R4	0.05*
R5	0.05*
R6	0.05*
R7	0.11
R*8(?)*	*0.02*
Average depth of R1 and R7: **0.11 m**	
* Not preserved to original depth	

c. Average distance between slots		
Feature (m)	**Width (side-to-side) (m)**	**Width (centre-to-centre) (m)**
R1–R2	*ca* 0.85	*ca* 0.96
R2–R3	*ca* 0.76	*ca* 0.87
R3–R4	*ca* 0.70	*ca* 0.80
R4–R5	*ca* 0.72	*ca* 0.83
R5–R6	*ca* 0.61	*ca* 0.72
R6–R7	*ca* 0.67	*ca* 0.78
R*7*–R*8(?)*	*ca 0.73*	*ca 0.84*
Average side-to-side distance: **0.72 m**		
Average centre-to-centre distance: **0.83 m**		

d. Elevation of highest preserved bottom surface		
Feature	**Elevation (m)**	**Relative to previous (m)**
R1	-0.71	-
R2	-0.83	-0.12
R3	-0.82	+0.01
R4	-0.89	-0.07
R5	-0.90	-0.01
R6	-0.93	-0.03
R7	-0.97	-0.04
R*8(?)*	*-0.96*	*+0.01*
Average difference in elevation between R1–R7: **0.04 m**		

Table 5.1. Ramp of Slipway 2, dimensions of rock-cut slots for transverse timber sleepers. Average bottom width: 0.11 m; average depth: 0.11 m; average side-to-side distance: 0.72 m; average centre-to-centre distance: 0.83 m; average difference in elevation between slots: 0.04 m.

(Figs. 168, 186, 192a–192b, 105–110; Table 5.1). Based on its width and its distance to R7, R8(?) could be a ramp feature (see Table 5.1a, c); if so, the preserved ramp length may be extended to 5.92 m. The construction of the ramp of Shipshed 9 in Phase 2 has removed major parts of Slipway 2's ramp structure, thus providing important chronological information (Fig. 168). To the east, the ramp was not excavated due to the poor preservation of the bedrock. Intrusive dredging has destroyed the structure to the west.

The ramp features of Slipway 2 are aligned at a different angle (by 3.8°) than that of the surrounding Phases 2 and 3 colonnades dividing Shipsheds 8/9 (17(η)/18(χ)) and Shipsheds 9/10 (C18(χ)/19(φ)) (Pl. 11). This angle was computed following the orientation of the two longest and well-defined rock-cut slots (SW2:R4, 1.34 m; SW2:R5, 1.33 m) and three shorter slots (SW2:R2, 0.37 m; SW2:R3, 0.26 m; SW2:R7, 0.60 m). The features of this Phase 1 slipway are clearly not related to the surrounding Phases 2 and 3 features.

Open-passage

PL: 5.43 m; PW: *ca* 1.37 m

The northern part of OP/SWR2&3:1–2 was removed by the subsequent construction of Shipshed 9's ramp (S9:R3–R5). Similarly, the construction of the Phases 2 *a. Average bottom width*

Feature	Width (m)	Average (m)
R1	0.08–0.09	0.09
R2	0.07–0.08	0.08
R3	0.13	-
R4	0.11–0.12	0.12
R5	0.08–0.11	0.10
R6	0.08–0.10	0.09
R7	0.10	-
Average bottom width of R1–R7: **0.10 m**		

b. Average depth

Feature	Depth (m)
R1	0.05*
R2	0.04*
R3	0.10
R4	0.12
R5	0.12
R6	0.11
R7	0.07
Average depth of R3–R7: **0.10 m**	
* Not preserved to original depth	

c. Average distance between slots

Features	Width (side-to-side) (m)	Width (centre-to-centre) (m)
R1–R2	*ca* 0.76	*ca* 0.85
R2–R3	*ca* 0.76	*ca* 0.87
R3–R4	*ca* 0.64	*ca* 0.77
R4–R5	*ca* 0.68	*ca* 0.79
R5–R6	*ca* 0.58	*ca* 0.67
R6–R7	*ca* 0.58	*ca* 0.67
Average side-to-side distance: **0.67 m**		
Average centre-to-centre distance: **0.77 m**		

d. Elevation of highest preserved bottom surface

Feature	Elevation (m)	Relative to previous (m)
R1	-0.68	-
R2	-0.75	-0.07
R3	-0.79	-0.04
R4	-0.86	-0.07
R5	-0.88	-0.02
R6	-0.88	0.00
R7	-0.92	-0.04
Average difference in elevation between R1–R7: **0.04 m**		

Table 5.2. Ramp of Slipway 3, dimensions of rock-cut slots for transverse timber sleepers. Average bottom width: 0.10 m; average depth: 0.10 m; average side-to-side distance: 0.67 m; average centre-to-centre distance: 0.77 m; average difference in elevation between slots: 0.04 m.

and 3 colonnades (C9/10:1, C18/19:4) destroyed OP/SWR2&3:1–2 towards the south (Figs. 168, 186). To the west, the open-passage was destroyed by dredging, and the remains to the east were probably destroyed either by modern harbour works or the construction of U:14B(?) (Pl. 40).

The bedrock around the southern ends of SW2:R1 (*ca* 0.10 m) and R7 (0.11 m) is preserved to a height similar to that of the well-preserved open-passage (OP/SWR3(S):1) in Slipway 3 (average height above slots: 0.10 m; see Table 5.2b) (Fig. 225a), therefore indicating that parts of the Phase 1 open-passage are preserved in the areas around SW2:R1 and R7. The central portions have been damaged by erosion and by the construction of later unidentified features U:20–21 (Fig. 189). The poor state of preservation of original surfaces does not allow the gradient of this open-passage to be calculated with any degree of accuracy.

5.2.3. Slipway 3

Cat. nos: SW3:R1–R7; OP/SWR3(S):1

Ramp

PL: 4.61 m; PW: 1.47 m (SW3:R5); G1-HB: 1:20.1 (2.8°); G2-T: 1:18.9 (3.0°); G3-B: 1:18.6 (3.1°)

The ramp of Slipway 3 is preserved for a total length of 4.61 m (Pl. 3). Seven rock-cut slots for transverse timber sleepers were identified (Figs. 169, 193, 111–119; Table 5.2). Slipway 3 lies on a slightly different alignment (by 0.9°) from the surrounding Phases 2 and 3 colonnades (Pl. 11). The construction of the ramp structure of Shipshed 10 (S10:R1–R2) destroyed major parts of Slipway 3's ramp. Specifically, the construction of S10:R2 during Phase 2 demolished SW3:R1–R3 and shaved off the top parts of SW3:R4–R7 (Figs. 169, 193–194, 198b, 226b, 111, 120), whereas the construction of S10:R1 left intact only the probable bottom surface of the rock-cut slot SW3:R7 (Figs. 169, 198a, 199e, 226a). Farther to the north, the construction of U:22 destroyed this part of the ramp. However, the southern part of Slipway 3 with its well-preserved features represents the best evidence of Phase 1 slipways in Area 1 (Figs. 193, 111).

Open-passages

PL: 7.60 m; PW: 2.62 m; G2-T: 1:19.8 (2.9°)

OP/SWR3(S):1 is defined on the north side by the ends of the rock-cut slots SW3:R1–R7. The south side of this open-passage has been destroyed by the possible Phase 3 colonnade feature C19/20:3(?), the Phase 2 column base foundation trench C10/11:2 and U:31 (Figs. 169, 198e, 199a, 111). The west side of OP/SWR3 (S):1 was destroyed by dredging, and the remains to the east were probably destroyed either by modern harbour works or the construction of U:14C(?) (Pl. 40).

