The Seventh-Century Punjulharjo Boat from Indonesia:
A study of the early Southeast Asian lashed-lug boatbuilding tradition

By Agni Sesaria Mochtar

Internal strengthening of the Punjulharjo boat after the excavation, June 2009
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A thesis submitted in partial fulfilment of requirements for the degree of Master of Maritime Archaeology

Maritime Archaeology Program

College of Humanities, Arts and Social Sciences

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Abstract

The study of the lashed-lug tradition, one of the traditional boatbuilding techniques of Southeast Asia, had predominantly relied on historical and ethnographic data. To date, there are nearly twenty sites with lashed-lug vessels, albeit many of them are only fragmentary remains, that had been found in various places in Southeast Asian region but a closer examination of them has still scarcely conducted. The Punjulharjo boat is one of these lashed-lug watercrafts which were found in a rather remarkable condition, with the majority of its hull preserved. The excavation in 2009 revealed that the boat still has its internal strengthening in place, with the vegetal ropes still intact. This thesis aims to further study the assembly method and technology used in the Punjulharjo boat and to see how they fit within the current theories of the lashed-lug tradition of boat building.

The author re-examines the boat remains that are still *in situ* to study details that are missing from the previous archaeological studies. The analysis is undertaken by comparing the collected data to the documentation of the boat during the initial excavation, as well as the related reports and publications about other lashed-lug vessels. This study reveals various aspects of the assembly techniques of the Punjulharjo boat, including the planking, the fastening and the internal strengthening. In particular, this thesis discusses the way that the ropes were used in several different ways to tighten different parts of the boat, as well as how the builders assembled the bow and the stern using a wing-end, one of the distinguishing features of a lashed-lug vessel. By comparing the Punjulharjo boat to other watercrafts belonging to the same tradition; the author argues that this boat is one of the lashed-lug vessels built using early technological techniques, which heavily relied on the lashings to fasten the boat with the aid of dowels.

The author concludes that further research of the Punjulharjo boat is, however, still needed to study the fastening system of the boat. An experimental archaeology might aid in understanding how the builders applied each sequence of lashing patterns and the reason behind this choice of the pattern. The propulsion method and the rigging of the boat are other aspects that need to be examined closer. It is also recommended that studies of more vessels that were found in the last ten years be expanded to add to the prevailing knowledge of the lashed-lug tradition.

Declaration

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Agni Sesaria Mochtar

2019

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Chapter I

Introduction

Introduction

In 2008, the almost complete remains of an ancient boat were uncovered in Punjulharjo, Central Java, Indonesia (Abbas 2010). Since dated to the seventh century AD[1], the boat is one of the few examples found in Southeast Asia, and more importantly is one of the oldest found to date (Abbas 2010:42; Sulistyarto 2010:56). The archaeological study of traditional boatbuilding in Southeast Asia as a line of research in maritime archaeology is still in its infancy. Only since the 1980s have scholars been documenting and investigating the traditional boats from archaeological context, as well as the boatbuilding, and seamanship of insular Southeast Asia people (Manguin 1985, 1989; Ronquillo 1987). The research then was on a mostly sporadic basis and remains so to date.

Nearly four decades later, fundamental questions remain and have been debated to different degrees. The major research question related to the nature of Southeast Asian boatbuilding tradition as put forward by Lacsina: is there such a thing as an encompassing regional tradition? or are there similar, but localised traditions? If there is indeed a regional tradition, what are the origins of this boatbuilding and seafaring tradition (Lacsina (2016:225)? Are they descended of Austronesian boats (Horridge 1985; Manguin 1985, 2016), or rather influenced by a tradition from the Indian Ocean? What impact has the Southeast Asian insular ecosystem had on seafaring and boatbuilding in the region, and what impact, in turn, have these had on the societies involved (Manguin 2001)? Even such mundane details as joinery terminology remains unsettled and often still hypothetical; for example: do they have sewn planks or stitched planks?

A principal reason for this state of affairs is the paucity of archaeological remains of the boats themselves. What few remains have been found have been mostly incomplete–some with only a few planks preserved (Manguin 1989, 1993)—and others have been

[1] All dates in this thesis are AD, unless otherwise specified in the text.

destroyed in the process of recovering the artefactual contents of the wrecks, for instance, *Cirebon* wreck (Liebner 2014) or have deteriorated due to a delays in conservation being undertaken. Examination of these boat remains also has typically lacked the close attention to detail and expert treatment required to capture the all important details of construction methods and processes involved in their construction, and to fully exploit their archaeological potential to inform. In light of this, ethnographic studies so far have been the primary sources of information used to interpret this ancient, but now extinct, boatbuilding technology (Barnes 1985; Burningham 1990; Haddon 1920; Horridge 1985).

The Punjulharjo boat is a significant archaeological resource, which can answer questions related to Southeast Asian boatbuilding technology providing information that was lacking in shipwreck finds located to date. Studying the boat would significantly contribute to the debates on the topic of traditional boatbuilding in Southeast Asia. With the boat intact, it provides a unique opportunity to record nearly the entire hull construction, along with the fastenings and ligature patterns. The recording results will be a substantial addition to the database of traditional boats found in the region. The database would serve as the data to understand the emergence, advancement, and the decline of traditional boatbuilding in Southeast Asia.

Research Design

Research Question

This study of the Punjulharjo boat in Central Java, Indonesia will answer the following question:

> How does the assembly method and technology used in the Punjulharjo boat's construction fit with current theories of the development of Southeast Asian wooden boatbuilding?

Research Aims

Based on this research question, this thesis aims to:

- Give an overview of current theories related to Southeast Asian boatbuilding technology.
- Analyse the application of the edge-joined and lashed-lug boatbuilding technique in Punjulharjo boat.

- Compare and analyse what is known about boatbuilding technology used throughout Southeast Asia from the archaeology, iconography, and ethnography sources.
- Confirming and/or correcting the interpretations of the Southeast Asian boatbuilding technology that have been done to date.

Methodology

The decision to revisit the Punjulharjo site and undertake this study came from the recognition that, during the previous two excavations, the boat remains were treated similarly to other terrestrial findings. As a result, many features were missed during the observation and recording processes (Abbas 2010; Sulistyarto 2010). This project fit within nautical archaeological research aims, but the analysis and discussion can go beyond the technical and technological aspects of a boat or vessel. The study of shipbuilding rather covers broader perspectives where any changes in technology can be seen as an impact of social and environmental dynamics (Adams 2001:307).

The research in this thesis uses the terminology for Southeast Asian traditional boatbuilding as put forward by Manguin (1980:272–273), rather than an arbitrary definition. This research attempts to closely examine the Punjulharjo boat remains to understand its place within boatbuilding technology and practices. It is argued that the boat was intentionally abandoned on the beach, rather than wrecked since valuable commodities like ceramics were absent from the boat (Riyanto 2010:4). The state of boat remains, however, makes this finding an important data set for the study of traditional boatbuilding in Southeast Asia. The primary data for this thesis is the timber recording gathered in a fieldwork in late 2017 and early 2018. A thorough literature review provides a background understanding of the lashed-lug tradition and traditional boatbuilding in Southeast Asia. Other data sets that are also applied to this thesis include archaeology, iconography, and ethnography. They are used to aid the interpretation to examine if ‘Southeast Asian boatbuilding’ was actually a regional as opposed to a local tradition. As suggested by Lacsina (2016:227), a more robust database of similar boat remains found in Southeast Asia is needed to fully understand the typical and atypical in the said tradition.

Location

The boat remains are mostly still in their original location: a site located in Punjulharjo village on the northern coast of Rembang District, Central Java, Indonesia (Figure 1.1). The intact boat was uncovered at 111° 24' 30.7" E dan 06° 41' 35.3" S after locals accidentally found the wooden vessel while digging the intertidal land for new salterns.

Figure 1.1. Map of the Punjulharjo site.

Since being surveyed and excavated in 2008–2009, the boat had undergone a series of conservation works. The procedure had not been done in the laboratory, but rather *in situ*. The wood remains were disarticulated and immersed in Poly Ethylene Glycol (PEG) liquid. Apart from the boat remains, ligatures and wooden pegs/dowels from the boat are currently being treated with conservation works by a conservation office in Java, *Balai Konservasi Borobudur*. Meanwhile, artefacts that were found inside and near the boat during the excavation were taken to the research centre, *Balai Arkeologi Yogyakarta*, for further analysis and are still being kept there.

Project Significance

The investigation of the Southeast Asian boatbuilding is still rarely conducted. This is due to the minimum amount of data, funding, and even personnel available to undertake research. At times when a shipwreck is found, often scholars' lack of detailed knowledge on how the find is a potential data set for shipbuilding studies prevents them from performing sufficient research. The lashed-lug tradition was practised for more than a millennium, before the coming of the Europeans to the region in the sixteenth century. Bearing in mind Southeast Asian's strategic location in the trade and migration routes at the time, and the fact that the study of shipbuilding can contribute to the discussion about the dispersal of people and goods, this situation is somewhat rather disappointing.

This study is one of the rare detailed and in-depth investigations of one of the not so many wreck sites which date from the seventh century. The state of preservation of the Punjulharjo boat provides a promising chance to gain insights into extinct techniques. A study of traditional ship's construction is often limited by the state of archaeological finds, where only a small section of a shipwreck is found intact. The missing gap causes difficulties in interpreting the sequence of the ship's construction and the result is therefore speculative (Castro 2005:147; Van Duivenvoorde 2015:143). With the still intact, nearly complete hull, frames and even ligatures to lash the timbers, this boat had become an important site in the study of the Southeast Asian boatbuilding and the maritime history, not only in Indonesia but also in Southeast Asia context and the even wider context of the Indian Ocean.

The tropical climate of Indonesia is one of the major challenges in preserving a shipwreck, let alone the timber vessel ones, like the Punjulharjo boat. Being found and preserved in-situ in an intertidal coast put this boat in an unsafe condition that could hasten the deterioration of the boat elements. Some conservation works had been done on the timbers, but it is highly important to record this boat in any possible means to preserve the information of the second-oldest shipwreck found in the Indian Ocean. It is even older than Belitung wreck, which was previously considered as the second-oldest shipwreck site in the Indian Ocean after the Godawaya shipwreck (Gaur et al. 2011).

Limitations

This thesis studies the assembly methods and technology of the Punjulharjo boat in the context of the lashed-lug boat building tradition. Due to the availability of data, the examination focuses more on the hull assembly. While being an essential component of a boat building technology, examination of other aspects, such as rigging, are beyond the scope of this thesis. It has been almost a decade since the first discovery of the boat. Although some level of conservation has been reported, many parts of the boat had deteriorated or were damaged. It is, thus, difficult to interpret the data without making a hypothetical reconstruction of the boat, which is not possible to be accomplished within the time limit of this thesis.

Chapter Outline

This chapter has provided the foundation of the research for this thesis. It has addressed the research question and aims derived from the debates surrounding the topic, along with a brief methodology used in the research. It also has provided the location of the Punjulharjo boat site, and associated artefacts of the boat remains, as well as the significance and the limitations of the research.

Chapter 2 reviews the prevailing literature on the maritime history of Indonesia, also of the broader context of Southeast Asia and the Indian Ocean. It then reviews existing scholarly publication on traditional boatbuilding in Southeast Asia drawing from archaeological, iconographic, and ethnographic studies. Finally, it assesses previous research of Punjulharjo boat to emphasise aspects that have not been closely examined.

Chapter 3 outlines the methods used to collect all the data for this research. It starts with the examination of previous archaeology. It then describes the recording method of boat remains (i.e., photography, drawing, and photogrammetry), followed by reconstructing the disarticulated remains to produce construction drawings. It also describes methods used to examine associated artefacts found with the boat, along with similar boat remains in Southeast Asia and ship iconography from the region, to aid the interpretation.

Chapter 4 presents the data collected through the fieldwork for this research. This includes a description of the boat remains including the assembled hull and the separated components of the boat. The observed components comprise of the keel plank, strakes, lugs, as well as the internal strengthening such as frames, stringer, and beams. Photographs and drawings will also be presented to aid the descriptions.

Chapter 5 initially discusses the boatbuilding aspect of the Punjulharjo boat, which covers the hull construction (keel, planks, lugs, frames, fastening and lashing patterns), but also addresses the problems caused by the current state of the boat remains. It later discusses the comparison between Punjulharjo boat and the archaeology, iconography, and ethnography data to put the boat in Southeast Asia and the Indian Ocean context.

Chapter 6 concludes the research by summarising the findings and restating the research question and aims and showing how the research has fulfilled them. It also recommends several issues that should be answered in future research.

Chapter II

Literature review

Introduction

This chapter discusses current knowledge about the so-called Southeast Asian boatbuilding tradition and identifies gaps that could be filled in by this research. It will assess previous studies (archaeological, ethnographic, iconographic, and historical) about the edge-joined and lashed-lug vessels. A summary of maritime history in Indonesia, Southeast Asia, and the Indian Ocean will be provided as a background to evaluate how the prevailing research has contributed to a broader context discussion. The discussion covers the topic from the prehistoric era up to the arrival of Europeans to these regions. This chapter will finally discuss former investigations of the Punjulharjo site, as well as other boat remains in Indonesia, to critique the nautical archaeological practices used in Indonesia and to evaluate how the investigations have furthered the understanding of Southeast Asian boatbuilding tradition and general history.

Indonesia, Southeast Asia, and the Indian Ocean Maritime History

Indonesia Maritime History

Indonesia has a significant place in maritime archaeology, particularly in the study of early seafaring. It is still widely accepted among researchers that the oldest human maritime activity was the crossing of the 70-km water bodies by anatomically modern humans, from eastern Indonesia to colonise Australia, despite the ongoing debate of precise timeline, which ranges from at least 45,000 to 65,000 years ago (Balme 2013:68; Bulbeck 2007:319; Clarkson et al. 2017:309; Kealy et al. 2015:379; O'Connell and Allen 2004:835). By that time, *Homo sapiens* had apparently acquired the skills to make a seaworthy watercraft. Unfortunately, there is insufficient data to interpret the type of watercraft they made. Balme (2013:72–73), Bednarik (2003:48–51), and Horridge (1995:143–144) argue that people from the lesser Sunda reached Australia by bamboo rafts, simply because they had already mastered string technology. Their arguments, however, are not based on adequate verifiable data.

This theory of early seafaring might now be challenged by the recent findings from Flores, Indonesia. The archaeological excavation in Soa Basin, Flores — a nearby site of Liang Bua, the habitation cave of *Homo floresiensis* — unearthed stone tools that dated from 880–900 000 years ago (Brumm et al. 2010:749). Hominin fossils from the same site were dated to ca. 500 000 years ago (Brumm et al. 2016:252). Morwood and his colleagues (1998:173–174) argue that these findings are evidence of hominin's ability to cross the sea since Flores had never been connected to the Sunda shelf by land bridges, and can only be reached by crossing at least three straits from the island of Java. Balme (2013:68) disagrees with this by arguing that the distance between islands in lesser Sunda in the past could not be greater than 20 km. Thus, the strait crossing event might be accidental.

Excavations in Talepu, one of the sites in Walanae Basin, Sulawesi, revealed another indication of sea-crossing activity that occurred long before the colonization of Australia. The stone tools found in situ are dated to 200,000 to 100,000 years ago (Morwood and Jungers 2009:646; Van den Bergh et al. 2016:210). From the similarity of attributes found on stone tools from Flores, and by considering the oceanic current, the research team suggests that hominins might have crossed the ocean from lesser Sunda to Sulawesi, and later continue their journey to Sahul. They further argue that, at that time, pre-modern humans had invented some form of watercraft and were capable of undertaking long distance voyages.

Interestingly, archaeological studies of human migration scarcely discuss the maritime aspect. The theory and narration of how *Homo sapiens* managed to reach Southeast Asia region (Bartstra et al. 1991; Stringer 2000; Sutikna 2016) barely touch the possibility of people taking the sea route. It was only when archaeologists started to investigate the dispersal of the Austronesia-speaking people southward from Taiwan at around 7,000 years ago (Bellwood 2001; Diamond and Bellwood 2003), that they acknowledged human's activities on, or related to, the sea. Scholars generally agree that Austronesians introduced boatbuilding technology to island Southeast Asia and to as far as Micronesia on the east and Madagascar on the west (Horridge 1995; Mahdi 1999). Again, the maritime-focussed debate of the study of Austronesian dispersal is rather limited, despite the intensive research conducted on this topic.

In Indonesia, this debate is almost absent among archaeologists. Prehistorians have built robust discussions about Austronesian migration to Indonesian archipelago. One of these debates was about their migrating routes: from the Philippines southwards (Horridge 1995:144) or via the mainland Southeast Asia (Bellwood 2001; Donohue and Denham 2010; Hill et al. 2007). The maritime aspect of the migration, however, seems only be addressed in the investigations of the occupation of Madagascar by Austronesian Indonesians around 1,200 years ago (Cox et al. 2012; Fitzpatrick and Callaghan 2008; Hornell 1928:1, 1934; Manguin 2016:63–67). Among these studies, only Manguin's (2012b, 2016) publications are based on archaeological data. It is critical to notice that, however, the data comes from Indonesia and other Southeast Asian countries, not from Madagascar. This makes Manguin's conclusion rather assumptive and, therefore, somewhat questionable. Despite the absence of solid archaeological evidence, Indonesian people's voyage to Madagascar is confirmed by mitochondrial-DNA analysis (Cox et al. 2012). Ethnographic studies also support this, based on the similarity of boatbuilding traditions on East African coast with Indonesia (Hornell 1928, 1934).

Since the dawn of first millennium AD., Austronesians were not the only community coming to Indonesia, as people from India started to come during the long process of Indianisation (Beaujard 2005:420–421). While there have been a multitude of studies on the period of Indian influence in Indonesia, only a handful of them discuss the issue from the maritime perspective. Researchers often mention that Indianisation played a key role in the emergence of maritime routes from central Indian Ocean to Southeast Asia and the China Sea. Insignificant attention, however, is given to shipwrecks found in the region which dated from the fifth to fifteenth century. Hall (2010) and Liebner (2014:217–289) are probably the only publications that intensively discuss the data from shipwreck sites in combination with iconography from Hindu or Buddhist temples, and also with epigraphy.

