FUTURE PROSPECTS FOR CONTINUATION WELDING OF PIPE STEEL PILES ON CONSTRUCTION SITE

Lappeenranta–Lahti University of Technology LUT

Master’s Programme in Mechanical Engineering, Master’s thesis

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Examiners: Associate professor, Tuomas Skriko

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ABSTRACT

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Future prospects for continuation welding of steel pipe piles on construction site

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76 pages, 27 figures, 10 tables and 1 appendix

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Keywords: Steel pipe pile, continuation welding and construction site

Steel pipe piles are used as support structures for bridges and buildings. Steel pipe piles are drilled into the ground at the construction site, and steel pipe piles are extended by welding, in a vertical or horizontal position. Continuation welding of steel pipe piles on the construction site is affected by the location of the work site, weather conditions, and the diameter and wall thickness of the steel pipe pile. The continuation welding of the steel pipe pile works like the bottle neck drilling process.

The research examines the status of continuation welding at the construction site and how continuation welding can be developed at the construction site in the future. Finding out the current state of continuation welding provides information about the continuation welding process of the steel pipe pile, the continuation welding location, and the development targets for continuation welding in construction site. The Delphi interview provides information on the future development targets of continuation welding on the construction site.

As a result of the research, get three-level development proposals for the future and a knowledge base about the current situation in continuous welding at the construction site. The development proposals are divided into actions that can be implemented immediately, actions that can be implemented after a year, and longer-term actions. The research results provide new research information on the continuation welding of steel pipe piles on the construction site.

TIIVISTELMÄ

Lappeenrannan–Lahden teknillinen yliopisto LUT

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Teräputkipaalujen jatkoshitsaamisen tulevaisuudennäkymät työmaalla

Konetekniikka diplomityö

2024

76 sivua, 27 kuvaa, 10 taulukkoa ja 1 liitettä

Tarkastajat: Apulaisprofessori, Tuomas Skriko ja DI, Miro Mykkälä

Avainsanat: Jatkoshitsaus, teräsputkipaalu ja työmaa.

Teräsputkipaaluja käytetään siltojen ja rakennuksien tukirakenteina. Teräsputkipaalut porataan työmaalla maahan ja teräsputkipaaluja jatketaan hitsaamalla, pysty tai vaaka-asennossa. Teräsputkipaalujen jatkoshitsaukseen työmaalla vaikuttaa työnmaan sijainti, sääolosuhteet ja teräsputkipaalun halkaisija sekä seinämäpaksuus. Teräsputkipaalun jatkoshitsaaminen toimii pullon kaulana porapaalutusprosessissa.

Tutkimuksessa selvitetään jatkoshitsaamisen nykytila työmaalla ja miten jatkohitsausta voi tulevaisuudessa kehittää työmaalla. Jatkoshitsaamisen nykytila selvittäminen antaa tietoa työmaalla tehtävästä teräsputkipaalun jatkoshitsausprosessista, jatkoshitsauspaikasta ja teräsputkipaaluille ennen toimitusta tehtävistä esivalmisteluista. Delfoi-haastattelu antaa tietoa työmaalla tehtävän jatkoshitsaamisen tulevaisuuden kehityskohteista.

Tutkimuksen tuloksena saadaan tietopohja nykyhetken tilanteesta jatkoshitsaamisessa työmaalla ja kolmen tason kehitysehdotukset tulevaisuudelle. Kehitysehdotukset on jaettu heti käyttöön otettaviin, vuoden päästä käyttöönotettaviin ja pidemmän aikavälin toimiin. Tutkimustulokset antavat uutta tutkimustietoa työmaalla tehtävästä teräsputkipaalujen jatkoshitsaamisesta.

SYMBOLS AND ABBREVIATIONS

Roman characters

A	cross sectional area	mm^2
C	length of perimeter	mm
i	root gap	mm
L	weld length	mm
M	Deposition metal mass	kg
r	radius of the circle	mm
s	plate thickness	mm
T	Deposition rate	kg/h

Greek characters

α	groove angle	°
π	pi	
ρ	density of filler material	kg/m3

Subscripts

t_{at}	Arc time
t_{pat}	Production auxiliary time
t_{pt}	Processing time of workpiece
t_{pwa}	Post weld activities time
t_{wp}	Weld preparation

Abbreviations

FCAW	Flux Core Arc Welding
NTD	Non-Destructive Testing
SMAW	Shielded Metal Arc Welding
WPS	Welding Procedure Specification

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1 Introduction

Steel pipe piles are used as a supporting structure for buildings and bridges. Steel pipe piles are drilled into the ground with a drilling rig and the steel pipe piles remain in the ground vertically, horizontally, or diagonally. The steel pipe piles are extended by welding on construction sites in a horizontal or vertical position. The welding place of the steel pipe pile construction site and the steel pipe pile preliminary preparation are not always ready, which interrupts the drilling process. The aim of the construction site is to drill as many steel pipe piles as possible without interrupting the piling work during the welding operation.