5.2.4. Slipway 5

Cat. nos: SW5:R2–R8; OP/SWR4&5:1

Ramp

PL: 6.07 m; PW: 4.34 m (SW5:R6); G1-HB: 1:19.3 (3.0°); G2-T: 1:18.7 (3.1°); G3-B: 1:16.9 (3.4°)

A 6.07 m-long section of the Phase 1 ramp of Slipway 5 was excavated in the sea (Pl. 3; Figs. 170, 200, 205b; Table 5.3). The structure continues under the modern quay to the east. Towards the west, the structure appears to have been destroyed, but it may continue into the unexcavated area farther west. The southern part of the structure is mostly covered by the concrete foundations of a modern sewage outlet built directly on top of the ancient remains. The ramp elements are very eroded and completely destroyed in some areas. A total of seven ramp features, or rock-cut slots, were identified as belonging to this slipway: four of these are quite distinct (SW5:R4, R6–R8) and three are only partially preserved (SW5:R2–R3, R5; Fig. 200). There was probably a ramp feature in the damaged area between SW5:R3 and R4.

The side-to-side measurement between SW5:R4 and SW5:R5 (0.47 m) is the shortest documented in Area 1; the side-to-side distance from SW5:R5 to SW5:R6 (0.75 m) falls within the distance range of other ramp features associated with Slipway 5 (range: 0.56–0.81 m).

The southern part of SW5:R6 was destroyed by the construction of the Phase 2 colonnade feature C13/14:2 (Figs. 170, 200–201). The Phase 3 colonnade C22/23:5 (Fig. 202) removed the southern end of ramp feature SW5:R5. There are no traces in this area of ramp features SW5:R3–R4, as the northern top edge of C22/23:5 is constructed below their respective bottom elevations (*ca* 0.01 m to 0.13 m; Fig. 227a).

The preserved remains of rock-cut slots SW5:R4, R6–R8, slope 0.05–0.07 m downward to the south along their axes, probably due to the natural shape of the bedrock. This strongly indicates that less work was expended in levelling the timber sleepers placed in the slots, or less likely, that the individual rock-cut features were not levelled because the sleepers were the foundations for a more complex timber ramp structure that was adjusted above the sleepers. To the north, the later construction of U:14D in all probability removed SW5:R5 (Figs. 170, 205b), while the southern portion of the ramp feature remains preserved because it, like the other slots SW5:R4, R6–R8, was also sloping down towards the south along its axis.

Compared with the orientation of the rock-cut slots SW5:R4, R6, R8, slot SW5:R7 is misaligned slightly

a. Average bottom width		
Feature	**Width (m)**	**Average (m)**
R2	*ca* 0.14	-
R3	*ca* 0.12–0.15	0.14
R4	0.13–0.16	0.15
R5	*0.19*	-
R6	0.12–0.14	0.13
R7	0.11–0.15	0.13
R8	0.12–0.13	0.13
Average bottom width of R2–4 and R6–8: **0.14 m**		

b. Average depth	
Feature	**Depth (m)**
R2	n/a
R3	n/a
R4	0.08
R5	0.02*
R6	0.10
R7	0.08
R8	0.06*
Average maximum preserved depth of R4, R6–R7: **0.09 m**	
* Not preserved to original depth	

c. Average distance between slots		
Features	**Width (side-to-side) (m)**	**Width (centre-to-centre) (m)**
R2–R3	*ca 0.76*	*ca 0.90*
R3–R4	*ca 1.55*	-
R4–R6	*ca 1.41–1.45*	-
R4–R5	*ca 0.47*	*ca 0.64*
R5–R6	*ca 0.75*	*ca 0.91*
R6–R7	*ca* 0.78	*ca* 0.91
R7–R8	*ca* 0.57	*ca* 0.70
Average side-to-side distance: **0.68 m**		
Average centre-to-centre distance: **0.81 m**		

d. Elevation of highest preserved bottom surface		
Features	**Elevation (m)**	**Relative to previous (m)**
R2	-0.41	-
R3	-0.44	-0.03
R4	-0.53	-0.09/2: -0.045
R5	-0.61	-0.08
R6	-0.63	-0.02
R7	-0.69	-0.06
R8	-0.68	+0.01
Average difference in elevation between R2–R3 and R6–R8: **0.03 m**		

Table 5.3. Ramp of Slipway 5, dimensions of rock-cut slots for transverse timber sleepers. Average bottom width: 0.14 m; average depth: 0.09 m; average side-to-side distance: 0.69 m; average centre-to-centre distance: 0.83 m; average difference in elevation between slots: 0.03 m.

more than 3° (Fig. 200). This is most likely an error in construction rather than a variation in orientation representing two building phases. The northern end of SW5:R4 curves slightly eastward, and is probably also an error in construction. The differing alignments and curvature in the sleeper cuttings, however, would have had no effect on how the structure functioned when ships were being hauled and launched.

Three unidentified rock-cut features (U:32–U:34) were recorded in the slipway area, but they have no apparent relation to Slipway 5 (Figs. 170, 203).

Open-passages
PL: 3.54 m; PW: 1.68 m
The remains of OP/SWR5(N):1(?) are severely damaged and eroded, with no original top surface preser-

ved (Fig. 200). The feature is the worked and inclined bedrock between the southern side of the later colonnade features C12/13:1 and C21/22:6, and the northern side of ramp features SW5:R3–R4 (Fig. 170). The construction of later colonnade features destroyed the northern side. To the west the feature was destroyed by U:14D (Fig. 170). To the east it continues under the modern quay. The state of preservation does not allow the gradient to be calculated with any accuracy.

5.2.5. Slipway 6

Cat. nos: SW6:R1, R2(?); OP/SWR6(S):1–2

Ramp

The construction of the ramp structure of Shipshed 14 during Phase 2 has completely destroyed the northern side of the slipway remains (Figs. 171, 206, 121). The southern portion is mostly destroyed also, with the exception of SW6:R1 and perhaps SW6:R2(?). The top of SW6:R1 was shaved off during the construction of the later ramp feature S14:R1 (Figs. 171, 121). The rock-cut slot SW6:R1 (bottom depth: -0.36 m) has roughly the same longitudinal orientation and bottom elevation as SW5:R2 (bottom depth: -0.41 m). The side-to-side distance between the adjacent slots SW6:R1 and R2(?) is 0.61 m, and the centre-to-centre distance is 0.71 m. These figures fall within the range of the spacing of other identified slots from Area 1 (side-to-side: 0.57–0.85 m; centre-to-centre: 0.67–0.96 m), thus suggesting SW6:R2(?) is likely a ramp feature.

Open-passages

PL: *ca* 6.16 m; G2-T: 1:17.0 (3.4°)

The top surfaces of the rock-cut open-passage OP/SWR6(S):1–2 is eroded and heavily damaged by rock-boring marine organisms. The delineation of the ramp towards the north is defined by the southern end of SW6:R1 (Fig. 206). The construction of the Phases 2 and 3 colonnades (C14/15:1, C23/24:8) has destroyed parts of the open-passage (Fig. 171). Part of the same open-passage, OP/SWR6(S):2, is preserved to the south of these colonnades (C14/15, 23(Π)/24(Φ)). This is clearly shown in the sections surveyed on either side of the colonnade features (Fig. 225b). OP/SWR6(S):1-2 continue east under the modern concrete quay, and OP/SWR6(S):2 continues into the unexcavated area to the south, and the total excavated width of OP/SWR6(S):1–2 is 3.41 m. U:14E has destroyed OP/SWR6(S):1 towards the west (Fig. 171).