The Indian Ocean and Southeast Asian Maritime History

The study of maritime history in the Indian Ocean is still in its infancy. In contrast to the extent of its coast, only limited maritime archaeology projects have been done in the region. Until recently, the study of maritime history in the Indian Ocean relied on the historical accounts, one example is the *Periplus Maris Erythraei,* (Beaujard 2005; Seland 2011). Based on that source, Beaujard (2005:425–429) maps early maritime routes in the Indian Ocean. He further suggests that the maritime network in the Indian Ocean was established by European movement to the east, Austronesian dispersal from Southeast Asia westward, the Indianisation of Southeast Asia and the emergence of pre-Swahili culture on the eastern African coast during the first century AD.

Human exploration of the sea in the Indian Ocean region, however, started around five millennia before those migrations commenced. An impression of a reed raft, or possibly a boat, on a bitumen fragment from Kuwait was dated to ca. 7,500–7,000 years ago (Carter 2002:44; Lawler 2002:1791). Along with the bitumen fragment, some depictions of ship were painted as a decoration on pottery. Further direct evidence of maritime activity in the Indian Ocean is the Godavaya shipwreck, which dated roughly to the first century AD. (Gaur et al. 2011:16; Muthucumarana et al. 2014:55). Besides these two sites, there is no other direct evidence of maritime activity found in the region. Johnstone (1988) in one of the chapters of his book described prehistoric vessels of the Indian Ocean, based on ship iconography as well as ship models. He argued that they date to the third-millennium BC. However, the location of the artefacts that bear the iconography and the models were no longer in situ and, mostly from a museum collection. Hence, there is some level of doubt in the authenticity of the source.

Other investigations of maritime history, including the study of traditional ships in the Indian Ocean, are mostly based on ethnographic data (Kapitän 2009; Manguin 2012b; McGrail et al. 2003) and emphasise trading networks among the sub-regions. In terms of boatbuilding traditions, the Indian Ocean has more than one single tradition. Each sub-region developed their own distinct tradition, to form a complex nexus. The western region, such as Tanzania, Mozambique, and Oman, has the *mtepe* as their trademark ship and timber logs as their primary commodity (Gilbert 1998; Lydekker 1919). The central region, like India and Sri Lanka, have the laced-plank boat and they exported fine garments and gems (Kapitän 2009; McGrail et al. 2003). The eastern region, the Southeast Asia islands, has the lashed-lug boat tradition and were well-known for their spices (Lacsina 2016; Liebner 2014; Manguin 2012a).

There is little investigation into how these traditions from different sub-regions interacted with each other. The question of whether they evolved separately in parallel or influenced each other remains unanswered. However, it is known that each tradition built a ship that could be sailed to the other end of the Indian Ocean. A couple of decades ago, the finding of a shipwreck proved that a *dhow* was already undertaking long-distance journeys since the end of the first millennium AD. The *dhow* was found far from the African coast, near Belitung Island, just southeast of Sumatra in Indonesia. The shipwreck was later known as the Belitung shipwreck or the Tang shipwreck, named after its cargo of more than sixty thousands Changsha wares produced during the Tang Dynasty (Caixia 2011:41; Flecker 2000:199). This *dhow* is solid evidence that people from the West Indian Ocean in the ninth century were capable of building a seaworthy ship that accomplished a voyage all the way to China, through Southeast Asia, to trade for Chinese ceramics.

Southeast Asian Traditional Boatbuilding Technology

Archaeological research of watercraft in Southeast Asia is still infrequently undertaken. The existing research, however, shows that Southeast Asian people had developed a distinctive boatbuilding tradition called the edge-joined and lashed-lugs tradition. Lacsina (2016:222–223) referred to this as the "lashed-lug" tradition, and described the building sequences of a boat of this tradition as follows:

> …a process that begins with preparing the keel piece and hull planking with a series of protrusions, or lugs. When the hull is assembled by edge-joining with dowels, and sometimes in combination with lacing, the lugs are drilled with holes and used primarily to fasten frames, thwarts, and other vessel components, with ligatures to lash them together.

The description given is based on historical, ethnographic and archaeological data. The first two, however, served as primary data and archaeological remains are, to some extents, treated merely as a confirmation of them (Barnes 1985; Lacsina 2016:23–24). This is due to the fragmentary findings — some boats only have few planks left —, and the rarity of close investigations of those boats (Manguin 1989:204, 206, 208, 1993:255–257, 264).

Essential identification of the edge-joined and lashed-lug boatbuilding tradition was gained through a series of Manguin's works on boat remains from many sites throughout Southeast Asia (1980, 1985, 1989, 1993, 2012a, 2012b). Due to limited data, in his early publications, he misses some technological aspects, such as frames and lashing pattern. The later finding of the Cirebon and Punjulharjo boats are discussed in the latest publications, but are treated as components in understanding the evolution of the boatbuilding technique itself, without looking into the details of their features (Manguin 2012a:4–6, 2016:59–62).

Previous investigations of archaeological evidence of lashed-lug boats from Malaysia, Indonesia, Thailand, Vietnam, the Philippines and Hong Kong resulted in dates from the third to sixteenth century A.D. (Lacsina 2016:98–142; Liebner 2014:255–232; Manguin 1985, 1989, 2012a, 2012b). The oldest boat was found in Pontian, Malaysia, dating from the third to the fifth century AD. (Manguin 1989:212). Although each site provided aids to understanding this tradition at various levels, three sites were prominent: Butuan in the Philippines; Cirebon in Indonesia; and Punjulharjo, also in Indonesia. The level of preservation of these boats was generally remarkable, with nearly complete assemblage's still intact (Abbas 2010:42–43; Lacsina 2016:143–162; Liebner 2014:243; Ronquillo 1987; Sulistyarto 2010:56–57).

Despite the remarkable condition of six excavated Butuan boats, early research on them (Ronquillo 1987) did not reveal significant information, other than expanding the list of the lashed-lugs boat found in Southeast Asia. Lacsina (2015, 2016) later closely investigated these boats and demonstrated how archaeological data provided more information beyond simply confirming historical accounts and ethnographic studies. She revealed that aside from the general edge-joined and lashed-lug characteristic, these boats also had variations of lug patterns, plank fastenings, and wood materials. The limited scope of her study, however, caused difficulty in identifying the contributing factor of this variation. She acknowledged that data from other places in the region might contribute to this investigation (Lacsina 2016:227).

The Cirebon wreck was studied by Liebner (2014) as his Doctor of Philosophy thesis. This study covered the ship and its cargo and placed them in the context of social and economic aspects of Javanese society at the time. He also included additional data from iconography and epigraphy in his analysis. On the ship itself, the investigation was intensive. Some peculiarities were identified, in comparison with Butuan boats and other lashed-lugs boats in Southeast Asia (Liebner 2014:267–290). The Cirebon shipwreck was a large ship which carried around 60,000 pieces of Chinese ceramics, indicating the involvement of this type of boat/ship in trading activity.

Both Lacsina (2015, 2016) and Liebner (2014) provide a significant contribution to the understanding of the lashed-lugs boatbuilding tradition from their research on the Butuan boats and Cirebon shipwreck, respectively. However, there are still many gaps in knowledge left by Manguin and other researchers due to inadequate data. Technological aspects, such as fastenings, joinery, lashing patterns, and wing end construction, are still missing from the site recordings and thus cannot be studied adequately.

Previous Investigations of the Punjulharjo Boat

Boat and Ship Investigation in Indonesia

Overall, studies of boats in Indonesia are divided into the pre-colonial boats and the colonial ships. In this chapter, only studies of pre-colonial boats will be discussed. These studies generally can be categorised into three groups: archaeological research; commercial salvage; and ethnographic study. The first group, unfortunately, is the smallest in number. Only the investigation of lashed-lug boats by Manguin (1980, 1985, 1989, 1993, 2012a, 2012b, 2016) and the survey and excavation of the Punjulharjo boat (Abbas 2010; Sulistyarto 2010) can be included in this group.

Manguin's works are exemplary, considering the state of the timber remains that he worked on. Despite having only a few planks from each site, the level of information gathered from them is remarkable. After establishing the definition of the lashed-lug boatbuilding tradition, Manguin (2012b, 2016) put the information into a wider context of Austronesian culture. He suggests that the voyage of people from Southeast Asia to the Indian Ocean, including the occupation of Madagascar by Indonesian people, was possibly done with lashed-lugs boats and ships. Nearly all Manguin's research emphasis was on generalising the characteristics of boat remains in Southeast Asia to set up a firm definition of the lashed-lug tradition. He further attempts to fit this tradition into the theoretical framework of Austronesian's dispersal. Those features appearing atypically in each boat seem to have been overlooked, despite their potential to provide more information about the tradition, such as the contributing factor of the particularity to the general construction technology of lashed-lug vessels.

Besides investigating the boat remains, archaeologists also study iconography to understand the tradition of boat and ship construction in Indonesia. Two types of iconography are examined, rock arts in eastern Indonesia (Ballard et al. 2004; Octaviana 2009) and the reliefs of the Borobudur temple in Central Java (Inglis 2014). Ballard and his colleagues focus on the comparison between Southeast Asian and Scandinavian rock arts in studying ship images as cosmology symbols and their work, therefore, does not provide many insights in traditional shipbuilding. Meanwhile, Octaviana (2009:107–118) and Inglis

(2014:108–138) extensively attempt to identify the components on each ship depiction within their research. The results of their research might aid the interpretation of the construction of a ship, especially of the rigging and the propulsion, whose physical remains are scarcely found. It is important, however, to notice that the dating of the rock arts remains inconclusive. While the reliefs can be soundly dated to the ninth century (Inglis 2014:1), some scholar argue that the dating of the rock art varies from 10,000 to 1,000 years ago (Octaviana 2009:6) and others propose that some sites are not much older than the thirteenth century (Awe 2000:14). To use them in a comparative analysis, therefore, should be undertaken carefully.

The second group consists of studies of shipwrecks that were initially salvaged by commercial salvage companies. Despite ethical concerns about the commercial exploitation of any underwater cultural heritage, the information gathered from salvage activities can still be used in this thesis. Some of the pre-colonial ships that were salvaged are the Intan shipwreck, the Belitung shipwreck, the Java Sea shipwreck, and the *Cirebon* shipwreck (Flecker 2000, 2002, 2003; Hall 2010; Liebner 2014). All of the salvaged shipwrecks were later a subject of arguably academic research, and the results are published either as a Doctor of Philosophy thesis or as peer-reviewed journal articles. Two of the shipwrecks, Belitung and *Cirebon*, are discussed in detail in other parts of this chapter.

The last group are the studies of traditional boats that were still in use at the time of observation (Barnes 1985; Burningham 1989, 1990; Dwyer 1998; Haddon 1920; Horridge 1985). The results from these studies provided sufficient data for comparison in cases where limited archaeological data was available. This type of study is also useful for understanding the process of building a ship. Barnes's (1985) recording of a whaling ship in eastern Indonesia and Horridge's (1985) compilation of traditional *prahu* in Indonesia present significant information for the study of the lashed-lug tradition. However, just like with any ethnographic data, the information needs to be used with caution.

The Punjulharjo Boat

The Punjulharjo boat, named after the village where it was located on the north coast of Java, was found in 2008 when the locals dug out the intertidal soil, only 500 meters from the shoreline, in preparation for new salterns. The site was immediately surveyed and two campaigns of excavation completed in the same year (Abbas 2010:39). The boat was well preserved with the entire length of 15.6 m from bow to stern still intact. This plank-built vessel lost several strakes, but a 4.6 m amidships section could still be measured (Figure 2.1). Protruding lugs found on each of the hull planks, assisted by frames that were still securely fastened to the lugs by *Arenga pinnata* rope ligatures, showed that the boats were indeed built with lashed-lug technique (Sulistyarto 2010:59-63).

Further evidence for the origin of this vessel came from the wood species identification of the timbers used (Abbas 2010:46; Nugroho 2010). Three different genus of timber were identified: *Palaquium gutta* from a plank, *Scorodocarpus borneensis* from a stringer, and *Melaleuca leucadendron* from a dowel. All three were common trees in Indonesia and Southeast Asia. A comparison of the wood species identified in this boat with timber from other boats has yet to be undertaken. The shipyard origin of the boat or even the possibility of timber trade in the region could therefore not be established at this time.

The ligatures that lash the frames to the planking run through pre-drilled holes on the surface and the seam of the lug. Sets of lugs were aligned transversely to accommodate one full frame, which consisted of two to three pieces of wood, the Punjulharjo boat had seventeen sets of them, although only twelve frames were still in place. Stringers were fastened on top of the frames and accommodated stacks of bamboo arranged above them, possibly as thwarts (Figure 2.2). This arrangement was only preserved and, thus, visible in the stern area (Sulistyarto 2010:63-64).

A carbon date of the *Arenga pinnata* (*Ijook*) rope sample taken during the second survey provided a date of AD 660-780 (Abbas 2010:42; Manguin 2012a:5, 2016:61). The two publications in which the C-14 dates were published mentions only one sample was taken and do not provide detailed information on from which parts of the boat it was taken. The validity of the nature of the sampling and thus the result is therefore questionable. This date, however, added to the significance of the boat as the oldest intact boat remains found not only in Indonesia but also in Southeast Asia and the Indian Ocean.

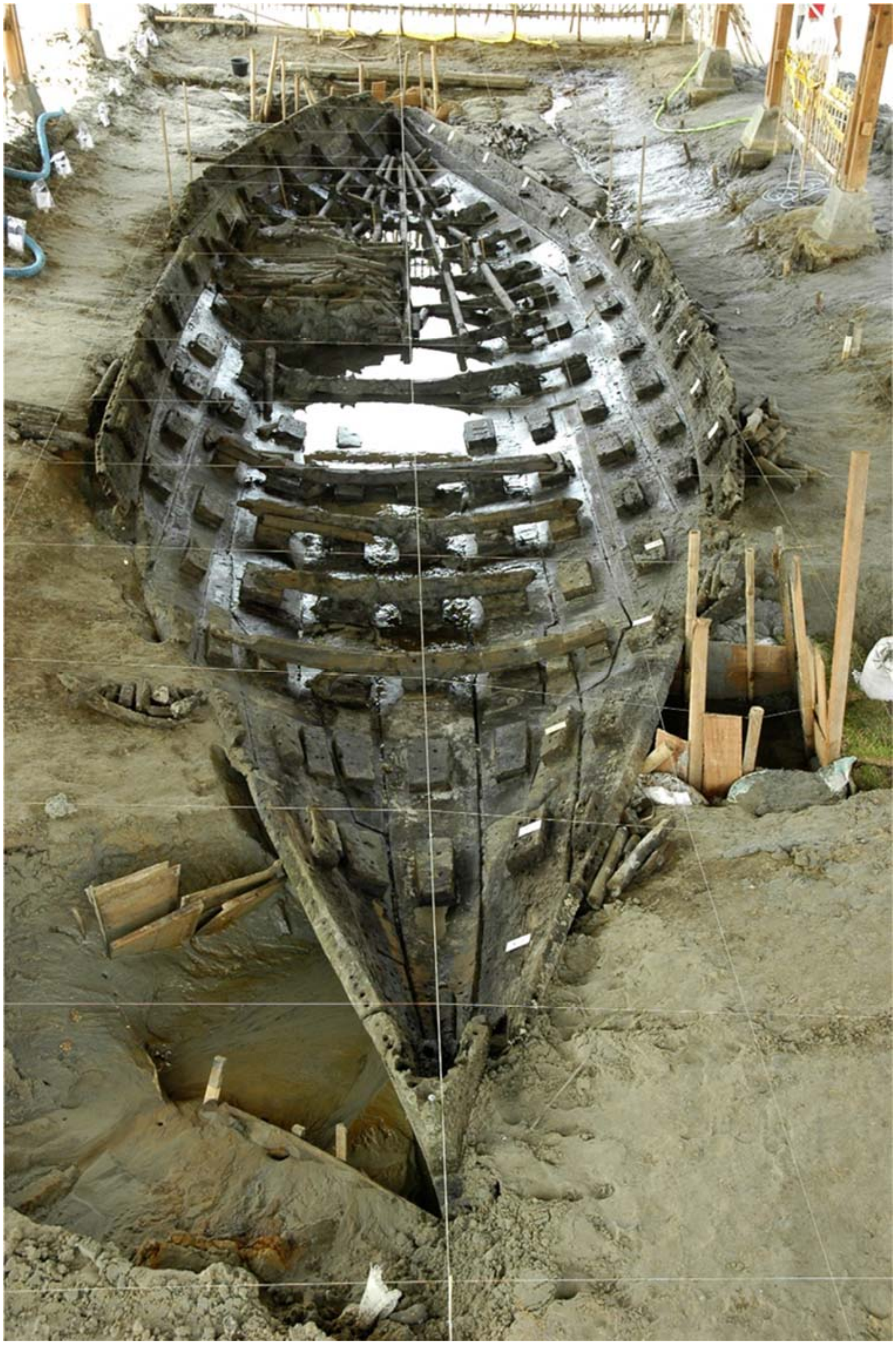

Figure 2.1. The condition of the Punjulharjo boat at the end of the excavation in 2009, most of the hull is still intact with the lugs protrude throughout the inner side of the strakes (Photograph by Balai Arkeologi Yogyakarta, 23 June 2009).

Figure 2.2. The remains of the internal strengthening in the stern area of the Punjulharjo boat (Photograph by Balai Arkeologi Yogyakarta, 20 June 2009)

The artefacts associated with this watercraft included both non-element and elements of the boatbuilding. The non-boatbuilding elements were ceramics, wood objects, bamboo objects, coconut shells, metal objects, and a fragment of stone statue (Abbas 2010:44–47), while the boatbuilding elements were wooden pegs, and a quarter-rudder mounting which was found near the stern (Sulistyarto 2010:63–64). The excavation reports by Abbas (2010) provided a summarised description of these artefacts without providing details of each object. It even failed to include ceramic sherds in the list of associated artefacts, even though they were part of the assemblage kept in *Balai Arkeologi Yogyakarta*.