Summary

From the data discussed above, it is possible to furnish working averages of the dimensions of the Phase 1 rock-cut slots for transverse timber sleepers. Table 5.4 lists the averages and range of these dimensions.[9] Twenty-two ramp features furnish an average width of 0.11 m for the rock-cut slots. Twelve features give an average preserved depth of 0.10 m. In 14 instances an

a. Width and depth averages

Slipway	Width average/range (m)	Depth average/range (m)
1	0.14 [1]	0.11 [1]
2	0.11 [7]/0.10–0.12	0.11 [2]/0.10–0.11
3	0.10 [7]/0.08–0.13	0.10 [5]/0.07–0.12
5	0.14 [6]/0.13–0.15	0.09 [3]/0.08–0.10
6	0.08 [1]	0.11 [1]

b. Distance, side-to-side and centre-to-centre

Slipway	Side-to-side/ centre-to-centre (average) (m)	Side-to-side/centre-to-centre (range) (m)
2	0.72/0.83 [6]	0.61–0.85/0.72–0.96
3	0.67/0.77 [6]	0.58–0.76/0.67–0.87
5	0.68/0.81 [2]	0.57–0.78/0.70–0.91

Table 5.4. Phase 1 Slipways 1–3, 5–6, averages and range of dimensions of rock-cut slots for transverse timber sleepers. The figure in brackets is the number of features on which the average calculation is based.

9. The individual features used in the average calculation are listed under the detailed description of Slipways 1–3, 5–6.

	Length (m)	Width (m)	Depth (m)	Distance (m)	Centre-to-centre (m)
Range	3.00–3.20	0.13–0.23	0.09–0.13[16]	0.62–0.89	-
Average	*ca* 3.13	*ca* 0.19	*ca* 0.12	*ca* 0.80	0.99[17]

Table 5.5. Kos City: dimensions of slots for transverse timber sleepers (Kantzia 1987: fig. 12).

average side-to-side distance of 0.69 m was obtained between adjacent rock-cut slots, with an average centre-to-centre distance of 0.80 m.

5.3. Comparative Ramp Data from Other Slipway and Shipshed Sites

Shipshed and unroofed slipway sites in the Mediterranean have construction features comparable to Slipways 1–3, 5–6 in Area 1 of Zea Harbour. At Zea (Pl. 3) these include one identified and one posible ramp structures with similar rock-cut slots for transverse timber sleepers that were found in Area 2 (partially destroyed and overbuilt by later shipshed structures), and two possible ramp structures in Area 3. A single ramp feature was found in a built-up ramp structure in Area 5; work in these areas is ongoing.[10] In Mounichia, Graser found "grooves/furrows in the bedrock" (*rillen im felsboden*) that may be cautiously interpreted as rock-cut slots for transverse timber sleepers, although they could also be remains of quarrying activities or other features.[11]

Slipways and shipsheds with comparable ramp constructions incorporating transverse timber sleepers and open-passages or side-passages have been found in Kos City, Mandraki (Rhodes City), Marseille (Place Villeneuve-Bargemon and Place Jules-Verne), Sitea (Crete) and Punic Carthage (the Circular Harbour). The data from these structures are supplemented by two possible ramp blocks found in Thasos harbour. These sites are analysed here to determine whether the conclusions regarding the forms and construction methods of the Phase 1 slipways in Area 1 have parallels at other sites around the Mediterranean. It should be cautioned, however, that much of the evidence is published only in preliminary reports of variable quality, and all of these structures postdate those identified in Zea, some by as much as three centuries.[12]

Kos City, Kos (Dodecanese)

During rescue excavations in the ancient harbour, Kantzia excavated *ca* 14 m of a very well-preserved ramp structure in the shipshed to the north-west. Two parallel rows of blocks with rock-cut slots for transverse timber sleepers comprise the frame-constructed ramp structure and the transition to the side-passages (Fig. 52). This structure is dated to the 3rd century BC.[13] Kantzia reports a ramp gradient of 1:10 and Blackman mentions an inclination of 1:11.[14] According to spot-heights on Lianos' plan the southeast row of blocks forming the transition between the ramp and side-passages has an inclination of 1:11 (5.2°), whereas the northwest row has an inclination of 1:18 (3.2°) (Fig. 52).[15] This discrepancy in inclination can be explained by the longitudinal-section E–E of the northwest row in Kantzia's report (Fig. 52c); it is clear that the ramp structure curves upwards at the southwestern end, and since this section is curvilinear, a gradient calculation is not attempted. The published gradients do not represent the actual gradient of the extant ramp structure.

10. The slipways, shipsheds, possible slipways and shipsheds found in Areas 2 and 3 will be published in the forthcoming volume, *The Ancient Harbours of the Piraeus, Vol. II*.
11. Graser 1872: 40.
12. For a discussion of the Phase 1 chronology see Chapter 9.2.1.
13. Kantzia 1992: 632–635, fig. 12. Ceramics dating to the 3rd century BC were found in the hard lime fill in the frame-constructed ramp. They furnish a *terminus post quem* for the ramp structure. In the southeast side-wall there are re-used ramp blocks similar to those found in the ramp structure, which suggests that there was more than one building phase.
14. Kantzia 1992: 634; Blackman 2004: 78.
15. Lianos 1999: 269, fig. 6. The southeast row of blocks descends from +1.03 m to +0.48 m over a distance of 6.2 m, so an inclination of 1:11 (5.2°); the northwest row of blocks descends from +1.19 m to +0.67 m over 9.3 m, so an inclination of 1:18 (3.2°).
16. Kantzia 1992. They are scaled off fig. 12: Sections Δ–Δ (0.13/0.13 m) and Λ–Λ (0.09 m).
17. Based on an average width of 0.19 m.

Ramp of shipshed BC				
Feature	**Length (m)**	**Width (m)**	**Depth (m)**	**Side-to-side/centre-to-centre (m)**
1	*ca* 0.40	*ca* 0.40	-	R1-R2: *ca* 0.55/0.95
2	*ca* 0.40	*ca* 0.40	-	
Average	**0.40**	**0.40**		
Ramp of shipshed CD				
Ramp	**Length (m)**	**Width (m)**	**Depth (m)**	
1	*ca* 0.25	*ca* 0.20 (Plan: *ca 0.25*)	*ca* 0.25	
2	*ca* 0.30	*ca* 0.30 (Plan: *ca 0.15*)	*ca* 0.25	
3	0.30	*ca* 0.20	*ca* 0.20	
4(?)	no measurements scaled			
5	0.25	*ca* 0.25	*ca* 0.20	
Average	**0.28**	**0.24**	**0.23**	

Table 5.6. Mandraki, Rhodes City: dimensions of slots for transverse timber sleepers (Blackman, Knoblauch & Yiannikouri 1996: figs. 6–7).

Six pairs of rock-cut slots for sleepers are preserved. Three blocks were found in the middle of the ramp structure, and they each have a slot aligned to a pair of rock-slots on both sides; they are a unique example of how extra stability was supplied to a transverse timber. The ramp dimensions in Table 5.5 are scaled from the plan published by Kantzia.

Mandraki, Rhodes City, Rhodes (Dodecanese)

Two or perhaps three shipshed ramps (Knoblauch's Period 4) dated to the first half of the 2nd century BC were excavated at Mandraki near the modern harbour of Rhodes City.[18] Each has probable rock-cut slots for housing transverse timber sleepers (Fig. 49). On the western side of shipshed CD, Knoblauch recorded four or perhaps five features that are most likely related to receiving transverse timber sleepers.[19] In the western side of shipshed BC were also documented two probable ramp features,[20] and in the eastern portion of shipshed DE were found the very eroded remains of two similar features.[21]

Knoblauch's data are not easy to interpret in all cases. The width of shipshed CD's ramp feature 2, for example, varies markedly between the plan and section (plan: 0.15 m; section: 0.30 m). Unfortunately, the investigators have failed to account for, or correctly report, certain critical dimensions such as depths and lengths of the slots for transverse timber sleepers. Further, no spot-heights were taken on these features.[22] On the section of shipshed CD, the inclination of the slots appears to be close to that of the side-passage structure (1:4.23) on which spot-heights were taken

18. Blackman, Knoblauch & Yiannikouri 1996: 408. The ceramics from layer 2α date from the 4th century BC to the first half of the 2nd century BC. The latest material provides a *terminus post quem* for the ramp features (Period 4).
19. Blackman, Knoblauch & Yiannikouri 1996: 379–380, fig. 6. In this study the Mandraki shipsheds are named after their load-bearing elements of the superstructure (e.g., shipshed CD; see fig. 40).
20. Blackman, Knoblauch & Yiannikouri 1996: 380–384, figs. 6–7.
21. Blackman, Knoblauch & Yiannikouri 1996: 384.
22. The dimensions listed in Blackman (1990a) are inconsistent and are therefore not included in this study. For example, in their 1996 article (p. 380), Blackman, Knoblauch & Yiannikouri describe the slot width of ramp BC as *ca* 0.30 m. Earlier, Blackman (1990b: 42) records it as 0.15–0.20 m. In Blackman's 1996 interpretation of these features (Blackman, Knoblauch and Yiannikouri 1996: 400), no measurements are listed. Fortunately Knoblauch's architectural drawings allow scalable dimensions: 0.40 m on average.

(Fig. 49).[23] The length and width of shipshed BC's ramp features, as well as the dimensions of the ramp features of shipshed CD, can be scaled from Knoblauch's plan and section (Table 5.6). The position of the rock-cut slots varies markedly, and in this study the distances between these features are not used.

The reconstructed length of the transverse timber sleepers, and thus the width of the ramp structure, is estimated at about 2.85 m, based on the distance between the western-most ramp sides of shipsheds BC and CD (*ca* 5.75 m), and the distance from the centre of the colonnade foundations dividing shipsheds CD and DE to the western side of ramp CD (*ca* 1.45 m).[24]

Blackman argues that these rock-cut slots were used either as (a) slots for timber shores used to stabilise the hull from its sides, or (b) slots for transverse ramp timbers (his favoured explanation) or (c) a combination of the two.[25] Although none of the features are preserved in pairs, it is more probable that the slots housed transverse ramp timbers rather than functioned as slots for timber shores, particularly with a width of just under 0.40 m, as seen in the ramp of shipshed BC where they are spaced 0.55 m apart.

Marseille (France)

At Marseille earthen ramps with well-preserved timber remains were found at two sites, Place Villeneuve-Bargemon and Place Jules-Verne (Figs. 53–54). At Place Jules-Verne the excavators found the remains of three well-preserved timber ramps, called here slipways A-C (Fig. 54).[26] A number of rounded timbers were found on these ramps with ropes tied around their ends, and they are identified as timber rollers by the excavators. It is not clear from the published material whether this interpretation is correct, or if the ropes simply fastened the sleepers to the ramp structures.[27] No detailed sections or measurements have been published, and the gradient remains unknown here, as well as at Place Villeneuve-Bargemon. The measurements discussed in the following paragraphs were scaled from the plan. No information on the wood type(s) of the sleepers has yet been published.[28]

Slipway A (length about 17.6 m) was constructed of interlocking timbers set in hard-packed sand (Fig. 54), creating a ramp area about 5.8–6.3 m wide. The longest timber features are about 4.3–4.6 m long. In Slipway B (length about 14.4 m) the ramp area is narrower (about 4.5–4.7 m) and the longest timbers are about 3.2–3.8 m. Slipway C's (length about 15.0 m) interlocking ramp is about 4.4 m wide, and the longest timbers are about 3.5–3.6 m. The open space between ramps A and B is about 3.1 m, whereas there is no discernible open space between ramps B and C. This may signify that it is one large ramp area.

There is no evidence of a ramp structure above the timber sleepers and possible rollers, a clear indication that the keel rested directly on them. These structures have been dated by the excavators to the 3rd to 2nd centuries BC (Fig. 54).[29]

At Place Villeneuve-Bargemon the transverse timber sleepers set in sand were associated with three walls (labelled here walls 1–3) and identified as shipsheds. This identification is problematic, however. Firstly, when extrapolated, the western-most wall (wall 1) runs across one of the timber sleepers. Wall 1 may belong to a later shipshed phase, but the ramp feature in question cannot belong to this superstructure. Secondly, between walls 1 and 2 the preserved ramp features are off-centre towards the west. The timbers could belong to one side of a ramp that was constructed with interlocking sleepers, as seen at Place Jules-Verne (Fig. 54). But one timber west of wall 1 is definitely off-centre, as wall 1 runs across it. If another wall is reconstructed to the west of wall 1, with the same interaxial spacing as walls 1–2 and 2–3 (*ca* 7.8 m), then this feature runs directly across one of the most substantial ramp timbers (Fig. 53). Thirdly, according to the plan, the nearest ramp feature was found about 23 m from the inside of the back-wall,[30] an excessive distance not seen at

23. Blackman, Knoblauch & Yiannikouri 1996: 380–384.
24. 5.75 m - (2 x 1.45 m) = 2.85 m. The measurements have been scaled off Blackman, Knoblauch & Yiannikouri 1996: fig. 6. The distance between the ramps (5.75 m) differs from the interaxial spacing between the colonnades of shipshed CD (fig. 24; 5.94 m).
25. Blackman, Knoblauch & Yiannikouri 1996: 400–401.
26. Hermary, Hesnard & Tréziny 1999: 125–126, plan (p. 156); Hesnard 1999: 37–38.
27. Hermary, Hesnard & Tréziny 1999: 125, detailed photos of possible rollers (Hesnard 1999: 37).
28. Hermary, Hesnard & Tréziny 1999: plan (p. 156).
29. Hermary, Hesnard & Tréziny 1999: 125, 127.
30. Hermary, Hesnard & Tréziny 1999: plan (p. 156).

any shipshed site, which suggests that these ramp features are not related to walls 1–3. No ramp would have been needed where the unknown point of a warship's stern rise began; in any event, the required distance was clearly shorter than 23 m (see p. 137). It is possible that the ramp was not preserved in this area. Furthermore, spur-walls projecting about 0.50–0.80 m from the side-walls are not an architectural feature observed at any other shipshed site; such a construction method would severely limit storage and working space and is not a logical shipshed design.