The ceramics significantly outnumbered other artefacts with 239 finds. One fifth of the sherds bore ornament of net and geometric motifs, applied through the impression and incision techniques. Some of the ceramics were identified as pots, saucers, and a water jug (Abbas 2010:44). The second largest assemblage was the coconut shells with fifty-four items. The shells were cut into half-sphere, possibly used as some kind of bowl, or to bail the water. Two of them had holes on the top side, indicated that they might serve as the net floats (Abbas 2010:45). Other artefacts only had a small number, but they were rather unique. They included a wooden stick, the fragments of a barrel lit, the metal rings, and a head of a stone statue (Figure 2.3). Further analysis of these objects, unfortunately, was absent in the report, even though the information gathered from them should be useful for interpretation of the boat.

Figure 2.3. A head of female statue found inside the hull of the Punjulharjo boat (Photograph author, 3 January 2018).

The reports argued that the boat was a "sewn-plank and lashed-lug boat" (Abbas 2010:39; Sulistyarto 2010:55). The latter statement was undeniably true since obvious Southeast Asian type-lugs were carved out on the inner surface of each plank. The former, however, needed a reanalysis since no trace of the sewn/laced ligatures were present. The seam of the planks showed that they were edge-joined with dowel fastenings, confirmed by numbers of loosened dowels found inside of the boat. There were holes drilled through the planks, close to the edge on both sides, in a pair pattern, positioned to align with the other pair in the next plank. The distance of each pair to the next pair, however, indicated that it was impossible to lace the two planks together with rope in one go. Independent ligature was used to stitch two planks through the holes.

Conclusion

This chapter has discussed current knowledge of the edge-joined and lashed-lugs traditions in Southeast Asia. Previous studies on the Punjulharjo boat and other lashed-lugs boats were evaluated, as well as the context of regional maritime history. It is clear that maritime archaeology, particularly nautical archaeology research in Southeast Asia is still rarely done. Thus, the contributions to maritime history discussion in the Indian Ocean barely exist. One of reasons for this is the lack of a reliable database of archaeological remains.

The Punjulharjo boat is one case where the nautical archaeology recording methods and analysis have not been applied adequately. This project will attempt to revisit the site and re-record the boat remains with more detailed methods, to produce more reliable datasets, such as ship lines, and drawings of each part of the boat. Detailed examination of the technological aspect of the boatbuilding technique used in Punjulharjo boat, combine with data from other lashed-lugs boats would help explain the development of this boatbuilding tradition. Furthermore, the analysis of artefacts recovered from the boat is another missing element in previous research that will be undertaken during this project. The results from the analysis, and other supporting data, like iconography and epigraphy, will be used to aid the interpretation of the boatbuilding tradition. All of these results will be discussed to further understand the lashed-lugs tradition in a broader maritime historical context.

Chapter III

Methods

Introduction

This chapter describes the methods used in this thesis. Each of the methods was applied to gather data from different data sources: previously undertaken archaeology: the boat remains themselves; boat iconography; and artefacts associated with the Punjulharjo boat. The project began with desk-based research, where results from previous archaeological studies and work were compiled to gather information about Punjulharjo boat before the commencement of fieldwork. The boat is still in its original location, in a coastal area, around a half kilometre from the ocean. Thus, a non-diving survey is conducted during fieldwork to record the boat remains. Data about boat iconography is collected through secondary sources, without any visits to their original sites. To understand the context of the boat remains, artefacts found during the initial excavation are re-examined using close observation. This chapter also outlines the obstacles experienced during data collection.

Examination of Previous Archaeology

The main previous archaeological work used in this research included the site-related documents produced by *Balai Arkeologi Yogyakarta*, based on the first surveys and excavations of the Punjulharjo boat. The documents included: reports, photographs, videos, maps, and drawings. These documents provide remarkable details about the process of finding, surveying, and excavation of the boat; and included post-excavation studies of the boat, as well as the results of each phase. Articles and other publications related to the boat by Abbas (2010), Manguin (2009), Nugroho (2010), Riyanto (2010), and Sulistyarto (2010) are also included in the examination .

This step was done prior to fieldwork as desk-based research. The aim of examining the results from previous research was to build up an understanding about the boat and its context. A consideration of the descriptions, both verbal and pictorial, of the boat, led the author to identify in a list of items that had been missed during previous observations, which possibly could be looked for during subsequent fieldwork. On the other hand, this data was also crucial as a reference during analysis, in case there were parts of the boat which had degraded or were missing after the passing of a decade since the initial discovery.

Reports, theses, and publications from other lashed-lug boats found in the Southeast Asia region were also consulted to understand the boatbuilding techniques used in similar boats, either from older or more recent times, as well as those of the same time period. Not only would this information aid the interpretation of the Punjulharjo boat's technology itself, but it would also become essential knowledge in analysing such technology in a regional context.

Examination of Boat Remains

Fieldwork to visit the site was undertaken from November 2017 to January 2018. There were two modules of field work, the first was seven days in mid-November, and second was another week in late December 2017 to early January 2018. During the fieldwork, there were two on-going projects on Punjulharjo site; the conservation work for the boat remains and construction work to build an exhibition building to display the boat after the conservation. The conservation process had been running since 2014 to treat the timbers so they would be strong and durable enough to be exhibited. Once finished, the boat would be replaced to its original position, covered by a semi-open shelter.

The boat was dismantled to make the conservation process easier. Importantly the dismantling process had failed to register each part of the boat as it was moved and had resulted in damage to many components. The disarticulated state of the boat, however, was beneficial for this researcher as it made it easier to make detailed observations of the individual components. The field work was scheduled carefully to ensure that it was possible to record the boat remains both as separated components as well as an assembled boat after reconstruction.

During the first module of the field work, the disarticulated timbers were undergoing conservation treatment using *Polyethylene glycol (PEG) 400* and *Polyethylene glycol (PEG) 4000*. Plank timbers had finished the PEG 400-phase and just started being treated with

PEG 4000. Meanwhile, smaller timbers of frames and stringers were still undergoing PEG 400 treatment. Nearly all timbers were submerged in PEG solution and, thus, inaccessible during most of this part of the field work. The keel plank and the rudder-mounting post were the only accessible timbers because both were being treated using a different technique. Due to their large size, PEG solution was smeared on their surfaces instead of submerging them in such a solution. Towards the end of the fieldwork, the PEG 400-treatment for frames and stringers was finished, and the timbers were prepared to start the next phase. This process opened a limited time for the author to record sampled-timbers.

In the second module, hull timbers were deemed strong enough to be displayed. Thus, the conservation team decided to start the reconstruction process. This process was rather hasty, but in between the re-assembling processes, the author managed to record some timbers individually. After all the hull timbers were re-assembled, details of the boat were recorded, again, over a limited time period. The construction work had not yet finished at that time, so after two days the boat was covered by a tarp to protect it from debris from construction work, and the field work had to be finished.

Recording Boat Remains

Despite the situation on the site during fieldwork, every attempt at recording the boat timbers was undertaken using an archaeological method to gain as much accuracy and detail as possible. During the first module, the keel plank and rudder stem were recorded using a baseline-offset technique. The author preferred the centre baseline and used the zero point of the measuring tape as the datum, for both horizontal and vertical measurement. The baseline served as a reference to measure the dimension of the timber piece, including length, width, diameter, and/or cross-section, to produce a 1-to-20 scale drawing. The two timbers each had different baseline and datum as they were stored in two different places and, due to their size, could not be easily removed.

Where possible, the author did a direct tracing of the timbers on clear polypropylene film to produce full-size scale drawings (1:1). This method allowed the recording of as many features on the timber surface. The results were later re-drawn to make a 1-to-20 scale drawing. Each object was carefully photographed. The photographs would serve two functions: as pictorial description and as comparison data for the tracings and the drawings.

Due to time constraint, it was unachievable to record all the frames, features and fasteners. Some questionable techniques during the dismantling of the boat caused severe damages - the timbers were broken into small pieces. The author used a purposive sampling technique to choose which type of timbers to be recorded: frames, stringers, and stanchions were chosen for this study. A sample from each of the different types of timbers allowed for the representation of diagnostic features such as the original curve of the frame and ligature holes. Each representative timber was photographed, then larger-size timbers were traced, and smaller ones were directly measured. When the author commenced this study, it quickly became clear that none of the existing site reports mentioned the systematic numbering and cataloguing of the boat timbers. The author, therefore, had to start her work by creating a numbering system to label and identify the hull timbers of this boat. The bow acted as the starting point of all numbering, for the planks, lugs, or frames. For strake numbering, the keel plank served as the reference point: the strakes were numbered from the keel up, i.e. the closer strake to the keel, the smaller the number or letter designation—both for port and starboard side. It must be noted that tags were attached to some hull planks and the author checked whether these tags appeared in any of the field photographs. However, the labels did not match any reference drawings or database. For the purposes of this thesis, only the labelling system created for this thesis, which is the most complete, recent, and accurate, is used to refer to the different timbers.

During the second module, after the boat's reconstruction, the whole dimensions of the boat were measured also using a baseline-offset method. Similarly to the keel plank and rudder post, a centre line served as the datum line. The tip of the bow acted as the zero point for horizontal and vertical measurement (Figure 3.1). This arrangement was used to produce the lines: sheer, half-breath, and body plan.

In addition to the hull recording, several timbers with diagnostic or representative features were individually recorded. These timbers included the hull planks on both extremities to show the various types of scarf joints. These timbers were also representative as they exhibited different types of fasteners, i.e. when compared to those amidships. Another set of representative timbers were the wing ends at the bow and stern—they also show different, unique fasteners, especially when compared to lashed-lug boats found on other sites in Southeast Asia. Each of these timbers was directly measured to create 1-to-10 scale drawings.

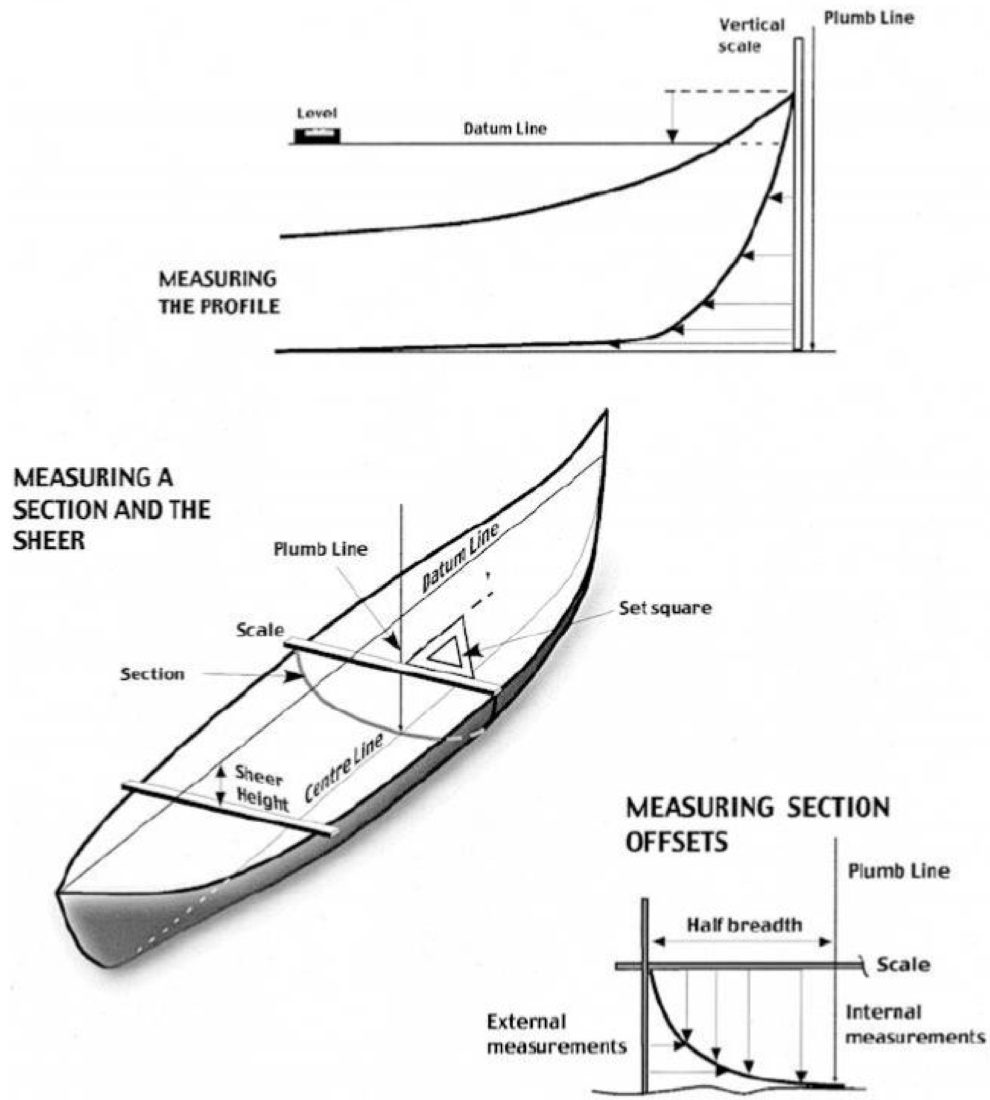

Figure 3.1. Diagram showing the method used to record the boat (McGrail et al. 2003:20)

Examination of Ship and Boat Iconography

Boat iconography was chosen as one of the datasets for comparative study and consists of reliefs—carvings on a temple's walls—and rock art, both limited to those found in Indonesia. Iconography has the potential to aid in the interpretation and reconstruction of the missing components of the Punjulharjo boat, such as the rigging and the propulsion. The only remnant alluding to the propulsion of the boat was its preserved rudder-mounting post, so it was rather difficult to gain much understanding only from the remains found in situ.

The aforementioned reliefs were those found on the Borobudur temple, the largest Buddhist shrine in Indonesia, even in Southeast Asia, built around the ninth century. Eleven ship reliefs were observed on the temple, ranging from a simple boat to an outrigger ship with tripod masts. These watercraft images have interested scholars since as early as 1912 (Inglis 2014:96). In addition to the Borobudur reliefs, depictions from rock art came from caves in Sulawesi, Papua, the Spice Islands, and Nusa Tenggara. The primary identification and recording of each image and the analysis of their context is beyond the scope of this thesis. This study, however, did assess and rely on secondary sources, mainly an unpublished thesis and journal articles. The main focus, however, was to establish (or not) a correlation between the Punjulharjo boat and the iconography to assess whether an acceptable analogy between the two exists.

Examination of Associated Artefacts

During the initial excavation of the Punjulharjo boat, the field team unearthed more than 250 artefacts; most of them were kept in the *Balai Arkeologi* office in *Yogyakarta*. The author visited the office and was granted a permit to examine these objects. The artefacts consisted of mostly pottery sherds, wood objects, metal objects and coconut shells (Abbas 2010:44–46). There were also ceramic sherds, which were surprisingly excluded from the published reports.

The artefacts associated with the Punjulharjo boat were not systematically catalogued; only a few had a particular note referring to their original location. It was, therefore, difficult to choose samples based on the position of the artefacts to, for example, understand the distribution of cargo or goods on the boat. The author decided to select, again, representative objects to study. The criteria used for the selection of samples was whether an object represented different material of manufacture such as earthenware, stoneware, porcelain, colours, and different elements of a vessel (base, body, lip, rim, etc.), or whether it had a specific decoration. Selected objects were photographed, and these photographs became the main source for detailed examination. The identification of each object was made by comparing photographs with reference literature and reports from previous archaeological studies.

Limitations

Due to the time constraint and the situation of the site at the time, the field work did not provide all the necessary data needed, which would have required the recording of every hull plank and pieces of the frame and stringer. The site presented less than ideal conditions for any recording, with all the rather hectic construction work occurring during the field work limiting ease of access to the boat. Thus, a slight inaccuracy in the recorded details might be expected, despite all efforts to maintain the recording process as scientifically accurate as possible.

Chapter IV

Data

Introduction

This chapter presents all data collected by the author during the 2017–2018 period of fieldwork at the Punjulharjo site in Rembang, Central Java, Indonesia. After undergoing conservation treatment for approximately three years, conservators from *Balai Konservasi Borobudur* recently reconstructed the Punjulharjo boat. They commenced the boat's reconstruction with a detailed recording of all individual timbers, and they did so again upon completion of the re-assembly process. The reassembled boat is positioned on its original, albeit elevated, location with the bow points west and, accordingly, the stern faces east.

The labelling of the timbers follows certain conventions. The keel plank (KP) serves as the reference point for all strake, lug, and frame numbering. The starboard strakes are labelled STR 1 to 6, where STR-1 is the one next to the keel plank and STR-6 is the outermost one. Meanwhile, the port strakes are labelled STR A to E, where STR-A lies just south of the keel plank and STR E is on the southmost side of the hull. Different code for each side is intentionally chosen to avoid confusion during recording. The numbering for frames and lugs starts from the one closest to the bow and the number gets higher towards the stern. Two lugs on the same strake that align to each other are labelled as A and B, for example STR-C-L12A and STR-C-L12B refer to the twelfth lug on the third strake of the port side; L12A is the lug closer to the keel plank. For a complete labelling of the boat, see Appendix A.

The plan of the boat as used in this thesis is an adaptation of the original drawing by *Balai Arkeologi Yogyakarta* of the visible condition of the boat when the excavation finished in 2009. Corrections made to the original plan are based on observations of the re-assembled boat and the most recent measurements of the position of the lugs and ligature holes on the hull remains. The plan therefore represents the current condition of Punjulharjo boat, as exhibited on the site (Figure 4.1). Two fragments of frame timbers originally placed on top of the third and the fifth lugs were omitted because their position in the hull is not *in situ* (and is therefore uncertain).