Based on the published data it is not possible to identify the structures at Place Villeneuve-Bargemon as shipsheds. Instead the timber ramps should be considered as belonging to unroofed slipways predating walls 1–3, and the walls may belong to another structure type, such as a storage building. Here the timber sleepers are spaced 1 m apart,[31] a measurement that probably refers to an average side-to-side distance. No other detailed dimensions are published to date, but the approximate length of the three longest ramp features at Place Villeneuve-Bargemon can be scaled from the published plan at about 3.5 to 4.4 m (Fig. 53). The excavators date the structures to the 3rd to 2nd centuries BC.[32]

Sitea (Crete)

In the rock-cut slipway, Baika identifies the submerged remains of four pairs of slots as being for timber sleepers, one of which is also visible on Davaras' plan and section. Based on the preliminary plan, the slots are 0.40–0.45 m wide and spaced about 1.5 m apart; they extend 7.0 to 9.5 m across the ramp.[33] The structure is in all probability ancient but cannot be dated with any precision.

Carthage, The Circular Harbour (Tunisia)

Hurst excavated two shipshed ramps with *in-situ* remains of transverse timber sleepers on Ilôt de l'Amirauté (ramps 13, 16; Figs. 37–39), and a similar ramp in the north/northeastern part of the harbour (ramp F762; Figs. 38, 40–41). The three excavated ramps were constructed of fill consisting of clay-sand with a high concentration of marine shells.[34] The shipsheds are dated to the 2nd century BC, with a *terminus ante quem* anchored to Carthage's destruction by Rome in 146 BC.

Ramp 13. A section of ramp 13 was excavated about 25 m from the waterline for a length of about 5 m (Figs. 38–39). The remains of two carbonised timber sleepers were found *in situ*. On the accompanying plan (1:50), the western sleeper is shown as *ca* 2.25 m long and *ca* 0.15 wide. The eastern sleeper is shown as *ca* 1.95 m long and *ca* 0.20 m wide. Their heights are not specified (Fig. 39). The gradient that was scaled off the section by the present author is 1:6.9 (8.3º);[35] according to Hurst the gradient between 25.5–29.5 m is about 1:6.[36] The distance between the two sleepers is *ca* 2.50 m (*ca* 2.70 m centre-to-centre). Ramp 13 has four compartments between the sleepers; Hurst tentatively recognises them as later features cut into a regular ramp.[37] Compared to other sites the spacing of the timbers on ramp 13 appears too wide (Table 5.8), especially when the elasticity of the foundation material is taken into consideration. On the other hand, these compartments, if related to the original ramp design, may have permitted access to the underside of a stored hull.

Ramp 16. Hurst excavated ramp 16 for 28 m and found several remains of well-preserved timber sleepers *in situ* (Figs. 37–38).[38] The sleepers are described generally as *ca* 0.15 m wide, *ca* 0.10 m high and set 0.60 and 0.70 m apart; the individual tranverse timbers were not excavated for their entire length.[39] Both measurements probably refer to the distance between the adjacent sides of two sleepers. Some of the individual sleepers appeared to have been made up of timbers laid end-to-end. Another timber was discovered perpendicular to the sleepers, but it was unclear whether it was related to the ramp structure.[40] No detailed plans, sections or information on the

31. Hesnard, Bernardi & Maurel 2001: 174.
32. Hermary, Hesnard & Tréziny 1999: 125, 127.
33. Davaras 1967: fig. 1; Baika 2003a: 104, fig. 16.6. Length and depth of features are not listed.
34. Hurst 1994: 34–35.
35. Hurst 1981: fig. 5, gradient measured between right bottom sides of depressions left by timber sleepers.
36. Hurst 1994: 35.
37. Hurst 1981: 17, figs. 4–5.
38. Hurst 1979: 24, fig. 1.
39. In Hurst 1979: 24, described as set at intervals of about 0.60 m; in Hurst 1994: 33, described as being set between 0.60–0.70 m.
40. Hurst 1979: 24.

Feature	Length (m)	Width (m)	Height/depth (m)	Distance: nearest sides of slots (m)
Block	*ca* 2.40	*ca* 0.50	*ca* 0.35–0.40	*ca* 0.95
Left-hand slot	*ca* 0.40	*ca* 0.20–0.30	*ca* 0.20	
Right-hand slot	*ca* 0.35	*ca* 0.20–0.25	*ca* 0.20	

Table 5.7. Thasos City: possible ramp block (Lianos 1999: fig. 5).

wood type(s) of the transverse sleepers have yet been published.

About 25 m from the modern shoreline the ramp was located at an elevation of +1.3 m. Hurst assumes that it may have had "the usual gentle slope" on the first section. On the section of ramp 16 (Fig. 38) the excavated middle portion has a gradient of 1:15 (3.8°); this measurement appears to be precise for the first section of the ramp.[41] Between 25.0 to 29.0 m the ramp changes to a gradient of 1:10 (5.7°). From 29.0 to 35.0 m it is more steeply inclined at 1:6.3 (9.0°).[42]

Ramp F762. According to Hurst the two timber sleepers making up ramp F762 are *ca* 1.7–1.8 m long and are set 1.70 m apart (Fig. 40). It is not impossible that there existed a timber sleeper between the two preserved features, especially when comparing the arrangement with ramp 16 where the timbers are set 0.60–0.70 m apart.[43] On the section (Fig. 41), the southern-most timber sleeper is *ca* 0.25 m wide and has a height of *ca* 0.07 cm. The bottom of the slot for the northern-most sleeper is *ca* 0.15 m; it widens towards the top and may have had an original width of about 0.25 m. The maximum depth is about 0.10 m.[44] Sleeper F779 has a slightly off-centre mortise hole, which Hurst reasonably argues is either the remains of a keel-runner or evidence of a re-used timber;[45] it is unlikely that a timber structure taller than a keel-runner was connected in this manner. The gradient of the first 24 m of the ramp is reconstructed at *ca* 1:20 (2.9°) based on the Punic 'quay' (the lower end of shipshed 4) in the south-east of Ilôt de l'Amirauté (-0.36 m) and a level point (+0.84) on the ramp. The gradient of the subsequent 4.70 m is about 1:6 (9.5°).[46]

The gradient calculations of ramps 16 and F762 should be used cautiously, as they are based on very few spot-heights. Hurst argues that the quay-side was likely submerged, but this is highly unlikely as the architectural details were clearly built to be seen (Fig. 38). The quay would have created a rounded *stylobate* and would have matched the Ionic columns described by Appian (*Libyca* 96). It is much more likely that the sea level in the 2nd century BC was below the third convex element (depth: below 1 m on section; Fig. 38).

Thasos City, Thasos (Northern Greece)

Two possible ramp blocks with slightly trapezoidal, rock-cut slots were found during dredging works in the western part of the ancient naval harbour of Thasos town. The dimensions in Table 5.7 were scaled of Lianos' drawings of one of these blocks.[47]

41. Scaled off Hurst 1994: fig. 3.2. If reconstructed with the elevation of the lower end of shipshed 4 (-0.36 m), the first 25 m of ramp 16 would have a gradient of *ca* 1:15 (3.8°) (1.66 m change in elevation over 25 m).
42. Hurst 1994: 35.
43. Hurst 1994: 34.
44. Scaled off Hurst 1994: figs. 12.2–12.3.
45. Hurst 1994: 33–35, figs. 12.2–12.3.
46. Hurst 1994: 34–35.
47. Lianos 1999: 262–263, figs. 5a–5c. If the block is related to a slipway or the ramp of a shipshed, it is not possible to determine whether it was lying on the wide side, or standing on the narrow side. The measurements are scaled as presented on the drawing.

Summary

Based on the analysis of other sites (Table 5.8), the following observations on transverse ramp sleepers, in most instances scaled from plans and sections, can be made.

The widths of the slots that received ramp timbers at Kos and Mandraki (shipshed CD), and the widths of the actual ramp timbers found at Carthage (ramps 13, 16 and F762), fall within a homogeneous group with an average width of between *ca* 0.15 and *ca* 0.25 m. The Phase 1 features at Zea are the narrowest (0.11 m), whereas those found at Mandraki (shipshed BC, *ca* 0.40 m) and Sitea (*ca* 0.45 m) are the widest (Table 5.8a).

The average depth of the ramp features at Kos and in Area 1 at Zea are comparable at *ca* 0.12 and 0.10 m, respectively, whereas the features in shipshed CD at Mandraki are much deeper at *ca* 0.23 m. At Carthage the preserved ramp timbers are *ca* 0.10 m in height (Table 5.8b).

The average length of the transverse ramp sleepers can be arranged according to three groups: 1) Carthage, ramp F762 (*ca* 1.75 m) and ramp 13 (*ca* 2.10 m); 2) Kos (*ca* 3.13 m) and Mandraki (reconstructed at *ca* 2.85 m); and 3) Marseille, Place Jules-Verne (maximum *ca* 3.6–4.6 m), Place Villeneuve-Bargemon (maximum *ca* 4.4 m) and Phase 1 in Area 1 at Zea (maximum preserved length 4.34 m) (Table 5.8c).

The average side-to-side and centre-to-centre distances between transverse ramp sleepers vary considerably, and there are no similarities (Table 5.8d).

5.4. Discussion of the Phase 1 Slipways

5.4.1. Method of Construction

At Zea Harbour, the tool marks identified in features SW3:R3, R7 and possibly in SW2:R2, SW3:R4–R5 and in other parts of SW3:R7 are particularly crucial for understanding the construction of the rock-cut slots for transverse timber sleepers (Figs. 193, 111).

Initially, the ramp and open-passage areas were hewn out of the bedrock at the required inclination, and this initial stage of construction appears to have been carried out quite precisely (see G2-T calculations, Table 5.10). The low gradient of the Phase 1 slipways would have required considerable removal of bedrock where the slope was steeper than their gradient (for example: ramp of SW3, G-T2: 1:18.9/3.0°; open-passage OP/SWR3(S): 1:19.8/2.9°). The process would have been labour intensive and in all probability dictated that the first slipways were laid out in areas where less bedrock would have had to be removed.

The locations of the rock-cut slots were roughly measured out next. As discussed above, the centre-to-centre spacing between the individual features varies noticeably, for example from 0.67 to 0.87 m (centre-to-centre) in Slipway 3. It is apparent that no standard unit of measurement was used. Furthermore, the change of depth of the bottom surfaces along the axes of the preserved individual slots varies from 0.01–0.02 m (Slipways 2 and 3) to 0.05–0.07 m (Slipway 5). The marked variation in bottom elevations of the rock-cut slots (Table 5.9) and the slope along the transverse axes of these features also indicate that precision was not an objective during this stage in the construction. The slope of the bottom of these slots must have been adjusted by or compensated for by the inserted timber sleepers, or perhaps levelled in a more advanced ramp structure.

The corners, sides and possibly points along the centre of the rock-cut slots were drilled (SW3:R6–R7; Figs. 116–117). Channels connecting the drill holes were then chiselled out where necessary (Fig. 118). The 0.06 m-wide chisel marks found in the southern end of SW3:R7 are stepped down toward the north, demonstrating that the working direction was northward into the cutting (Fig. 119). The shallow depression along the bottom edges in the southern-most part of SW3:R6 shows that the sides were chiselled vertically (Fig. 118). The tool marks cross each other in the southwest corner – again, an indication that precision in construction was not an objective.

5.4.2. Design of Transverse Timber Sleeper Ramps

The non-extant timbers for the sleepers of the Area 1 slipways were likely not square but rectangular in cross-section: a square 0.11 x 0.11 m timber would not have protruded more than 0.01 m above the average-size sleeper slot, and it is obvious that the timbers must have protruded farther above the rock-

a. Sleeper width average/range		
Site	**Average width (m)**	**Range (m)**
Kos	*ca* 0.19 [16]	*ca* 0.13–0.23
Mandraki, shipshed BC	*ca* 0.40 [2]	-
Mandraki, shipshed CD	*ca* 0.24 [4]	*ca* 0.20–0.30
Sitea	*ca* 0.45 [8]	*ca* 0.40–0.45
Carthage, ramp 13	*ca* 0.18 [2]	*ca* 0.15–0.20
Carthage, ramp 16	*ca* 0.15 [?]	-
Carthage, ramp F762	*ca* 0.25 [1]	-
Zea, Group 1 (Area 1)	0.11 [22]	0.08–0.15

b. Sleeper depth/height, average/range		
Site	**Average depth/ height (m)**	**Range (m)**
Kos	*ca* 0.12 [2]	*ca* 0.09–0.13
Mandraki, shipshed CD	*ca* 0.23 [4]	*ca* 0.20–0.25
Carthage, ramp 16	*ca* 0.10 [?]	-
Carthage, Ramp F762	*ca* 0.10 [1]	-
Zea, Group 1 (Area 1)	0.10 [12]	0.07–0.12

c. Sleeper length, average/range		
Site	**Average length (m)**	**Range (m)**
Kos	*ca* 3.13 [6]	*ca* 3.00–3.20
Mandraki, CD and BC	about 2.85	-
Marseille, Jules-Verne	-	max *ca* 3.6–4.6
Marseille, Vil.-Bargemon	-	max *ca* 4.4
Carthage, ramp 13	*ca* 2.10 [2]	*ca* 1.95–2.25
Carthage, ramp F762	*ca* 1.75 [2]	*ca* 1.70–1.80
Zea, Group 1 (Slipway 5)	4.34+[1]	-

d. Distance side-to-side/centre-to-centre average/range		
Site	**Average side-to-side/ centre-to-centre (m)**	**Range side-to-side/ centre-to-centre (m)**
Kos	*ca* 0.80/*ca* 0.99 [9]	*ca* 0.62–0.89/-
Mandraki, shipshed BC	*ca* 0.55/0.95[1]	-
Marseille, Vil.-Bargemon	*ca 1.00 [?]*	-
Carthage, ramp 13	*ca* 2.50/*ca* 2.70 [1]	-
Carthage, ramp 16	*ca 0.60–0.70 [?]*	-
Carthage, ramp F762	*ca* 1.20–1.30 (1.45–1.55) [1]	-
Zea, Group 1 (Area 1)	0.69/0.80 [14]	0.57–0.85/ 0.67–0.96

Table 5.8. Ramp comparanda: Zea and other sites. The figure in brackets shows the number of features on which the average calculation is based. Note that at Carthage and Marseille the dimensions are based on actual transverse timber sleepers, whereas the dimensions from the remaining sites are based on rock-cut slots for transverse timber sleepers. Note: [?] = Plan or section material does not allow for scaled measurements, and/or publication does not specify how measurement was taken.

cut slots in order to connect with a vessel's keel and allow it to ride on the wooden ramp structure. For example, the keel in all probability stood directly on the timber sleepers (perhaps rollers) in the slipways found in Marseille.[48] At Zea, some additional height may have been added to the timber sleepers to prevent wear on the permanent wooden structure. The timbers themselves are therefore hypothetically reconstructed with a cross-section of approximately 0.11 x 0.17 m (Pl. 12).

The transverse timbers probably also protruded if they served as the foundations of a more sophisticated ramp structure; a mortise-and-tenon arrangement between the sleepers and a top timber in a structure much taller than a keel-runner, for example, would probably have been too weak a join at this critical, weight-bearing location, whereas a protruding sleeper would allow for a 'housed joint' timber construction.