Hull Remains

The preserved hull timbers remain intact, which facilitated the re-assembly of all disarticulated components and allowed for an accurate and relatively easy reconstruction process. The hull measured 15.6 m in length, 3.6 m in the beam, and 1.1 m in depth amidships. It consists of a keel plank, a wing end on each extremity, six strakes on the starboard and five strakes on the port side. Each strake is composed of one to four planks of varying size. Only five strakes, however, have a complete set of planks while the rest were mostly missing their forward planks. The breadth plan of the hull shows the boat to have a pointed oval shape, with the bow and the stern shaped similarly (Figure 4.1). It is not a double-ended vessel, however, since the extremities differ in shape and size and the boat builders constructed both ends differently. On the extremities, the strakes end into a wing-end rather than in a traditional stem or a sternpost.

When the boat was dismantled after excavation, archaeologists observed three types of fastenings: dowels, lashings, as well as mortises and tenons. While dowels and ligatures for the lashings were used evenly throughout the hull, the mortise-and-tenon joinery only appeared on the timbers near the extremities, to join the strakes and the keel plank to the wing ends. Most of them did not survive, aside from several small sections of rope left in the holes and a few broken tenons. For the reconstruction, new dowels were used to join the planks on their edges. The dowels were the only fastening used in the reassembled boat since neither new ropes nor tenons were used to replace the perished ones.

Generally, the planking surfaces show various degrees of flaking, indicating the deterioration of the timbers, which probably happened before the conservation process commenced in 2014. Eight planks have damaged ends and two planks have broken edges. Most of the damage is concentrated in the aftermost section of the ship, only one forward hull plank has a broken end and one plank has a broken seam near the mid-ship.

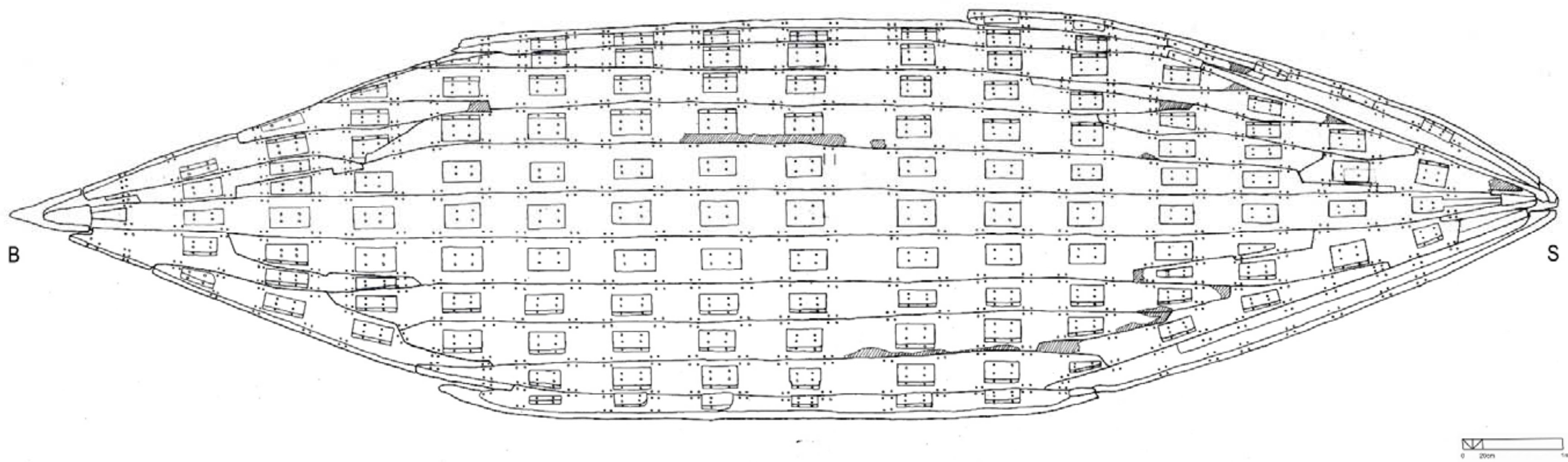

Figure 4.1. The preserved hull remains of the Punjulharjo boat without the internal strengthening to show the unobstructed planking, lugs, and ligature holes (Courtesy of Balai Arkeologi Yogyakarta 2009, with corrections by author).

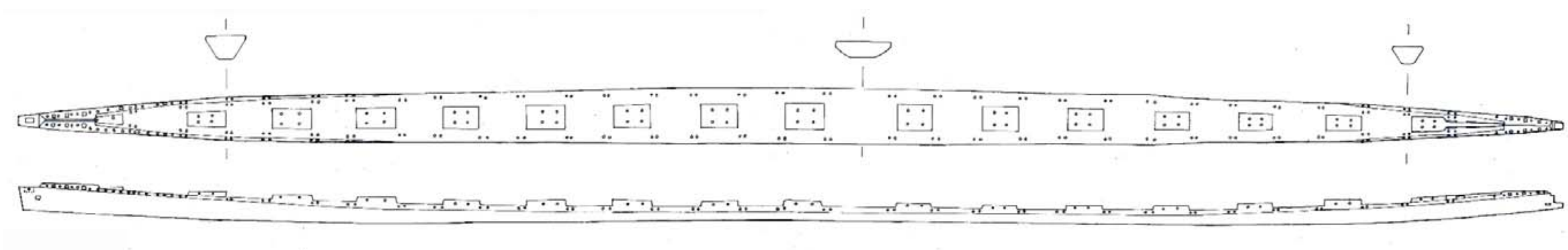

Figure 4.2. The sided and moulded profiles of the keel plank, the Punjulharjo boat (Illustration by author).

Deterioration is also apparent on the lugs, some were more degraded than the others, even though the form can still be recognised. There were 124 lugs on the remaining hull, aligning into transversal lines following the position of fifteen lugs on the keel plank. Some strakes, however, have more than fifteen lugs because they have one or more sets of pairing lugs, which consists of two lugs on two different planks corresponding to the same lug on the keel plank. Most of the lugs were rectangular, but some had an irregular shape, resembling triangles or polygons, these were spotted especially near the end of a plank where the timber tapered to a narrow tip. Each lug had four lashing holes, all with an L-shape, where one opening was on the surface side and the other was on the length-side of the lug (Figure 4.3). For a complete measurement of the lugs, see Appendix B.

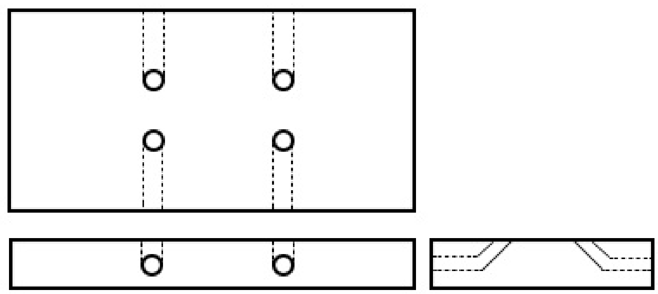

Figure 4.3. Diagram showing the ligature holes on a lug
(Illustration by author, not to scale).

Near every corner of a lug, a pair of ligature holes was drilled into the plank. The holes also have an L-shape as do the other opening ends on the seam, instead of on the outer surface of the plank. Every pair correspondence with another pair of holes drilled on the other adjoining plank. Because of the position of the lugs, these ligature holes form a transversal line parallel to the lug lines. Two lines, however, do not correspondence to any lugs; one close to the bow and another near the stern.

Keel Plank

The keel plank was carved out of a single piece of wood and was still in good condition. It measured 15.6 m in length, from the tip of the bow to the end of the stern. The plank tapers towards the bow and stern to form a tampered end (Figure 4.2). The end of the bow is rectangular in cross-section being 7 cm in width and 23 cm in thickness. Six centimetres towards its forward end, there was a mortise that measures 9 cm by 4 cm x 4 cm in size. At twenty centimetres from the end, the plank protrudes around 3 cm. The protruding part has both sides bevelled where the wing end should be placed. Five pairs of dowel holes were drilled in this part, along with three pairs of other holes that have a slightly larger diameter (Figure 4.4). The two holes of each pair were connected to each other, unlike the dowel holes. A small section of the broken ligature indicated that these pairs of holes were used to run the ligatures through and laced this timber to the wing end.

The plank then gradually broadens to reach a maximum width of 56 cm amidships, before narrowing again towards the stern. The keel plank holds fifteen lugs. The bevelled part near the end of the bow gradually joins the seam of the keel plank near KP-L3. The size of the lugs near the bow and stern were smaller than those amidships (Figure 4.5). The smallest measures 39 cm by 14 cm and the largest is 40 cm by 25 cm, while their thicknesses vary from 4.5 cm to 6.5 cm. The space between two lugs ranges between 45 cm and 50 cm, with the only exception being KP-L9, which is 74 cm away from KP-L8. Every corner of each lug has a pair of rope holes, which have an L-shape and their end is on the edge of the plank.

Figure 4.4. Bevelled part of the keel plank on the bow, with dowel holes and lacing holes. This part connects to the wing end (Photograph by the author, 11 November 2017).


Figure 4.5. Different size and shape between the lug on the amidship (left) and towards the end (right) on the keel plank (Photograph by the author, 11 November 2017).

The seam of the plank on KP-L14 tapers to join the bevelled protruding part on the stern. The protruding part, like the one on the bow, also has dowel holes and lacing holes to fasten the wing end on top of it (Figure 4.6). The stern also has three pairs of ligature holes, but slightly different to those on the bow; there were four, instead of five, pairs of dowel holes. There was a mortise at the end of the stern, which measured 9 cm in length, 5 cm in width, and 7 cm in depth. The tip of the stern also has a rectangular cross-section, like the bow, that measures 7 cm in width and 13 cm in thickness. The rectangular cross section on both extremities shifts gradually into a trapezoid and becomes broader and flatter towards amid ship, where the shape is rectangular with a concave bottom.

Figure 4.6. Bevelled part of the keel plank on the stern end, also with dowel holes and ligature holes (Photograph by the author, 28 November 2017).

Planks

Generally, each strake of the Punjulharjo boat had one large plank in the middle of the hull and one to two smaller planks toward each extremity which adjusts to fit with the hull's curvature (Table 1). While the large planks are similar in shape, their scarf ends are different. The smaller planks were shaped to accommodate their connection to the bow or the stern. The length of the large planks gradually become smaller as the strake goes farther from the keel plank.

Table 1. Summary of the number of planks and lugs on each strake

Side	Strake	Number of Planks	Number of Lugs
STARBOARD	STR-1	3	16
	STR-2	3	16
	STR-3	3	12
	STR-4	1	9
	STR-5	2	8

	STR-6	1	6
PORT	STR-A	4	19
	STR-B	1	10
	STR-C	3	13
	STR-D	1	7
	STR-E	2	8

Strake 1

STR-1 is a complete strake, i.e. preserved from bow to stern, consisting of three planks. It measures 14.6 m in length, 51 cm in width and 5 cm in thickness. STR-1-2 is the largest of the three planks, while STR-1-1 and STR-1-3 are the smaller ones. STR-1-2 measures 11.8 m in length, 50 cm in width and 5 cm in thickness. Meanwhile, STR-1-1 and STR-1-3 each measure, respectively, 2.6 m and 2.3 m in length, 32 cm and 50 cm in width and share the same thickness with STR-1-2. STR-1-1 has an irregular shape due to the scarf joint on its ends; a stepped scarf joint connects to the fore wing end, and a hooked scarf joint meets STR-1-2. Meanwhile, STR-1-3 has a stepped scarf joint on both ends adjoined to STR-1-2 and the aft wing end.

STR 1 has sixteen lugs, with two lugs on STR-1-1, twelve lugs on STR-1-2, and two lugs on STR-1-3. These lugs fit in parallel with the fifteen lugs on the keel plank, with the second lug on STR-1-1 and the first on STR-1-2 align to each other on lug line number 2. Thus, they were named STR-1-L2A and STR-1-L2B, with lug A is the one closest to the keel plank, in this case the first lug of STR-1-2. Generally, the lugs were rectangular, and they measured 30–41 cm in length, 16–22 cm in width, and 4–6.5 cm in thickness. Two exceptions are STR-1-L1 and STR-1-L2A, which are trapezoidal in shape— STR-1-L1 has a width of 16 cm on the forward end and 18 cm on aft end and STR-1-L2A bears more pronounced width-difference of 12 cm on the forward end and 18 cm on the aft end.

Strake 2

Similar to STR-1, STR-2 is a complete strake; it is also made up of three planks. This strake measures 13.7 m in length, 40 cm in width, and 5 cm in thickness. STR-2-1 measures 3.5 m in length and 32.5 cm in width. STR-2-2, the largest plank of strake 2, measures 9.8 m in length and 40 cm in width. Meanwhile, STR-2-3 measures 3.3 m in length and 31 cm in width. All three planks of this strake have 5 cm of thickness.

STR-2-1 has three lugs, L1 to L3. STR-2-2, the largest plank on this strake, holds ten lugs, where the first lug corresponds with the fourth lug on the keel plank. STR-2-3 has three lugs; the first two lugs adjoin with the last couple of lugs on STR-2-2, which correspond with lugs number 12 and 13 on the keel plank. Because the lugs on STR-2-2 were closer to the keel plank, they were named STR-2-L12A and STR-2-L13A while those on STR-2-3 became STR-2-L12B and STR-2-L13B.

STR-2-1 abuts to STR-2-2 using a nibbed scarf joint. Because the position of the joint is where the third lug of the stake supposed to be, this lug has a particular polygonal shape to adjust to the joint (Figure 4.7). The aft end of STR-2-2 sports two nibbed scarf joints, one starts near STR-2-L11 all the way to the end and another on the far end. The first one adjoins to almost two thirds of the lower seam of STR-2-3, and another connects to STR-1-3 from the previous strake.

Figure 4.7. A lug (STR-2-L3) on Strake 2 with an irregular form to adjust to the edge of the scarf joint (Photograph by the author, 30 December 2017).

Strake 3

This strake consisted of three planks with a total of twelve lugs. STR-3 measures 11.4 cm in length, 40 cm in width, and 5 cm in thickness. STR-3-1, the one that is near the bow, measures 2.6 m in length, 27 in width and 5 cm in thickness. The middle plank, STR-3-2, measures 8.9 m in length, 40 cm in width and 5 cm in thickness. STR-3-3 measures 3.3 m in length, 30 cm in width, also 5 cm in thickness.

A couple of lugs were carved out of STR-3-1, while STR-3-2 has nine lugs with the remaining one on STR-3-3. Each lug corresponds with KP-L2 to KP-L13, except two lugs, STR-3-L3A and STR-3-L3B, which correspond to the same on KP-L3. Another exception is that this strake does not have an L12. STR-3-2 has a nibbled scarf joint on each end to connect with STR-3-1 and STR-3-3. The first lugs on the fore end of both STR-3-1 and STR-3-2 have a trapezoidal plan, following the tampered shape of each plank's end. STR-3-L2 is 4 cm wide on the forward end and is 12 cm on the aft end, STR-3-L3B 5.5 cm wide on fore and 13 cm on aft.

Strake 4

STR-4 is presently a single plank strake, as it is incomplete, holding nine lugs. It has at least one fore plank missing. It measures 8.5 m in length, 32 cm in width and 5 cm in thickness. These lugs were parallel with KP-L4 to KP-L12. All lugs have rectangular plan, except the first one. The fore width on this lug is three-centimetre shorter that the aft width, which is 5 cm, resulted in a trapezoidal plan.

Strake 5

STR-5 was another incomplete strake with only two planks remaining. This strake measures 11.6 m in length, 35 cm in width and 5 cm in thickness. STR-5-1 measures 8.3 m in length, 35 cm in width and 5 cm in thickness, while STR-5-2 measures 3.8 m in length, 47 cm in width and 5 cm in thickness.

STR-5-1 holds eight lugs parallel to L5 through to L12 on the keel plank. This plank was attached to STR-5-2 using a scarf joint. The latter plank does not have any rectangular lugs. The lower part of this plank, however, protrudes from one end all the way to the other end, and served the same function as with the lugs (pic?). There were holes pre-drilled in pairs corresponding with other ligature holes on other planks above and below this plank. Three sets of pairs were parallel with L13, L14, and L15, and several pairs adjoin with ligature holes that held the rope to tie the two planks together.

Strake 6

There is only a single plank left on STR-6, the one near the stern. It measures 6.1 m in length, 33 cm in width and 5 cm in thickness. It has six lugs that correspond with KP-L10 to KP-L15. All these lugs have the regular rectangular shape. The continuous protruding found on the plank below it does not appear on this plank. The edge of the plank that is not connected to strake 5 has both dowel and lashing holes, showing that this strake is not the sheer strake of the hull.

Strake A

STR-A is the first plank next to the keel plank on the port side. It is a complete strake, consisting of four planks. Strake A measures 15.2 m in length, 40 cm in width and 5 cm in thickness. All four planks are similar in thickness being 5 cm despite sporting varied length and width. STR-A-1 measures 3.6 m in length and 42.5 cm in width. STR-A-2 measures 11.2 m in length and 40 cm in width. STR-A-3 measures 3.4 m in length and 43.8 cm in width. The last plank, STR-A-4 measures 66 cm in length and 22 cm in width.

The longest plank, STR-A-2, holds twelve lugs, STR-A-1 holds three lugs, and STR-A-3 holds four lugs. STR-A has a complete set of fifteen lines of lugs, with four sets of pairing lugs on lug number 2, 3, 12, and 13 (Figure 4.8). Both ends of STR-A-2 were shaped as stepped scarf joints with hooks to attach it to STR-A-1 and STR-A-3. In order to adjust the shape of the plank, the lugs near each joint have a triangular plan rather than the regular rectangle shape.

Figure 4.8. Lug number 12 and 13 on Strake A, each consisting of two parts on two different planks (Photograph by author, 2 January 2018).

Strake B

STR-B was a complete single plank strake, which measures 9.27 m in length, 30 cm in width and 5 cm in thickness. Both of its ends, however, were shaped into a scarf joint to connect this plank to STR-C-1 and STR-C-3. The later planks were made from a wider wood, so they not only adjoined to the largest plank on their strake, but also to strake B and strake D, another single plank strake. These timbers, however, were classified into STR-C because their lugs align with the STR-C-2. All ten lugs in STR-B were rectangular, except the last one, which was trapezoidal with 13.5 cm on the fore width and 10 cm on the aft width. The first lug corresponds with KP-L3 and the last one corresponds with KP-L12, without any pairing lugs.

Strake C

STR-C was a complete strake, which has three planks. This strake measures 13.05 m in length, 38 cm in width and 5 cm thickness. The longest plank, STR-C-2 measures 7.8 m length, 38 in width and 5 cm in thickness. The smaller planks, STR-C-1 and STR-C-3, are 3.6 m and 3.7 m in length, 45 cm and 41.3 cm in width, respectively. Both planks are 5 cm in thickness.

STR-C-1 has three lugs, STR-C-2 has eight lugs, and STR-C-3 has two lugs. Each of these lugs parallels with KP-L1 to KP-L13. STR-C-2 has a Z-scarf joint on each end to attach to STR-C-1 and STR-C-3. Anomalies on the lugs on this strake were STR-C-L1 and STR-C-L11, which both had trapezoidal plans. The first lug was on STR-C-1 with the aft end wider than the fore end. In contrast, the second lug, which is the last lug on STR-C-2, has a wider fore end than the aft one.

Strake D

Similar to strake B, this strake is also a single plank remaining on the port side of Punjulharjo boat. There is a possibility, however, that STR-D has other missing planks towards the bow.. This strake measures 7.16 m in length, 38 cm in width and 5 cm in thickness. The strake holds seven lugs, correspond with KP-L5 to KP-L11. The first and the last lugs have trapezoidal plans to adjust to the tampered end of the plank.

Strake E

STR-E has two remaining planks, one at midship and the other one toward the stern. This strake measures 11.8 m in length, 54 cm in width and 5 cm in thickness. STR-E-1 measures 6.8 m in length and 54 cm in width. STR-E-2 measures 5.5 m in length and 47.5 cm in width. Both planks are 5 cm in thickness.

STR-E-1 has eight lugs, each parallel to the fourth to the eleventh lug on the keel plank. STR-E-L11 is on the very end of STR-E-1 so the shape is trapezoidal with 8 cm on the fore end and 2 cm on the aft end. There is no rectangular or trapezoidal lug on STR-E-2. Similar to its counterpart on the starboard side, this plank has a continuously protruding lower part with ligature holes, which correspond with the holes on the lower strakes. Three sets of ligature holes are parallel with KP-L13 to KP-L15 and seven sets of holes adjoin with the plank-stitching holes on STR-C3 and STR-A-3.

Wing Ends

Punjulharjo boat does not have a stem or a stern post; instead it has a wing end on both extremities. Both wing ends consist of a single V-shape timber, where the stakes close in and adjoin to form the bow and the stern. The wing end sits on top of the bevelled-end of the keel plank. The fore wing end is generally larger than the one at the stern, even though they share a similar form.

The bow wing-end is 56 cm in height on the outer end. It has stepped arms; the left arm is significantly longer than the right one being 136 cm in length, while the right arm is 78 cm length. This timber has a tampered tip and descent to the arms (Figure 4.9). It sits on top of the keel plank, with three types of fastenings joining them: dowel, lashing, and a mortise and tenon joint. A mortise and five pairs of dowel holes were drilled on the bottom surface to meet their counterparts on the keel plank so they cannot be seen from the upper surface. Meanwhile, three lashing holes were apparent on the upper surface of the timber. These holes go through to the bottom and were adjacent to the ligature holes on the keel plank. On each side of the mortise, there was a hole that goes through the outer surface of the wing-end. This particular hole was parallel to the hole on the side of the mortise on the keel plank.

One mortise appears on the edge of the right arm to connect it with STR-A-1. The other arm has two steps; the first has a mortise to house a tenon, which joins the wing-end with STR-2-1, while the second has a couple of dowel holes that correspond with STR-1-1. Both steps have ligature holes; a pair on the first and two pairs on the second. The surface of the tampered end was deformed, and no timber remains attached on top of it to understand the original shape of this part.

The stern wing-end (Figure 4.10) is 48 cm in height on the outer end. Unlike the one on the bow, this timber has a bevelled end that gradually declines to the stepped arms. Similar to its counterpart, the stern wing-end also has a longer left arm. It measures 118 cm in length and the other arm is 66 cm long. It has a similar fastening system to the bow wing-end, but only four pairs of dowel holes are evident here. Three pairs of ligature holes correspond with the ones on the keel plank, and one of them still holds a small section of fibre ropes.

Figure 4.9. The wing-end on the bow of the Punjulharjo boat which sits on top of the keel plank (Photograph by author, 29 December 2017).

Figure 4.10. The wing-end on the stern of the Punjulharjo boat shows the three types of fastening used; dowel, mortise-tenon, and lashing (Photograph by author, 29 December 2017).

Both arms consist of two-stepped planks, the first has a mortise and a dowel holes and the second houses dowel holes and ligature holes. The seam of the first step connects to the bevelled end of the wing-end. The bevelled part holds two pairs of ligature holes and a pair of dowel holes. The lower step of the right arm adjoins with STR-1-3 and the upper one connects to STR-5-2. On the port side, the left arm's lower step supports STR-A-4 and the upper one attaches to STR-E-2. The dowel that is supposed to be on the bevelled end of the wing end also supports the same plank with the first step of the arm on each side. On those planks, however, there were no ligature holes that correspond with the ones on the wing-end.

Quarter-Rudder Mounting

When it was found, the rudder mounting was located around 30 cm east of the stern. It was unattached to the boat and no remains of the fastenings being found were mentioned in the reports. The post seems to have been made from a harder wood than the rest of the boat remains, as made evident by the condition of the timber which shows no flaking or other symptoms of degradation. Unfortunately, wood species identification of the timber has not been attempted, which would confirm or deny the suggestion that this was a deliberate decision on the part of the boat builders.

Figure 4.11. The rudder-mounting post found near the stern of the Punjulharjo boat (Photograph by author).

The mounting is 307 cm in length and 22 cm in the width. It consists of three parts (Figure 4.11), two cylindrical parts that connect to the middle section with a rhombus cross-section. Each cylinder meets the middle part on a notch, whose cross section is also a rhombus shape. The notches are likely to be placed on the aft strakes of the boat to lock the mounting to the hull. The cylinders have a protruding part along their length measuring 7 cm in width.

Despite the cylindrical and rhombus cross-section, the timber can generally be divided into two sides. On one side, there were four pairs of square holes on the rhombus part. The holes of each pair were connected to each other, indicating that they are to hold ropes. There was a concave notch on each cylindrical part, where a rudder should be placed. A mortise appeared towards each end of the post. On the other side, two mortises were chiselled on the rhombus part. No ligature holes were found on this side.

Frames

During the conservation process, all the non-plank timbers from the Punjulharjo boat were treated separately, but with the same method and solution. Unlike other timbers, the frames were mostly trapezoid in cross-section that makes them easily identifiable. One full frame mostly consisted of three pieces of timber, likely a floor timber and two futtocks. Unfortunately, every piece had been broken into smaller pieces, aside from three floor timbers.

Some timbers were broken into two or three sizeable pieces, with their moulded dimension measuring between 50 cm to 80 cm in length, around 8 cm in width, and between 7 cm to 10 cm in thickness. At least two of them can be matched to each other to form a possible floor timber. The rest of the frames have fragmented into smaller pieces, around 20 cm to 40 cm in length. These pieces were more difficult, although not impossible, to reconstructed. It still can be seen, however, that the frame timbers originally had a scarf joint on each end with two holes to hold dowels that fasten one piece to another (Figure 4.12). A couple of holes were drilled through the width, near the upper surface of the timbers. The larger pieces showed that each floor timber or futtock had at least two pairs of holes, with the distance between each pair being about 30 cm. The holes were 1.5 cm in diameter and were drilled as lashing holes as one of the floor timbers has holes with ropes remaining inside them.

Two of the three floor timbers were placed in the re-assembled hull on top of the lugs numbers 3 and 5 (Figure 4.13). They were not fastened by ligature to the lugs and their position is somewhat questionable. With around 150 cm of moulded length, these timbers were the largest piece of the remaining frame timbers. The timbers were mostly worn out, but the cross-section is still observable - a trapezoid with a convex base. The one placed on top of lug number 5 shows an apparent scarf joint of its ends. Both timbers were gently curved, in contrast to the other floor timber with a prominent curve (Figure 4.14). Consequently, this piece of wood is a floor timber from the boat’s extremities since its curve should fit the narrow width of the bow and the stern.

Figure 4.12. A scarf joint to connect pieces of frame-timber (Photograph by author, 21 November 2017).

Figure 4.13. Two pieces of floor timber of the frame (Photograph by author, 30 December 2017).

Figure 4.14. A floor timber of the frame on the stern area (Photograph by author, 20 November 2017).

Stringer, Beam, and Stanchion

Other than fragments of frame, the non-plank timbers consisted of stringers, beams, and stanchions. Among the three types, the stanchion is the only one that can be easily identified due to its particular shape. A stanchion is a piece of timber tied on top of a stringer to support a layer of beam laid out in parallel with the frame, so the beam would be level instead of following the curvature of the frame. It has the shape of a reversed slingshot-handle, with a main post and two feet (Figure 4.15). The diameter of the main post varies from 3 cm to 5 cm. This part has a rope hole, which is drilled in either parallel or perpendicular direction to the two feet.

After setting the stanchions aside, the remaining timbers were fragments of cylindrical poles, which would have once been the stringers and beams. A stringer is the long pole that goes along the length of the Punjulharjo boat, in parallel to the strake. This pole was lashed perpendicularly on top of the frame. Meanwhile, the beam of the Punjulharjo boat sits on top of several stanchions, parallel to the frames. The beams were therefore shorter than the stringers. It is difficult, however, to separate the stringer fragments from the others as they do not show any particular features. The length of the fragments varies between 10 cm to 40 cm and their diameter measures from between 2 cm to 5.5 cm.

Figure 4.15. A stanchion with one ligature hole drilled perpendicularly to the feet (Photograph by author, 20 November 2017).

Rope

The majority of the ropes attached to the boat when it was initially found did not survive. Originally, the ropes were one of the means of fastening on the boat, if not the primary one. Not only did they tie the hull planks together, but they also lash all the internal strengthening components to each other. Unfortunately, only a small amount of the ropes left on the site were available for observation. Several ligature holes on the hull planks still held a small section of the coil. Similar remains were also found in the holes on the frame fragments. They were, however, too fragile to be pulled out and thus cannot be sampled.

Fortunately, a sample was able to be pulled out from one of the lashing holes on the stern wing-end. The hole was larger in diameter than the ones on the planks or the frames and thus provided easier access to take out the section of rope. The sample is a coil consisting of ten lines of rope (Figure 4.16), held together by residual mud that was hardened by PEG when the wing end was submerged into the solution during the conservation process. The coil measured 9 cm in length and 1.5 cm in diameter. Each line of rope has two strands that are twisted counter-clockwise (Z-twist). Each strand consists of numerous yarns that are twisted clockwise (S-twist). One strand measures 3 mm in diameter.

Figure 4.16. Fibre ropes sample taken from the stern wing-end (Photograph by author, 1 June 2018).

Conclusion

This chapter has presented the data gathered from the visit to the Punjulharjo site. The condition of the boat remains has been described, both as an intact hull and as individual components. It can be seen that after ten years since the initial discovery, the Punjulharjo boat has experienced several changes that have affected its condition. The hull is generally still in a good condition; all the planks were able to be reconstructed into an intact assemblage. The internal strengthening has under gone some major changes on the other hand. Almost all timbers are damaged, and the ligatures are close to perishing.

The observation of the boat remains during their disarticulated phase before the reconstruction began reveals much important information about the planking, joinery, and fastenings of the boat. This information was previously unattainable because many parts of the timbers were obstructed from view when they were attached to each other or being covered by other components of the boat. The sequence of how the ligatures lashed the hull and other internal components together can, however, no longer be established due to the current state of the boat. Therefore, a comprehensive comparison between this data with the results of previous research is critical to analysing the shipbuilding technology of the Punjulharjo boat.

Chapter V
Discussion

Introduction

An examination of the prevailing literature about the Punjulharjo boat reveals several gaps in the description and the analysis undertaken of the construction of the boat. The visit to the site to observe the boat remains, both when they were disarticulated during conservation treatment and after they were reassembled in the reconstruction, provided a considerable amount of new information to help in understanding the construction technology used to build this boat. The dismantling of the boat revealed many parts that were previously covered, such as the fastening system of the hull planks. The unsoiled timbers, after being treated by conservation work, presented details that were difficult to notice during the excavation because they were still covered by sand or mud. The reconstruction process and the resulting exhibit show how each part of the boat attached to and worked with each other, something that might be difficult to understand when they were all fragmentary.

The results from the timber recording undertaken during the latest fieldwork cannot provide all the necessary information to answer the research question; how does the assembly method and technology used in the Punjulharjo boat's construction fit with current theories of the development of Southeast Asian wooden boatbuilding? Even though the reassembled boat is indeed cleaner and more accessible for observation, it is still missing several original elements. From all the timbers, only the hull planks can be reassembled. Most of the internal strengthening was broken and thus difficult to reconstruct. It is therefore essential to combine the recordings from the latest fieldwork with results obtained from previous archaeology in this analysis. The report and photographs taken during the excavation were consulted and scrutinised to make the connections between the original condition and the re-assembled boat. Comparisons with other vessels from the same lashed-lug tradition, as well as other data such as iconography and ethnography was used to aid the interpretation with the aim to gain a more comprehensive understanding of the technology used to build the Punjulharjo boat.

Because the Punjulharjo boat is the only lashed-lug vessel with the hull and some internal strengthening still intact, it is also essential to place the boat within the Southeast Asian context, after some understanding of the construction is gathered. The reconstruction of a lashed-lug vessel is often conjectural due to the fragmentary archaeological remains located to date (Liebner 2014:267). This limitation causes the knowledge of this boatbuilding technology to not be fully advanced. This contextual analysis intends to see if additional information gathered from the Punjulharjo boat will confirm, negate, or add to the current theories of the lashed-lug tradition.

The Punjulharjo Boat

The boat unmistakeably belongs to the lashed-lug tradition as reported previously. The lugs projecting from the inner side of the hull are a clear indication, supported by several fragments of the frames lashed on top of them with intact ligature, made from vegetable fibre ropes. The planks were joined edge to edge with entirely discreet fastenings to leave the outer hull smooth. The internal strengthening preserved on the boat indicates how the builder heavily relied on *ijook* ropes to construct them.

A reconstruction of the hull is beyond this thesis, but it is interesting to discuss several variations related to the boat's dimension, noticed in the reports as well as resulting from the fieldwork undertaken. The only consistent number is the length of the boat which measured 15.6 m. The reports mention the widest beam of the boat to be 4.5 m (Manguin 2009:4) and 4.6 m (Abbas 2010:42; Sulistyarto 2010:56). Based on the hull profile and extrapolation, Manguin (2009:4) then argues that the boat should have originally measured 17 m in length, 5.7 m in beam, and 2.3 m in depth. The drawing attached in the excavation report, however, shows that the boat only has 4.15 m of the remaining width. The author tends to use the measurement from the drawing because there is inadequate data to support the number mentioned in the reports, not even a photograph from the excavation uses a proper scale to support the description. Meanwhile, the measurements taken during fieldwork shows that the reassembled boat is 3.6 m at the widest beam. The reconstruction process might be responsible for this half-a-metre difference, as the boat is assembled on top of new concrete supports and thus the curvature of the hull is slightly altered (Figure 5.1).

It seems that Manguin (2009) wrote the report before the excavation was finished because there is also inconsistency in the number of strakes mentioned, compared to the reports by *Balai Arkeologi Yogyakarta* (Abbas 2010; Sulistyarto 2010). On how the incomplete measurement might impact his estimation of the original dimension of the Punjulharjo boat is, again, beyond the scope of this thesis. The observation of the profile of the boat's extremities, however, finds no indication of a projecting bow or stern. Such projecting trend should be present for the hull to reach the proposed 17-m length. Further reconstruction study is, therefore, encouraged to support this estimation.

Figure 5.1. The Punjulharjo boat after conservation and reconstruction, on display *in situ* (Photograph Dit. PCBM, January 2018).

Planking and Fastenings

Keel plank

The keel plank of the Punjulharjo boat shares one of the characterics of the lashed-lug tradition and with all other vessels found to date; it is carved out of one piece of timber. A single-wood keel plank offers more strength and endurance to enhance the seaworthiness, especially when a true keel is absent from the boat. The plank is slightly rockered towards amidship. While the width gradually narrows from the midship towards the ends, the thickness increases in the same time as the concave bottom shifts to a rectangle end. This form is also found in the Butuan boat 1 and Butuan boat 2 (Lacsina 2016:148, 165), and even in the *Cirebon* shipwreck (Liebner 2014:246) which is argued to be the only lashed-lug vessel with a real keel found to date. This type of keel plank stabilises the hull when moving on the water, but will not cause any problems during beaching (Liebner 2014:246).

Besides in thickness and in cross-section, the keel plank also differs from the strake planks on its ends, where a slightly protruding, bevelled part presents before a mortise at the very end. This part was necessary to hold the fastening holes, primarily the V-shape lashing holes but also the dowel holes; and at the same time works as a notch attached to the wing-end, to provide a stronger grip. The rest of the keel plank, on the other hand, does not substantially differ from the other planks. Its width is not that much wider than the central plank on each strake, and its lugs have a similar shape to the others. Although, most of them were slightly wider than the other lugs on the same row, and some were the longest lugs on their row. The only lug with distinctive feature was the fifteenth lug, which is connected to the bevelled end by a continuous ridge.