At Zea, the Phase 1 transverse timbers sleepers would have been set fast in their slots along their entire length, thus minimising the need for greater sleeper width. By contrast, the timber sleepers set in clay-sand at Carthage were wider (0.15 m, 0.18 m and 0.25 m); the extra width was probably needed to compensate for the elasticity and softness of the ramp foundations. At Carthage, a mortise hole found in a timber on ramp F762 and the timber laid perpendicular to the transverse timbers in ramp 16 could be evidence of features that strengthened the ramps longitudinally. Perhaps these were the remains of keel-runners[49] or more advanced ramp structures (Figs. 37, 40). Since the timber sleepers of Phase 1 slipways at Zea were held in place by a rock-cut slot with an average cross-section of 0.11 x 0.10 m along their entire length, there would most probably have been no need for longitudinal stabilisation.[50]

At Kos the ends of the transverse timber sleepers were locked into slots in the parallel walls forming the ramp and the transition to the side-passages (Fig. 52); they were also likely set partly into the ramp fill between these parallel walls. Although the average widths of the slot cuttings at Kos are wider (0.19 x 0.12 m) and the sleepers shorter (ave. *ca* 3.13 m) compared to Slipway 5 at Zea (4.34 m+), central blocks with a slot were still required for extra support in the area on which the keel sat at Kos.[51] This may explain the massive timber sleepers found at Mandraki in Rhodes City (shipshed BC: 0.40 wide, depth unknown; shipshed CD: 0.24 x 0.23 m). Here the sleepers were probably also locked partly into the fill between the side-walls forming the transition between the ramp and the side-passages (Fig. 49).

The marked difference in sleeper cross-sections at Mandraki cannot be explained by the hypothesis that the larger sleepers were due to larger ships since the wider features are located in shipshed BC, whose inter-axial width (5.45 m) was narrower than shipshed CD (5.94 m). At Sitea, on Crete, the massive width of the rock-cut slots (0.45 m) can be explained by the wide span between each pair (7.0 to 9.5 m). Here the transverse timber sleepers may also have supported a jetty-like working area next to the ramp and side-passages.

The sturdy ramp structures at Zea would have permitted the replacement of whole or partial timbers worn down, broken or damaged by use or *Teredo navalis* and other marine organisms in the surf zone. Hurst reports that some of the carbonised timber sleepers found in ramp 16 at Carthage appeared to have been sawn and positioned end-to-end.[52] These features may be indicative of repairs or the use of shorter pieces of timber in the original ramp design, or both. Obviously, this design would reduce the strength of a ramp structure set in clay-sand.

At Marseille and Carthage, it is unlikely that the transverse timber sleepers set in an earthen or sandy fill extended under the water level, as even moderate wave action or current would re-deposit the earth and clay-sand foundations. On Ilôt de l'Amirauté at Carthage the outer end of shipshed 4 was reinforced by three courses of stone blocks,[53] but even then the water-logged timbers in the sediment would greatly increase the elasticity of the foundations at this critical point. As discussed above, the lower end of the Ilôt

48. Hermary, Hesnard & Tréziny 1999: 125, detailed photos of possible rollers (Hesnard 1999: 37).
49. Hurst 1994: 34.
50. The statics of the slipways were not calculated as the weight of a *trireme*, the wood type used for the transverse timbers, and thus the friction coefficient between ramp and *trireme* keel are unknown.
51. Lianos 1999: 268, fig. 6.
52. Hurst 1979: 24.
53. Hurst 1979: 26–27.

de l'Amirauté formed a rounded *stylobate* that was in all probability built to be seen (i.e. was above waterline). Furthermore, Coates argues that it is unlikely that timber ramps continued into the sea, because they would have been destroyed by *Teredo navalis* in a matter of a few months.[54]

On the other hand, timbers set close to the waterline, which would be perpetually wet, could have been smeared with pitch or another type of preservative to extend their use for as long as possible, as was routine practice for the hulls of wooden ships in antiquity. It will be argued in Chapter 8.1 that the Phase 1 transverse timber sleepers ramps at Zea in all probability extended under water to compensate for the changing tide, but the discussion of whether or not the wooden ramps at Marseille and Carthage extended into the sea must await full publication of these important sites.

5.4.3. The Width of the Phase 1 Slipways

The division between individual slipways is not as clear compared with shipsheds, where the superstructure creates a clear delineation between the individual ramps and their side-passages. In Area 1 at Zea there are no Phase 1 ramps or open-passages preserved to their full width, as the construction of later shipshed features obliterated major parts of this initial building phase (Pl. 40). The total slipway width, i.e. the *space* assigned to one ship, can only be derived by measuring the average distance between the southern ends of adjacent rock-cut slots making up the ramps of Slipways 2 and 3. This yields a width of *ca* 6.60 (average distance: 6.63 m) (Pl. 3). It should be noted that the ends of the rock-cut slots in the individual ramps are not aligned (Figs. 186, 193; Pl. 3). Further, attention should be drawn to the 4.7° difference (computed from rock-cut slots) in axial orientation between Slipways 2 and 3, which results in a convergence of the reconstructed ramps at the reconstructed shoreline, based on the hypothetical *maximum* sea level change of -2.90 m (Pl. 11; see Chapter 8.2.1). Therefore, it must be pointed out that the estimated total slipway width measurement applies only to this section of Slipways 2 and 3. The open access to Slipways 2 and 3 at the seaward end would still easily have allowed for the hauling and slipping of ships one at a time (Pl. 11).

The orientations of the rock-cut slots for transverse timber sleepers in the ramp of Slipway 5 and the single such feature in Slipway 6 are roughly similar to those features in Slipway 3 (Pl. 3). Thus the difference in orientation of 4.7° between the ramps of Slipways 2 and 3 may signify the corner or the beginning of a corner between two groups of slipways.

The average distance between the southern ends of the slots in Slipway 3 (SW3:R1, R3, R5–R7) and the northern ends of those in Slipway 5 (SW5:R4, R6–R7) is 16.51 m (Pl. 3). This distance probably represents the width of two full slipways plus the width of the additional two 'half' open-passages between their hypothetical ramps and the existing ramp structures in Slipways 3 and 5. The width of each of these hypothetical slipways would amount to about 6.60 m. These calculations lend some support to the estimated width between Slipways 2 and 3 of *ca* 6.60 m.

The width of the ramps and open-passages can be estimated only in approximate terms based on the following direct evidence:

1) *Slipway 2*. The maximum preserved width of the ramp is 1.34 m (preserved bottom length of SW2:R4). At this point the ramp has been destroyed by Shipshed 9 (S9:R2; Fig. 168), and as the northern top edge of Shipshed 9's ramp foundations (S9:R1–R2) is either at the same level or 0.04–0.05 m above the corresponding Slipway 2 ramp features south of them (Fig. 224b), it is not possible to determine if the Phase 1 ramp features passed above the top edge of S9:R1–R2. A section was surveyed *ca* 1.10 m to the north of the Phase 2 ramp foundations (Fig. 191a); the damaged but relatively level surface here suggests that the Phase 1 ramp features may have been removed or levelled to create relatively horizontal foundations for later structures (Figs. 224a, 190). It is impossible to determine how far the Phase 1 ramp of Slipway 2 extended northwards.

The open-passage between the ramps of Slipways 2 and 3 (OP/SWR2&3:1–2) is preserved to a maximum width of *ca* 1.37 m (measured at SW2:R3, R5; Fig. 168).