On the outer surface, near the bottom end, of the rectangular area of the keel plank, both on the fore and aft end, there is a square hole that goes through the two sides. The photographs from the excavation show, albeit unclear, that these holes held ropes, which possibly were woven into a loop (Figure 5.2). The loop circles the end of the keel plank and holds the mooring line of the boat. Similar to the ropes used on other components of the boat, the mooring line was also made from *Arenga pinnata* fibres.

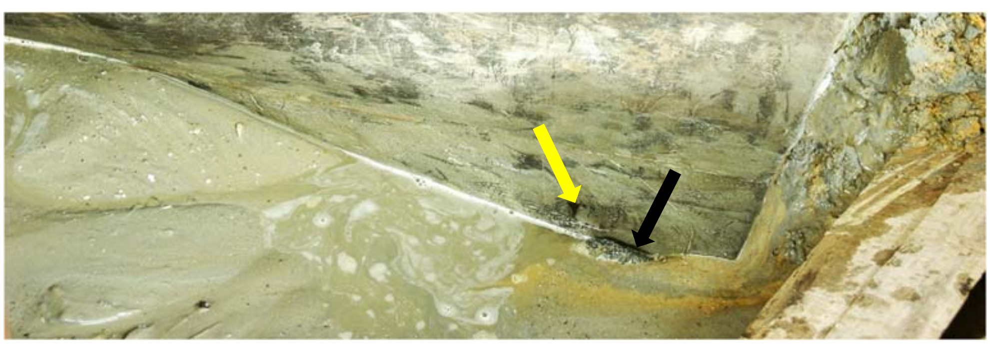

Figure 5.2. The square hole on the outside of the bow (yellow arrow) that holds ropes for mooring (black arrow) (Photograph *Balai Arkeologi Yogyakarta*, 24 June 2009).

Planking

On each side of the keel plank, long planks are arranged into strakes to build the beam of the hull, up to the sheer line. These planks become the central plank of each strake, which were joined by fore and aft planks to accommodate the curvature of the hull towards the bow and the stern and, supposedly, make a full strake (see Appendix C for the shape of the fore and aft planks). The planking of the Punjulharjo boat, however, shows some irregular patterns. The central planking of the boat are consistently the longest planks on the first to, at least, the third strake on each side. Only the fore and aft plank of the first strake on each side connects to the wing-end on the bow and stern, while the other two strakes end before reaching the wing-end. The planking shows that the aft plank of the fifth strake, on both sides, adjoins all the lower aft planks and the middle plank of the fourth strake, connecting them to the stern wing-end. This arrangement leaves the fourth strake without an aft plank. The fourth strake of the port and starboard sides, on the current reconstruction of the boat, consists only of one middle plank. While a forward plank might still be a possibility, it is likely that these strakes also do not have a fore plank, assuming that the forward planking has the same pattern with the aft.

The trend of a long central plank and shorter fore/aft planks shifts on the fifth strake. While the starboard still indeed has a fifth middle plank that is longer than its aft plank. The opposite side has a middle plank and aft plank with a similar length. The missing fore plank would also have had the same length if the gap left between the mid plank and the bow wing-end is an indication. The remaining sixth strake has only an aft plank on the starboard side. This plank is rather long and nearly reaches amidship. If this strake has the same pattern as the previous strake, it is likely that the middle plank would be shorter than the fore/aft planks. This assumption is also supported by the trend shown on the central planks that were becoming shorter towards the upper strakes.

The forward and aft planks, in contrast to the middle planks, do not have an apparent pattern related to their shape; each plank has a different shape and dimension. At least four of these planks have their one side meet two different middle planks on a scarf joint. It is somewhat difficult to decide which plank goes to which strake if the position of the planks is the only reference. The easiest way to identify the strakes is, thus, by following the longitudinal position of the lugs, as explained in chapter 3. This planking indicates that the fore and aft planks were carved out after the builders finished carving all the central planks.

Fastenings

The planks were joined edge to edge by dowels and rope lashings. Each plank lashing works independently on a four holes basis. Two L-shape holes on an edge of one plank correspond with another two holes on the edge of the adjacent plank. The lashing holes were not drilled in a random position on the plank. The majority of them used a lug as a reference point, and systematically form two rows of lashing holes on each side of a row of lugs. On the bow and stern, where no lug can be used as a reference, the lashing holes were drilled in a position that was carefully chosen so the holes still form a row. At least thirty-two rows of plank lashings were counted on the reassembled hull.

The ropes do not, however, indicate a rectangular or diagonal lashing over the four holes. They instead make two independent stitches, each goes through one hole to another one on the other plank, resulting in two side-by-side stitches. A bamboo stick was later put in between them, and a racking seizing then secures the two stitches. One bamboo stick was used to help tighten several lashings instead of a small wedge for each lashing (Figure 5.3). An exception was apparent on the stitches that attach the fifth strake's aft planks to the lower planks. A single smaller piece of bamboo was placed under the lashing, perpendicular to the other bamboo (Figure 5.4). This was possibly to accommodate the sharp angle between the ridge lug on the fifth strake and the other planks.

Figure 5.3. Plank lashings arranged into a row on each side of a frame (Photograph *Balai Arkeologi Yogyakarta*, 23 June 2009).

The dowel holes were drilled on the seam of the planks following a particular pattern. The builders drilled one dowel hole on each side of a pair of lashing holes to form a set of four holes with one dowel-two lashing-one dowel pattern. Another dowel hole was later drilled in between two sets of holes (Figure 5.5). A few anomalies of two dowel holes in between two sets were identified, but the reason behind it is still unknown. While dowels were present throughout the whole, additional fastening of a mortise and tenon joint appears only towards the boat's extremities. They added strength to the scarf joinery that attaches one plank to another on their ends.

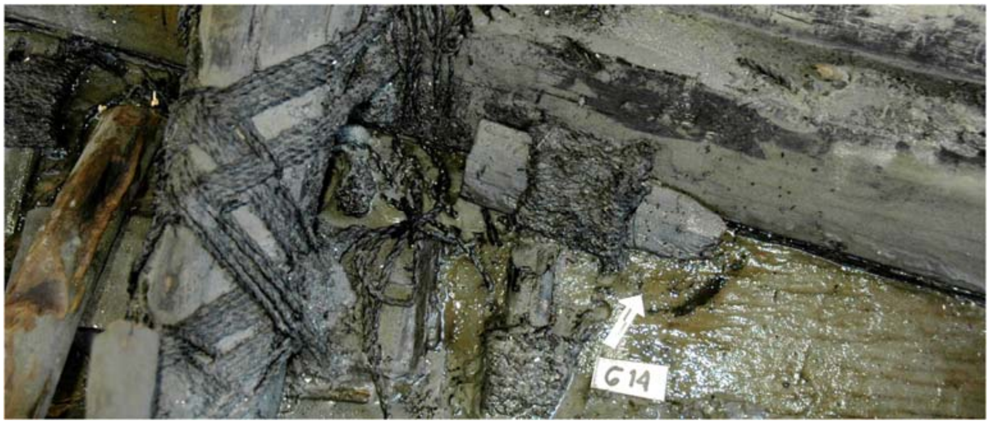

Figure 5.4. A plank lashing on the fifth strake's aft plank with a bamboo wedge (Photograph *Balai Arkeologi Yogyakarta*, 22 June 2009).

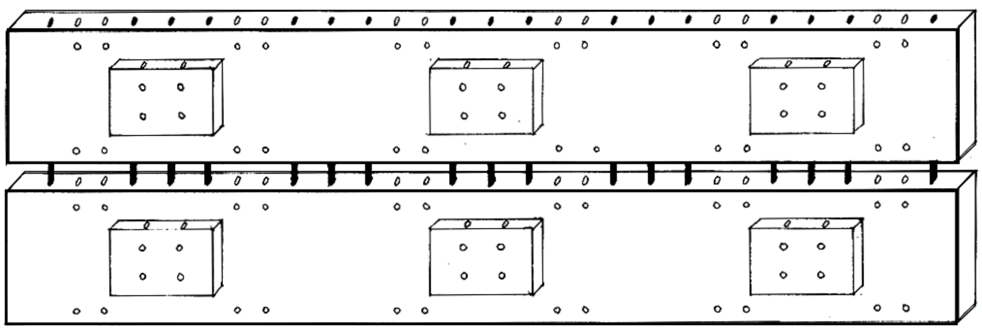

Figure 5.5. Diagram showing the pattern of the holes drilled into the seam of the planks (Illustration by author, not to scale).

Lugs

Generally, all the lugs on the hull of the Punjulharjo boat were divided into the forward and aft lugs. The separation was made apparent by the distance between lug row number 8 and number 9, which was around 25 cm longer than the distance between the other lugs. This division seems to have been applied not only for the lugs but also to the hull in general since other parts of the construction of the hull mainly use the lugs as the reference. This division results in a longer forward ship than the aft, because the gap was not precisely amidship. The builders purposely plan this partition when they carved the lugs on the keel plank, with the other lugs following this pattern they would have end up producing a boat with a 70-cm gap in the hull. The reason behind this is, unfortunately, still difficult to know.

The majority of the lugs on the Punjulharjo boat have a rectangular shape, each with four L-shape lashing holes that work in pairs. Each pair collaborates with another pair of holes drilled on the adjacent lug to hold a lashing, which binds a frame placed on top of the lugs. The non-rectangular lugs were the result of the lack of space on the end of a plank for a rectangular lug since it had to be shaped into a scarf joint. These irregular shape lugs indicated that all the strake planks would have been planned out first and the lugs were possibly shaped last.

Another variation to the lugs on the hull is the continuous ridge lug on the aft plank of the fifth strakes on both sides. They had a similar function to the other lugs, but they only have one pair of lashing holes instead of two. The ridge goes along on almost all the length of the planks. Seeing the position of these planks, and the fact that they adjoin the ends of the four lower strakes to the stern wing-end, it was likely that the ridge is intended to make the plank thicker. The planks act as a pseudo-wale and add strength to the hull construction.

Bow and Stern Assembly

The bow and stern assembly were one of the distinguishing features of lashed-lug vessels, with the use of wing-ends instead of the stem and stern-post. The Punjulharjo boat is the only archaeological discovery with a wing end still intact on both extremities. The central part and the arms of the wing-end correspond to the keel plank and the strake planks (Figure 5.6). Both the bow and stern wing-ends have a similar feature related to the fastenings: they used lashings, dowels, and mortise-tenon joints. The shape of the two timbers was generally also comparable, consisting of the central part and two arms, each with a different length. The sequence applied to the wing-ends should, therefore, resemble one another.

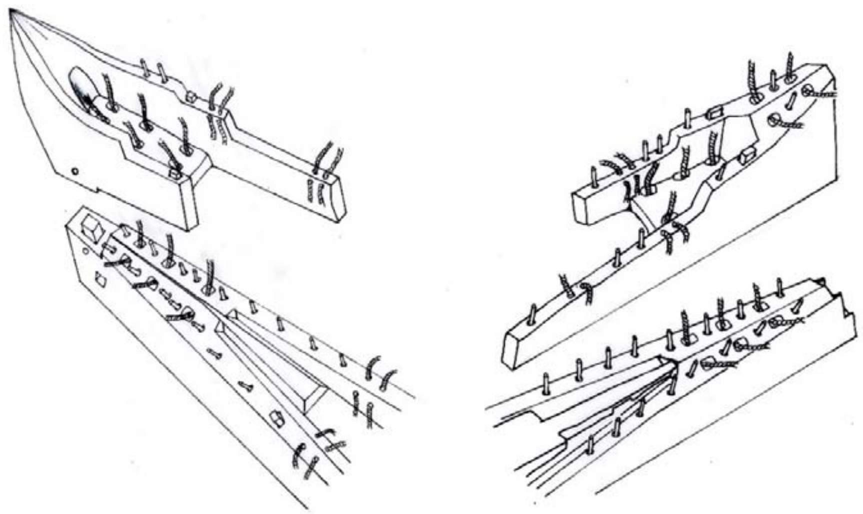

Figure 5.6. Fastenings of the wing end on the bow (left) and stern (right) (Illustration by author, not to scale).

The central part was also attached to the keel plank by dowels and lashings. Three pairs of ligature holes hold *ijook* ropes to form three independent lashings. A photograph from the excavation shows that, initially, there was another small piece of timber that was also a part of the wing end and functions like a stopper (Figure 5.7). The stopper timber was placed on top of the ligature holes and the rope was then secured in a lashing. This stopper was only found on the stern and not on the bow. It is likely, however, that the bow wing-end also had it but the timber had already deteriorated when the boat was found. The upper part of the central part is bevelled, resembling the one on the keel plank, with two pairs of ligature holes and several dowel holes. This part corresponds with the aft plank of Strake 5 and Strake E, and two independent lashings tighten the three timbers. There is not enough rope left to understand the full lashing pattern, but possibly a piece of stopper was put on top of where the edges of the planks meet. Meanwhile, the arms of each wing-end were connected to the aft planks by dowels, lashings, and free tenons. This finding negates the excavation team's interpretation, which says that dovetails and dowels connected the timber to the keel plank, while only dowels were used to join the wing end with the hull planks (Sulistyarto 2010:60,62).

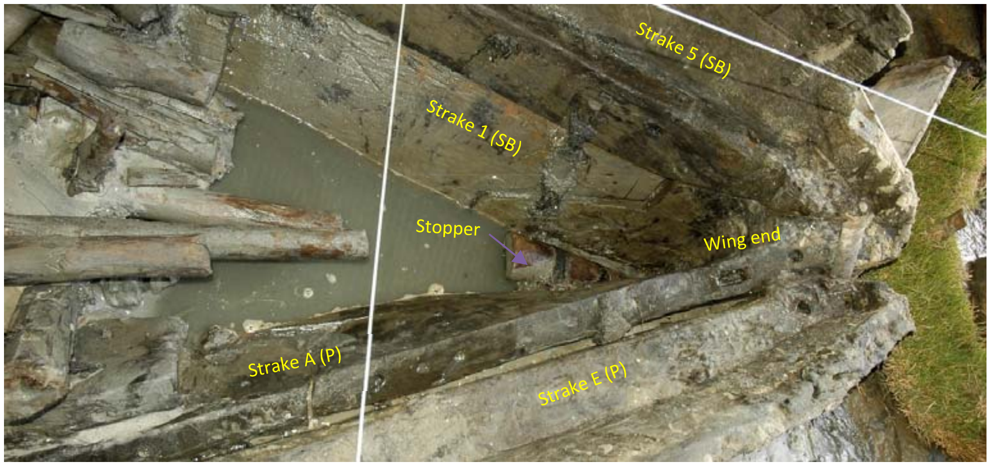

Figure 5.7. The stern assembly using wing end (Photograph by Balai Arkeologi Yogyakarta, 21 June 2009).

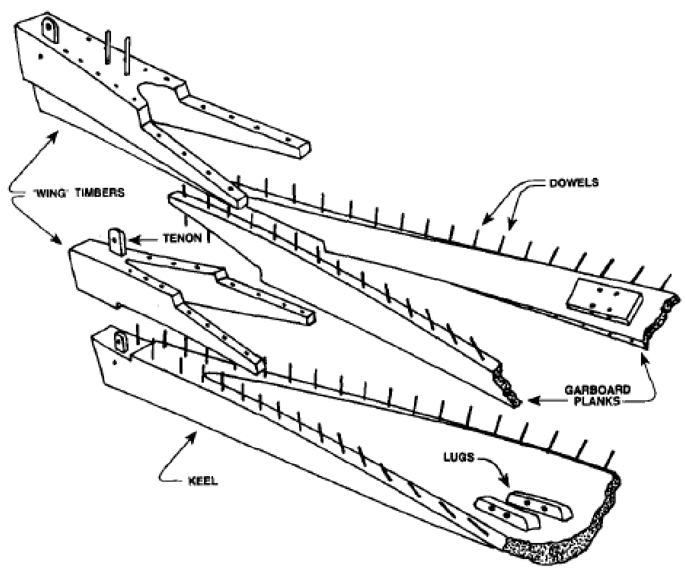

Figure 5.8. Hypothetical arrangement of wing stem for the Butuan boat 2 by T. Vosmer (Clark et al. 1993:151).

This reconstruction of the wings disagrees with the hypothetical reconstruction offered by Vosmer for the wing-end of the Butuan boat 2 (Figure 5.8). He argued that the wing consists of several sections, stacked on top of end other, with each section corresponding to a strake (Clark et al. 1993:154). The wings on the Punjulharjo boat consisted of two pieces of wood, one large and another small timber, and each serves a different function. Only the large piece works on the construction of the hull, while the small piece has a similar role to the bamboo wedges put under the plank lashing: to hold and tighten the lashing of the keel plank to the wing. Unlike Vosmer's reconstruction, not all strakes correspond directly to the wing. On the stern, we can see that the wing corresponds only to the first and the fifth strake of both the port and starboard side.

Internal Strengthening

The internal strengthening that was still lashed to the hull is one of the significant values of the Punjulharjo boat. Unfortunately, as described in the previous chapter, most of them were broken or perished. The current condition of the internal strengthening drives this analysis to rely primarily on the photographs from the excavation, while the observation of the remaining fragments provides details that cannot be seen in those pictures.

Frame

The excavation report mentioned there should be seventeen frames on the boat (Abbas 2010:42; Sulistyarto 2010:56). By the time it was found, only twelve rows of lugs still held the floor timber, some of them with one futtock. A closer look to the hull showed that there are only fifteen rows of lugs to support the same amount of frames. There were indeed two rows of lashing holes, one on the bow and the other on the stern, which might be mistaken as having the same function as the lugs; to support a frame. These holes were, instead, drilled to hold the plank lashings.

All the frames have a slightly different cross-section to each other, even though generally they were trapezoidal. The shape provided a better grip to the rope (Pomey and Poveda 2018:46), unlike the circle that is too slippery or the rectangle that will wear the rope fast, especially on the sharp edge. The top surface of the frames was flattened so a bamboo stick could be placed on top of it. The bamboo added additional grip, so the lashing would be adequately tightened. The floor timber was joined with the futtocks on a scarf joint and fastened by a pair of dowels.

Stringer, stanchion, and beam

The arrangement of these strengthening elements follows the division of a boat, so there should be the forward set and an aft set. Unfortunately, there are not enough photographs to provide detailed information about the strengthening on the fore ship. By the time the excavation started a few months after the locals had found the boat, the timbers were already broken into small pieces, possibly due to the harsh weather and inadequate first-aid. The interpretation of the arrangement, thus, is based on the remaining components on the astern ship, with an assumption that the forward set also had the same arrangement (Figure 5.9).

Figure 5.9. The remains of internal strengthening on the fore ship of the Punjulharjo boat after the finding in May 2008 (left) and before the excavation in December 2008 (right) (Manguin 2009:2).

The stringers provided additional longitudinal strength to the hull construction. One pole of stringer was placed on top of the frames and tightened by lashings. The rope on each lashing went through a pair of holes pre-drilled near the top surface of the frame. The setting of the stringers follows the curvature of the hull: the distance of one to another was wider in the midship and narrowed towards the extremities. For the aft set, the poles practically touch each other on the fifteenth frame.

It is important to notice that this arrangement was reflected in the frames, particularly on the lashing holes. This information would be helpful in the reconstruction of the boat's internal strengthening in the future. A frame piece with a broader distance of the lashing holes should be placed towards amidship, and vice versa. On the fifteenth frame, only the middle stringer was lashed on to the last frame, and therefore the floor timber should only have a single pair of lashing hole drilled in the middle. A comparable setting should be expected for the fore stringers, even though the poles might be at least 50 cm longer than the aft since they sit on top of eight, instead of seven, lugs.

On top of each lashing which bound a stringer to a frame, a stanchion was lashed to the stringer. The top end of the stanchions should be levelled to each other to support a beam. Each of these stanchions, thus, had a different height to accommodate the lateral curvature of the floor. The number of beams seen in the photographs does not correspond with the stanchion rows: they are too many beams found in between two stanchion rows.

The absence of any lashings on the poles indicated that they might belong to a temporary addition placed to support cargo or other items that need to be stacked on the floor. This type of temporary arrangement was also suggested by Liebner (2014:287) in his reconstruction of the *Cirebon* shipwreck.

Lashing patterns

It is evident that the builders used *ijook* ropes extensively to fasten the internal strengthening elements of the Punjulharjo boat. They would have been highly skilled in rope working as various types of lashing were used to bind different parts of the boat, such as the frame to lugs lashing, the stringer to frame lashing, and the stanchion to stringer lashing. The former two types have a fairly similar pattern throughout the whole hull, but the last type shows varied patterns.

Figure 5.10. A fragment of frame lashed to the lugs and stringers lashed to the frame (Photograph *Balai Arkeologi Yogyakarta*, 21 June 2009).

A frame was tightened to the lugs by several sets of lashing. One set of lashing ropes tied a frame to two lugs, instead of one (Figure 5.10). Apparently, the two pairs of holes on a lug do not belong to the same lashing sequence; instead one pair was partnered with another pair on the adjacent lug to form one lashing. Each frame lashing consists of seven strands of rope that were flattened over the frame's surface to make a diagonal lashing. A piece of bamboo was placed on top of the frames, under the ropes, to tighten the lashing. This frame lashing technique is different to those used in more modern watercraft recorded in ethnographic studies. In these vessels, each lug holds one independent lashing to bind the frame (Horridge 1985:54). For the Punjulharjo boat, because they were formed between two adjacent lugs, the frame lashings also served as plank fastenings.

The pattern of the stringer to frame lashing varies between a diagonal and a rectangular lashing. The reason for this variation is, however, still unknown. Similarly, the stanchion to stringer lashing also has several different patterns. Some of the patterns demonstrate more complicated rope work skills than the stringer lashing, with seized ropes used to form the lashing. It is possible that the position of the rope hole on the stanchion determined which pattern was used on them. Another possibility is that there was no strict rule related to these lashings, as oppose to the frame lashing which seems to have a certain standard to follow.

Propulsion

Quarter-rudder mounting

The only indication of the propulsion used on the Punjulharjo boat was the quarter-rudder mounting found close to the boat remains, facing downward. Such a position suggests that the boat owner must have removed the mounting from the hull when they abandoned the boat. Assuming that the mounting was not merely placed on top of the sheer strake, and other components might have been attached on top of the timber, the upper stern strake(s) must have been taken down deliberately, rather than deteriorated due to natural factors.

The two concave notches indicated that the boat had a double quarter-rudder, confirming the interpretation of the images of watercraft carved on the bas-relief of Borobudur temple. The images show a timber with circular cross-section to mount the quarter-rudder, a definition that matches the profile of the mounting found on Punjulharjo site. Burningham (2000) in his ethnographic study of the quarter-rudder mounting of the traditional boats in Indonesia observed that the mounting was made of a composite structure of planks and is positioned on the aft sheer strake of a watercraft. A different arrangement is found on the Borobudur ninth-century vessels, where the mounting is placed approximately a third under the sheer strake, between two planks and left both ends to protrude outside the hull (Figure 5.11). The mounting of the Punjulharjo boat seems to conform to this arrangement, assuming the rabbet notches should lock the timber on the plank below and above.

Without any archaeological remains found in situ, the shape of the Punjulharjo boat's quarter rudder can only be interpreted in light of the iconography and findings from other sites. Three quarter-rudders were found in two sites in Sumatra: Sungai Buah and Mulya Agung. All three rudders shared a similar shape, a long shaft and a blade carved out of a single wood, but they differed in size. The two rudders from Sungai Buah measured 8 m in length, while the one from Mulya Agung only reaches 3 m and was 11 cm in diameter (Wiyana 2010:113). They all have a through square hole near the tip of the shaft, possibly to attach the tiller. Another quarter rudder was also found with Butuan boat 1 but only the blade part remained (Lacsina 2016:160–161).

Figure 5.11. One of the Borobudur vessels that shows a quarter-rudder placed on a mounting (Photograph Anandajoti 2009 in Inglis 2014:109).

Punjulharjo Boat and the Lashed-lug Tradition

Through an overview of all the archaeological evidence of the lashed-lug vessels found to date, Manguin (2016:61) proposed that in the span of two millennia the tradition had evolved, which can mostly be observed through the plank joinery. Previously, a definite timing of when this change happened could not be established, only that it should have happened sometime before the twelfth century A.D. when the Butuan boats were built with dowel-only plank joinery. The latest dating of the Butuan boats, however, pushes the date to around the tenth century A.D. (Lacsina 2016:206). This result suggests that the change might have occurred sooner than previously thought. The *Cirebon* shipwreck supports this argument since it also used only dowels to join the planks on their edges and, according to the dating of the cargo, the vessel should have been built around the tenth century (Liebner 2014:6).

Manguin (2009:7) further argued that considering the presence of plank lashing and the high amount of dowels, the Punjulharjo boat should be one of those transition vessels in between the two types in lashed-lug tradition. There are a few issues related to this argument, however, which need to be addressed here. Lacsina (2016:206) proposes that the Butuan boats should chronologically be put between the Punjulharjo boat and the *Chau Tan* shipwreck as well as the *Cirebon* shipwreck. This statement supports Manguin's argument since the Punjulharjo boat seems to have been the last lashed-lug vessel with plank lashing. A closer look to the latest publication on the *Chau Tan* shipwreck, however, finds that the vessel still has ropes lashing their plank. It is interesting how this information does not appear in the description, but the figure of the keel planks clearly shows lashing holes on each corner of the lugs, many of them still holding ropes (Figure 5.12). Assuming that the dating of the *Chau Tan* shipwreck is correct, it means that the plank lashing was still in use until the ninth century, at least over a century after the Punjulharjo boat.

Figure 5.12. Photogrammetry of one of the fragments of the Chau Tan shipwreck's keel plank by K. Edward (Nishino 2017:112).

The frame lashing on the Punjulharjo boat, as put forward by Lacsina (2016:208), is another critical feature that needs further scrutiny. Each lashing that tightens a frame goes over two lugs on two adjacent planks, instead of on one lug only as previously thought. Aside from this boat, the archaeological evidence of this frame lashing pattern is non-existent. The interpretation, thus, relies on ethnography of more modern vessels. Horridge (1985:51–54) reports that a traditional watercraft from the Kei Islands, eastern Indonesia still have rows of lugs carved out of its inner hull up until the 1970s. A row of lugs mounted a frame that was tightened to it by rattans that go into the holes pre-drilled on a lug to form one lashing (Figure 5.13). The lashing holes on the lugs of the boat from Kei Islands were drilled on the side of the lug through to the other side and possibly had only two holes per lug.

Reconstruction of the lashed-lug watercraft seems to accept this one lug-one lashing technique as the sole possibility for lashing the frame to the lug. The frame lashing of the Punjulharjo boat shows that the builders do not just use the lugs to mount the frame, but also used them to hold another plank fastening, besides the stitches and dowels. The frame lashings have a more complicated pattern than the plank lashing, and they seem stronger and more durable since more of them have survived than the later. With multiple fastenings applied, mainly rope lashings, the boat has a hull that is sturdy and flexible at the same time. This type of hull should be able to voyage on waters with high tides, like the insular Southeast Asian islands waters.

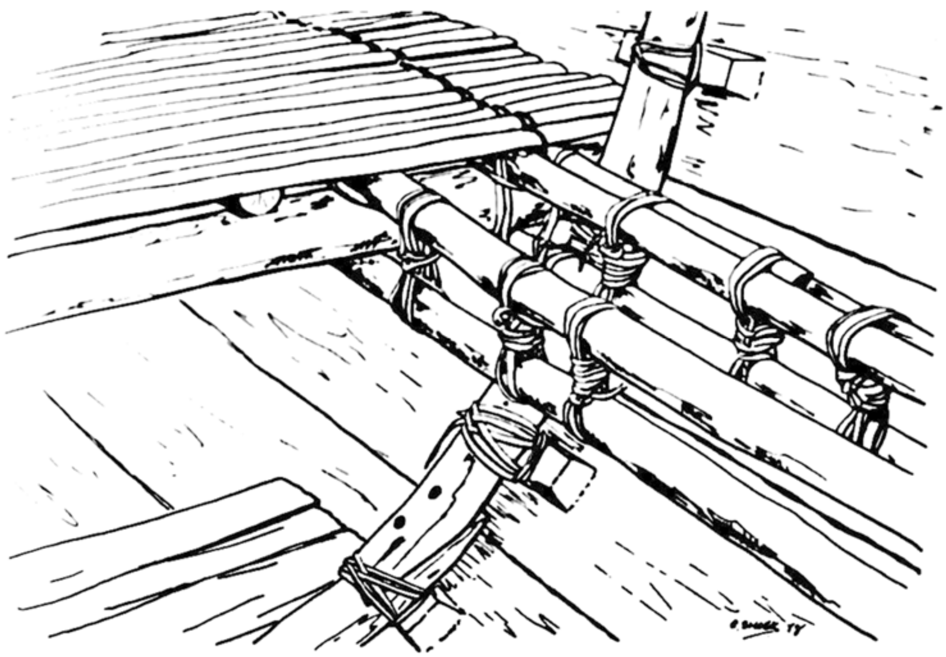

Figure 5.13. Frame and stringer lashings on the boat from Kei Island (Horridge 1986:45).

It would instead be hasty to suggest that other lashed-lug vessels all have the same frame lashing technique with the one used in the Punjulharjo boat. The method of fastening two lugs in one lashing, however, might be more than just a particularity of this boat only. As the stitches have disappeared from the planks of the later vessels, it only makes sense to continue using such lashing method to provide another strength to the hull construction. There is no significantly apparent difference between the fastenings of the dowel-only vessels from their predecessors, other than the increase in the number of dowels used to join the planks and the occasional use of locking pegs. The absence of a locking peg on the dowels in some watercraft also raises a question about the competency of the dowel-only system to hold the whole construction without other fastenings.

The remaining timbers suggest that the Punjulharjo boat had a slightly different hull from the *Cirebon* shipwreck, the only lashed-lug remains that have been entirely reconstructed, albeit virtually. While Liebner (2014:273) proposed that the *Cirebon* wreck had a length to beam ratio of 3:1, it seems that the Punjulharjo boat had a narrower beam and a sharper bow and stern. Unfortunately, the artefacts found in situ were not conclusive as to suggest the original function of the boat. Neither historical data nor ethnography offers information about this type of boat other than its possible role as cargo or transport vessel, so it is difficult to know whether such a hull shape indicates a specific type of vessel.

The examination of the Punjulharjo boat also shows that this boat adds another variation within the lashed-lug tradition. Some vessels found with a keel or a keel plank, such as the Butuan boats, the *Chau Tan* shipwreck, and the *Cirebon* shipwreck, have a different lug shape on their keel plank, compared to the rest which protruded on the hull planks. The Punjulharjo boat, on the other hand, has uniform lugs on the keel plank and the strakes. Another vessel with a possible same arrangement is the Pontian boat, as its survey report mentioned that the lugs on both the keel plank and the strakes had similar shape of half-oblong cylinder. The drawing attached to the report, however, showed the ligature holes of the keel plank's lugs were slightly different to those on the strakes (Lacsina 2016:124). The dating and the location of these vessels where they were found are all diverse and, thus, might need to be omitted from the factors influencing this variation.

Conclusion

This chapter has presented an analysis of the assembly methodology and the construction technology of the Punjulharjo boat. This analysis provides the answers to several questions related to various components of lashed-lug vessels that previously were unknown due to a lack of archaeological evidence. The same reason also leaves some questions related to the boat itself unanswered. Information gathered from this analysis, once put into a broader context, contributes to the current debate concerning the Southeast Asian traditional wooden boatbuilding techniques. All this information needs to be concluded to finally answer the research question mentioned at the beginning of this research.

Chapter VI

Conclusion

Readdressing Research Question and Aims

This thesis attempts to answer the primary research question: How does the assembly method and technology used in the Punjulharjo boat's construction fit with current theories of the development of Southeast Asian wooden boatbuilding? Several aims were outlined to aid this thesis in answering the question. The aims are:

1. *Make an overview of current theories related to Southeast Asian boatbuilding technology.*

The current theories were amassed by examining and assessing current literature about Southeast Asian boatbuilding technology. Scholars agreed that the lashed-lug tradition is one of the traditional boatbuilding techniques in Southeast Asia that lasted for at least 1,500 years since the dawn of the Common Era (Lacsina 2016:37; Manguin 2016:63). Over a millennium, the technology within which the tradition evolved, particularly in the construction of the hull planking. The earlier vessels had dowels and lashings to fasten their planks, while the later only relied on the dowels. They were disagreements, however, on when this change occurred (Lacsina 2016:206; Manguin 2012a:5–6; 2016:62; McGrail 2001:306). Another issue that is still open for further debate and discussion concerns the typology within the tradition (Lacsina 2016:224–226) —which features are common to all vessels? and which are the particularities?

2. *Analyse the application of the edge-joined and lashed-lug boatbuilding technique in the Punjulharjo boat.*

Fieldwork was conducted to re-examine the boat remains using archaeological methods for the first time since the first excavation ten years ago. The study of the boat remains which were in a condition that was entirely different from the original context —

dismantled, cleaned of sand and mud— provided essential information missing in the previous archaeology studies. The observation of the boat remains after the reconstruction added more information to help understand the techniques used to build this watercraft. Reports, drawings, and especially photographs from the survey and excavation offered essential aids in examining the application of lashed-lug boatbuilding techniques on the Punjulharjo boat.

This study provides a detailed analysis of the construction of the Punjulharjo boat. Where possible, it describes all elements of the vessel and then suggests the technique used to assemble them. The analysis includes the planking, the lugs, the assembly of the bow and stern, the propulsion, as well as the internal strengthening. The results show that while sharing several common features with other lashed-lug vessels, other features are only found in the Punjulharjo boat to date. The features comprise of, among others, the planking pattern and the wing-end assembly.

3. *Compare and analyse what is known about boatbuilding technology used throughout Southeast Asia from the archaeology, iconography, and ethnography evidence.*

After analysing the lashed-lug technique used in the construction of the Punjulharjo boat, this thesis consulted archaeological data about other watercraft built in the same tradition to look for an explanation of some parts of the boat which had not survived. When this data failed to aid the interpretation, iconography and ethnography were consulted. The iconography chosen as a comparable reference was the ship depictions carved on the bas-relief of the ninth-century Borobudur temple.

The analysis then further compared the characteristic features known on several lashed-lug vessels that have been relocated to date. Similarities and dissimilarities of the Punjulharjo boat compared to other boats within a broader context of Southeast Asia were sought, with additional information from iconography and ethnography. The results suggested identification of both similar and dissimilar features in lashed-lug boats and later contributed to further the debates about this particular boatbuilding technology.

4. *Confirming and/or correcting the interpretations of the Southeast Asian boatbuilding technology that have been done to date.*

The examination of the Punjulharjo boat remains, combined with revisiting of the reports and photographs from previous research, also with the aid from other related archaeology, iconography, and ethnography studies, reveals more evidence that can attest to current theories related to the boat's construction itself, and the technology of lashed-lug tradition on general. The findings confirmed that the boat used dowels and lashing to fasten the planks, indicating that it belongs to the earlier phase of lashed-lug tradition. Mortise and tenon joints also appeared, even though in a much lesser number than others. Another prominent fastening used in this boat was the lashings on the lugs that do not only bound the frame to the lugs, but also one lug to the other adjacent lug.