54. J. Coates, pers. comm., 2005.

2) *Slipway 3*. The maximum preserved width of the ramp is 1.47 m (preserved bottom length of SW3:R5). At this point it was destroyed by the construction of Shipshed 10's ramp (Fig. 169). The colonnade foundations of C9/10 and the later C18(χ)/19(π) were constructed at an elevation just below the bottom surfaces of the rock-cuts slots in the ramp of Slipway 3 (SW3:R3–R7), but it is not possible to determine whether these foundations removed parts of the open-passage between Slipways 2 and 3 (OP/SWR2&3), or the northern side of Slipway 3's ramp, or both (Fig. 227b). Timber sleepers SW3:R1, R4 and R7 could not have extended across OP/SWR2&3:1–2, which are preserved, respectively, 0.11, 0.10 and 0.11 m above the bottom of these features (Fig. 227b). Thus, the timber sleepers in SW3:R3, R5–R7 could have extended for a maximum ramp width of *ca* 5.20 m, a figure which, as discussed below, is unlikely.

The open-passage preserved south of Slipway 3's ramp (OP/SWR3(S):1) can be followed with certainty for a distance of 2.62 m along cross-section 53 (Fig. 199e) to the point where it was removed by U:31 (Fig. 169).

3) *Slipway 5*. The maximum preserved width of the ramp is 4.34 m (preserved bottom length of SW5:R6). The southern delineation cannot be traced, as the later colonnade features were hewn to a lower level, probably to remove the Phase 1 features in order to create level foundations (Figs. 170, 227a).

When added together, the widest preserved open-passage south of Slipway 3 (2.62 m) and the widest point in the ramp of Slipway 5 (4.34 m) amounts to *ca* 6.96 m, which is *ca* 0.36 m wider than the estimated total width of Slipways 2 and 3 (*ca* 6.60 m). The width of the ramp timbers in Slipways 2 and 3 was probably less than the total estimated slipway width (*ca* 6.60 m) minus the preserved width of open-passage OP/SWR3(S):1 (2.62 m), equalling *ca* 3.98 m.

The distances between the southern end of SW6:R1 and the points where the colonnades of Phases 2 (C13/14:2) and 3 (C22/23:5) have destroyed the ramp features of Slipway 5 (SW:R5, R6) are 4.87 and 5.01 m, respectively (Fig. 206). It is clear that the ramp of Slipway 6 and/or the now-missing open-passage between Slipways 5 and 6 were/was narrower than 4.34 m (SW5:R6) and 2.62 m (OP/SWR3(S):1). Furthermore, it is clear that Slipway 6 was in all probability narrower than Slipways 2 and 3.

Slipway	Average level difference (m)	Range (m)
2	-0.04	-0.12 to +0.01
3	-0.04	-0.07 to 0.00
5	-0.03	-0.06 to +0.01

Table 5.9. Zea, Group 1, Slipways 2, 3 and 5: average height difference between one ramp feature relative to the previous ramp feature.

In sum, the total width of Slipways 2 and 3 is estimated at *ca* 6.60 m in the excavated area, whereas the widths of their ramps and open-passages remain unknown. The maximum preserved ramp width of Slipway 5 is 4.34 m+, and it is likely that the widths of Slipways 1–3 and 5–6 varied markedly. The timbers of Slipways 2 and 3 are reconstructed tentatively at a length of 3.98 m on Pl. 11, based on the preserved width of OP/SWR3(S):1 (2.62 m) and the estimated total widths of Slipways 2 and 3 in the excavated area (*ca* 6.60 m). It must be stressed that this ramp width remains a qualified guess.

The delineation between the Phase 1 ramps and their open-passages in Area 1, then, is very fluid. The primary function of the transverse timber sleepers was to support the keels of ships and to create optimal conditions during hauling and slipping operations. In Area 1 of Zea and at other sites with wider ramp sleepers, such as Marseille's Place Jules-Verne (maximum length about 3.6 to 4.6 m; Fig. 54) and Place Villeneuve-Bargemon (maximum length about 4.4 m; Fig. 53), there is in all probability a transitional area between the ramp and open-passages where the transverse timbers also provided footholds for the hauling crew. At Marseille and Zea, this type of ramp was in all likelihood constructed intentionally to this width to provide the necessary footing. It is interesting to

Ramp	G1-HB	G2-T	G3-B
2	1:20.5 (2.8°)	-	-
3	1:20.1 (2.8°)	1:18.9 (3.0°)	1:18.6 (3.1°)
5	1:19.3 (3.0°)	1:18.7 (3.1°)	1:16.9 (3.4°)
Average gradient: 1:19.0 (3.0°)			

Open-passage	G2-T
SWR1&2	1:21.3 (2.7°)
SWR3(S)	1:19.8 (2.9°)
SWR6(S)	1:17.0 (3.4°)
Average gradient: 1:19.4 (3.0°)	

Table 5.10. Zea, Group 1, Slipways 2, 3 and 5: inclinations of ramps and open-passages.

note that the ramps of the unroofed slipways at Place Jules-Verne and in Area 1 at Zea (Phase 1) are considerable wider compared to transverse timber sleeper ramps that have been found in shipsheds in general (see Tables 5.8c).

5.4.4. Phase 1 Ramp and Open-passage Gradients

The rock-cut sleeper slots from Phase 1 at Zea were not laid out on a linear gradient, longitudinally nor along their transverse axes. Instead, where the original surfaces are preserved it is possible to see that their bottom elevations fluctuate markedly by several centimetres when compared to the average elevation difference between one ramp feature relative to the previous (Table 5.9; Figs. 217–219).

This demonstrates clearly that the gradient of the ramps has been smoothed out by the transverse timber sleepers or adjusted by more advanced ramp structures above the sleepers. Although the ramp gradients are relatively constant (Table 5.10), it is possible that the gradient of the transverse timber sleepers differed slightly from those of their bedrock foundations.

The inclinations of the well-preserved Phase 1 open-passage of Slipway 3 (OP/SWR3(S):1) was calculated at a G2-T gradient of 1:19.8 (2.9°; Fig. 219). This open-passage is raised 0.04–0.05 m above the well-preserved top surface of the ramp recorded in Section 47, or 0.13–0.15 m above the line defined by the G3-B calculation through the bottom surface of Slipway 3's sleeper cuttings (Fig. 228a). Is it possible that the ramp was smoothed using the edge of the open-passage as a reference, thus resulting in a timber sleeper cross-section of 0.11 x 0.13–0.15 m (this is 0.02–0.04 m shorter than the height used in the reconstruction on Pl. 12, see above). The difference in elevation between the two features can be seen at other sites. At Punic Carthage the side-passages are also raised above the ramp area forming a flattened U-shape section (Fig. 38) and there is also evidence of a similar slipway construction method at Oiniadai and at Mandraki (Figs. 43, 49).[55] Perhaps the open-passages and side-passages were slightly raised to allow seawater dripping from the ships hull to drain more easily, thus providing secure footholds.

The first 25 m or so of the ramps at Carthage (1:15/3.8° to 1:20/2.9°) had a gradient comparable to the slipways of Area 1 at Zea (Table 5.10). Despite the uncertain nature of the gradient calculations of ramps 16 and F762 at Carthage, they remain important data for showing that low-gradient transverse timber ramps existed in both Greek and Punic spheres – a construction arrangement that spanned at least three centuries.

55. Hurst 1994: fig. 3.2; Sears 1904: pl. X; Blackman, Knoblauch & Yiannikouri 1996: fig. 7 (Schnitt S2 von Süd).