This study also proposes for reconsideration the current hypothesis about the technological change in the construction of lashed-lug watercraft. The earlier vessels used predominantly ligatures to fasten the planks, while dowels held this role on later vessels. It was argued that the change happens before the construction of the Butuan boats just before the tenth century, and the Punjulharjo boat was a transition between the two phases considering the increasing number of dowels used for fastenings (Manguin 2009:7). The high amount of lashings in the Punjulharjo boat, however, indicates that they were the predominant fastenings and the boat, thus, could not represent such a transition. The *Chau Tan* shipwreck, dated to the ninth century, supports this argument because the vessel also still used a high proportion of lashings for the plank fastenings.

After re-addressing the aims, how then did the assembly method and technology of the Punjulharjo boat fit with current theories of the development of Southeast Asian wooden boatbuilding? The study reveals that the boat belongs to the lashed-lug wooden boatbuilding tradition, shown primarily by the protruding lugs on the hull planks to mount the frames. It further exhibits the assembly and technology of a lashed-lug vessel, including the bow and stern assembly and technology used to fasten the planks as well as the internal strengthening, that was mostly an interpretative suggestion previously. Through analysing and comparing such technology with those of other vessels, the Punjulharjo boat should be placed in the earlier stage of lashed-lug tradition, when ligatures serve as the primary fastenings before declining and being entirely replaced by all-dowels fastenings.

Significance and Limitation

Significance

This study provides much information related to the construction of the Punjulharjo boat. It shows that re-examination of archaeological remains to apply a different approach or method is essential in advancing the current knowledge of Southeast Asian traditional boatbuilding. The boat holds several significance values in the study of lashed-lug tradition because it has components that are not found in other archaeological evidence. The components include, among others, the wing-ends, the frames, and other strengthening elements that are still lashed with vegetable fibre ropes. Previously descriptions of the Punjulharjo boat in other research studies were based only on rather brief descriptions, despite its being the only archaeological evidence of a lashed-lug vessel with most of its components preserved.

Limitations

The fieldwork for this thesis was carefully planned to make sure that as much data as possible would be recorded, especially of those details that could only be seen when the boat was disarticulated. It turned out that there was only a limited time to do so in the middle of conservation work and a rushed reconstruction project. A full and detailed recording of every timber on site had to be cancelled due to this time constraint. Another aspect that is still missing in this study is a full reconstruction of the Punjulharjo boat. Despite the high proportion of hull timber preserved in situ, such an attempt was omitted from this thesis because it focuses more on the details of the boat components and assembly.

Recommendation for Future Research

A closer examination of the Punjulharjo boat manages to enrich the information about the vessel by adding details of the construction of the boat. Instead of proposing a conclusion, this study raises more questions, such as how was the boat rigged? A full reconstruction, both virtually and by building a model, would provide a better understanding of how the boat initially operated. It is also recommended experimental archaeology is attempted to reconstruct the lashings system used to bind all the internal strengthening on the vessel. The result of these studies should offer a reference, which is primarily based on archaeological evidence, for other research about the lashed-lug tradition. This reference would avoid a sole dependency on ethnographic data during interpretation of the research.

During the compilation of literature for this study, it was recognised that there is very limited publication of detailed archaeological works about traditional Southeast Asian boatbuilding. Re-examination of previous finds is recommended to test the latest hypothesis, and several lashed-lug planks found in Sumatra in the last decade need a closer observation using archaeological methodologies to build a robust database of lashed-lug watercraft. It is also essential to continue advancing the regional context of this topic; every time a site is discussed there are more gains in the comprehensive knowledge concerning the lashed-lug boatbuilding tradition.

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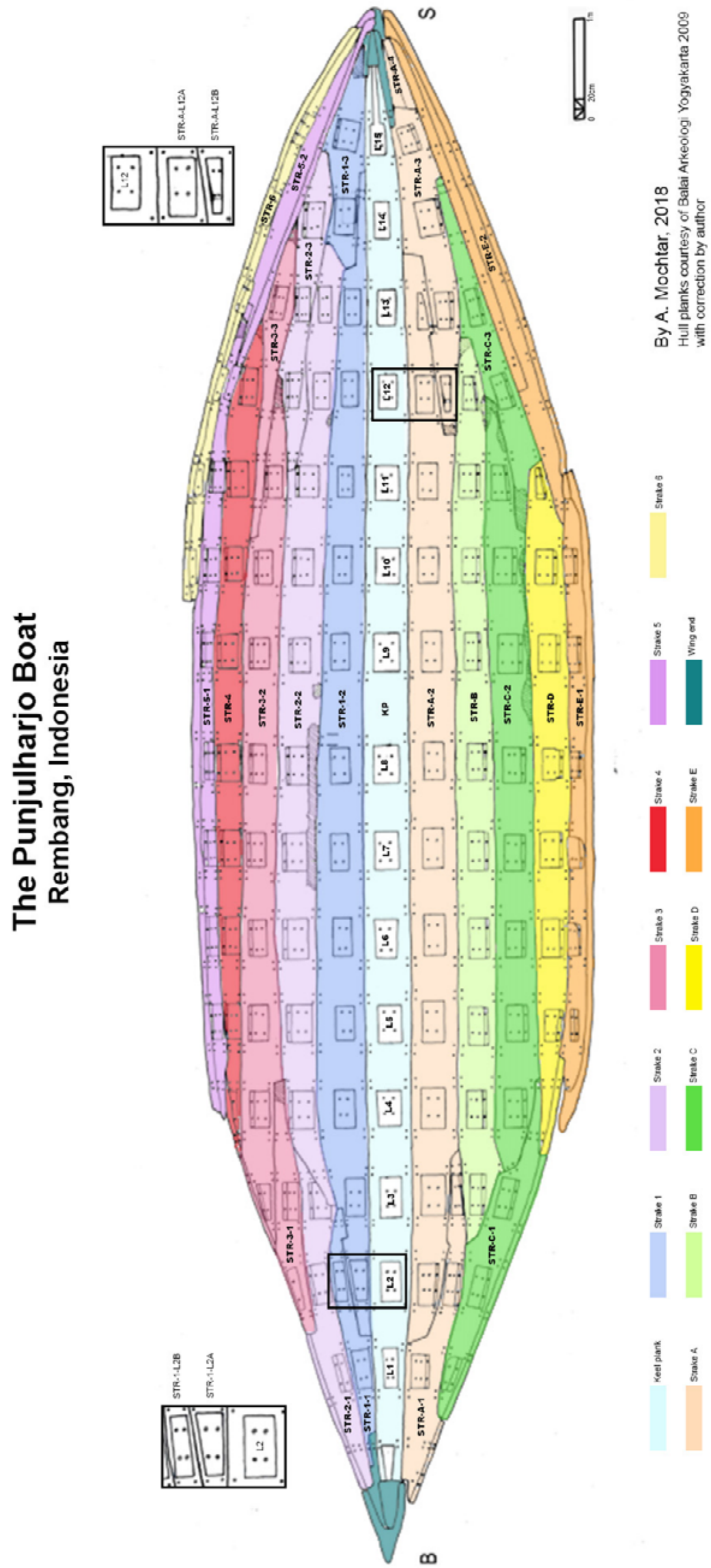
APPENDIX A

Labelling of the Punjulharjo boat.



APPENDIX B

The measurement of the lugs of the Punjulharjo boat.

STARBOARD (SB)

Lug		STR-1				STR-2				STR-3			
		D	L	W	T	D	L	W	T	D	L	W	T
1		174	39	16-18	6.5	174	38	9	6.5	n/a			
2	A	48	39	12-18	5.5	48	39	10	6	48	41	4-12	6
	B	46	41	12	3-6								
3	A	45	38	20	6.5	47	38-18	15-5	6.5	46	39	10	6
	B									51	35	5.5-13	6
4		49	37	19	6.5	55	35	22.5	6	56	35	13	6.5
5		50	33.5	18.5	5.5	47	38.5	20	6	49	35	16	6
6		50	39	17	5	47	40	20	6	51	36	15	6
7		48	36	18	6.5	47	38	19	5	52	33	13.5	5
8		49	36	18	4.5	48	38.5	18.5	5	51	37	13.5	5
9		76	36	17	5.5	75	34	18	5	77	30	15	5
10		50	38	17	5	52	36	18	5	55	33	13.5	5
11		48	30	16.5	5.5	49	32	19	6	52	31	14	6
12	A	59	37	16	6	54	36	17		n/a			
	B					6	58	36	11-15				
13	A	47	36	16.5	4	49	35	11.5	3.5	52	33	9	5
	B					50	33.5	13.5	5				
14		55	36	20	4.5	?	35	16	4.5	n/a			
15		53	30	22	5.5	n/a				n/a			

Lug		STR-4				STR-5				STR-6			
		D	L	W	T	D	L	W	T	D	L	W	T
1		n/a				n/a				n/a			
2	A	n/a				n/a				n/a			
	B												
3	A	n/a				n/a				n/a			
	B												
4			41	2-5	4	n/a				n/a			
5		52	36	16	5		36	20.5	6	n/a			
6		50	37	17.5	5.5	48	40	24	6.5	n/a			
7		51	36	18	6	49	36	23	5	n/a			
8		52	36	18.5	6	52	35	11	6	n/a			
9		76	33	16	5.5	78	33	18	5	n/a			
10		54	34	16	5.5	55	34	18	5		36	15	5
11		51	35	16	4.5	56	31	18	5	53	32	14	3.5
12	A	56	38	14	4	61	33	14	7	63	34	13	4.5
	B												
13	A	n/a				n/a				56	35	15	4
	B												
14		n/a				n/a				58	33	16	4
15		n/a				n/a				52	33	13	5

PORT (P)

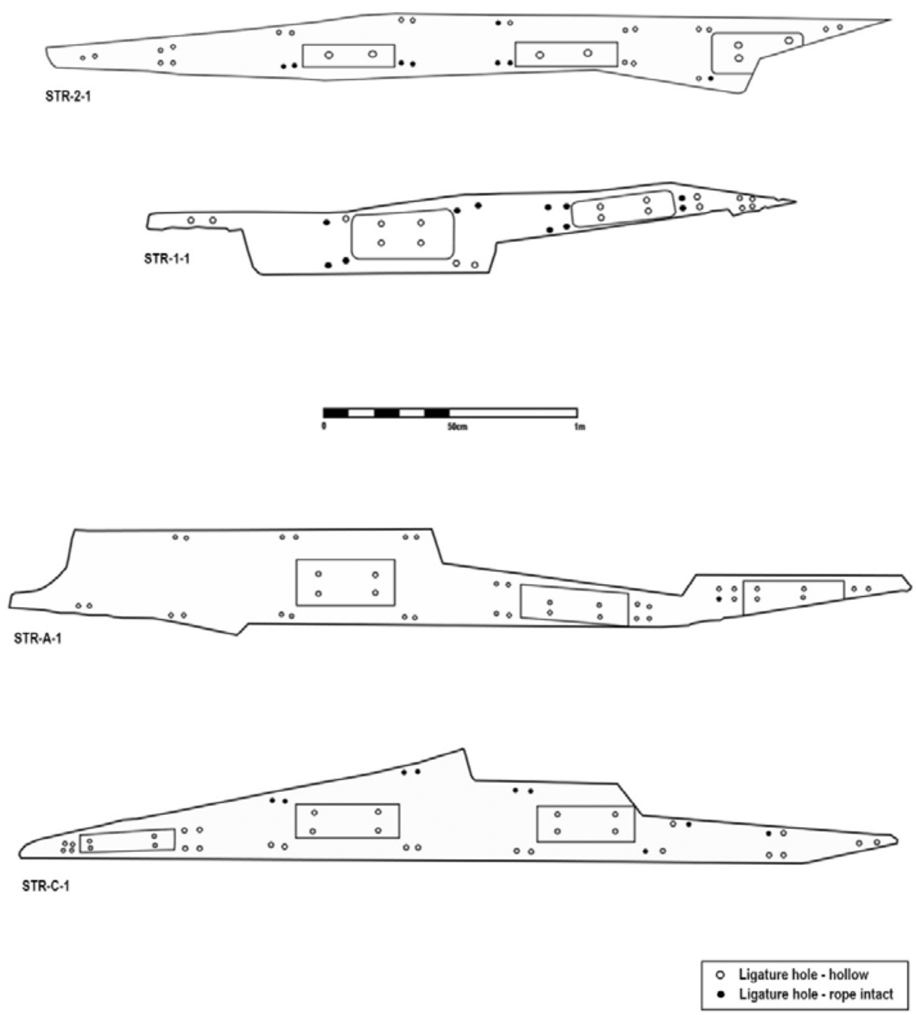
Lug		STR-A D	STR-A L	STR-A W	STR-A T	STR-B D	STR-B L	STR-B W	STR-B T	STR-C D	STR-C L	STR-C W	STR-C T
1		174	35	16	6.5	n/a				174	34	5-9.5	6.5
2	A	48	43	15-16.5	4-6.5	n/a				50	41	13	7
	B	49	42	12.5	6								
3	A	44	39	25	5		39	11	1-4.5	51	39	14	7.5
	B	47	39	12.5-9	4.5								
4		46	39	24	6	47	38	17	6	52	38	18	6
5		46	40	22.5	5.5	44	38	16.5	6	47	36	18	5.5
6		47	41	20	5	48	40	17	5.5	49	37	17	6
7		46	39	20.5	6	47	39	16	6	51	37	17	5
8		48	38	20.5	5	49	38	15.5	5.5	49	34	18	6.5
9		70	39	19	5	72	38	14.5	5	73	39	19.5	6.5
10		48.5	37	20	5	51	34	15	4	51	35	19	6
11		47	36	20	5	50	34	17	5.5	48	?	16-13	7
12	A	50	38	18	5	53	34	13.5-10	4-2.5	53	36	14	6.5
	B	52	37	6-10	6								
13	A	46	36	11-3.5	4.5	n/a				52	38	13	5.5
	B	46	38	12	7								
14		56	36	21	5	n/a				n/a			
15		51	33	19-16	6	n/a				n/a			

Lug		STR-D D	STR-D L	STR-D W	STR-D T	STR-E D	STR-E L	STR-E W	STR-E T
1		n/a				n/a			
2	A	n/a				n/a			
	B								
3	A	n/a				n/a			
	B								
4		n/a					36	13	4.5
5			32	12-15.5	6	50	33	24	5.5
6		53	38	19	6.5	55	33	19	6
7		53	36	19	5.5	57	31	26	5
8		52	31	16	5	58	28	23.5	6
9		78	36	17	6	78	34	21	4.5
10		52	34	17	5	56	35	21	5
11		50	29	7-2	4.5	50	28	8-2	7
12	A	n/a				n/a			
	B								
13	A	n/a				n/a			
	B								
14		n/a				n/a			
15		n/a				n/a			

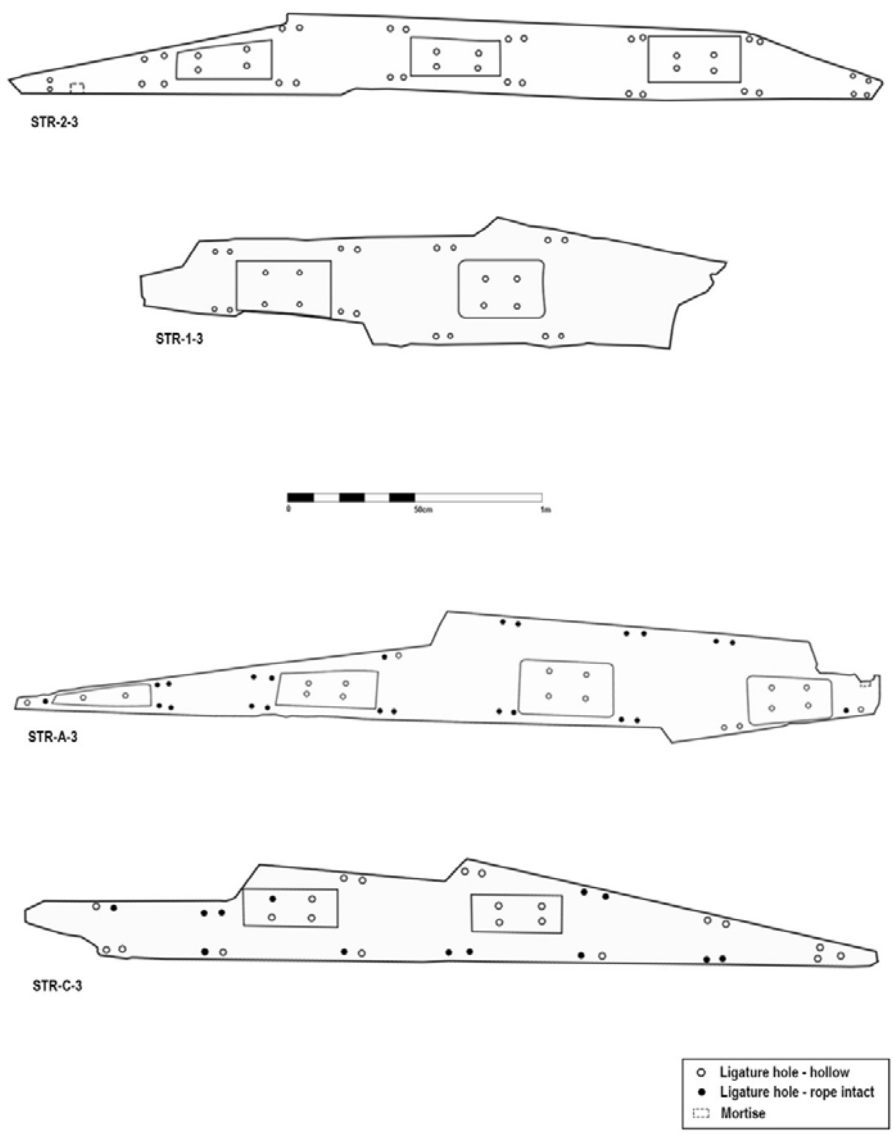
APPENDIX C

Fore and aft planks of the Punjulharjo boat.

Fore planks



Aft planks



STR-2-3
STR-1-3
0
50cm
1m
STR-A-3
STR-C-3
Ligature hole - hollow
Ligature hole - rope intact
Mortise