Previous research has shown that defining the requirements of the welding place, the welding method and the pre-weld preparations of pipe steel piles can reduce the welding lead time. Determining the requirements of the continuation welding place on the site and pre-welding preparations on the steel pipe piles can speed up the lead time of continuation welding the steel pile piles on the construction site. Could there be a more comprehensive way to address the future prospects in the continuation welding of steel pipe piles?

This research focuses on the future prospects of continuation welding of steel pipe piles in a construction site. To achieve this goal, the requirements of the welding place in construction site and the preparation of the steel pipe piles for further welding are investigated. The methods used in the research are a literature review and an interview with a Delphi expert. The results of the research will present new knowledge continuation welding and show what actions will do still same as now. The results of research also include future developments actions presented in three categories. The first level is easy to implement, the second level feasible in one year's time and third level longer time actions. The results show that a defined welding place and preliminary preparations of steel pipe piles for welding reduce interruptions in construction site drilling process.

1.1 Setting of research

The setting of research is figure out what problems are followed by interrupt of steel pipe piles continuation welding in piling work, what are the requirements for continuation welding place of steel pipe piles on construction site and what are preliminary preparations for pipe steel piles before delivery on construction site. The research includes an empirical study which concrete observations and measurements for steel pipe piles continuation welding. Knowledge for empirical study gathered with literature review and Delphi interview which are this research used methods. (Nummenmaa 2021, p.35-36.)

The collected data and future scenarios can be used to predict the future requirement of welding location of steel pipe piles on site and how to reduce the interruptions in drill piling caused by continuation welding. Currently, the customer is experiencing delays due to steel pipe piles not being prepared for welding and piling work is delayed by having to wait for the steel pipe pile continuation welding process to be completed. (Kuusi, Bergman & Salminen 2013, p.127-128.)

1.2 Background information

In this section earlier research and trends related to continuation welding of pipe steel piles are gone through. The use of steel pipe piles has become more common in Finland since 1989, when instruction for test applications of pipe steel pile published by the Road and Water Works Board. Target of use has pipe steel piles are supporting structures bridges and building. (Tie- ja vesirakennushallitus, 1989; Rajapakse 2016, p. 89-91.)

Foundation construction is being part of law Land Use and Building Act in Finland- In Foundation structures, the application of the law is specified in Decree of the Ministry of the Environment 465/2014. Degree of the Ministry of the environment is specified by amending the land use and building law 958/2012. The Ministry of the Environment acts as the supervisory authority for foundation structures in Finland. Eurocodes and standards define the jointly agreed rules of the game in foundation construction, and the national of building codes of Finland acts as a complement to these degrees. (132/1999; 465/2014; RIL 254-1-2016, p.27-28.)

“The soil formed commonly three levels which are rock, decaying plants and animals”. The Soil in Finland include nutrients, minerals, and organic matter. Drill piling of steel piles is the most used method due to the soil. Soils in Scandinavia, like Finland and in Europe different soils. Before starting drill piling, the soil in the area is investigated by means of ground surveys. The soil types in Europe presented in Figure 1. Soil map in Finland presented in Figure 2. (RIL 254-1-2016, p.35-36; European Soil Bureau Network European Commission 2005, p.10-11.)

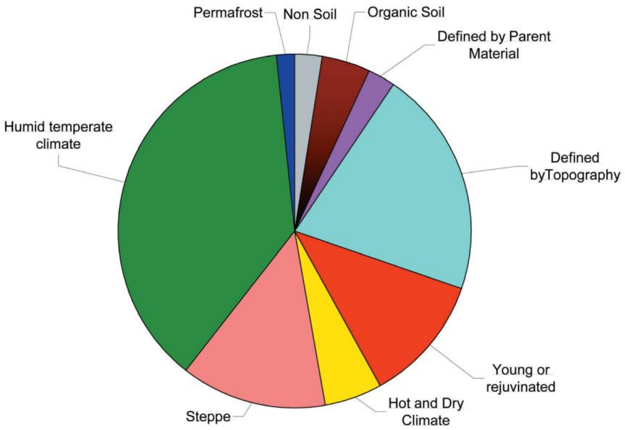

Figure 1. Soil types of Europe (European Soil Bureau Network European Commission 2005, p.87).

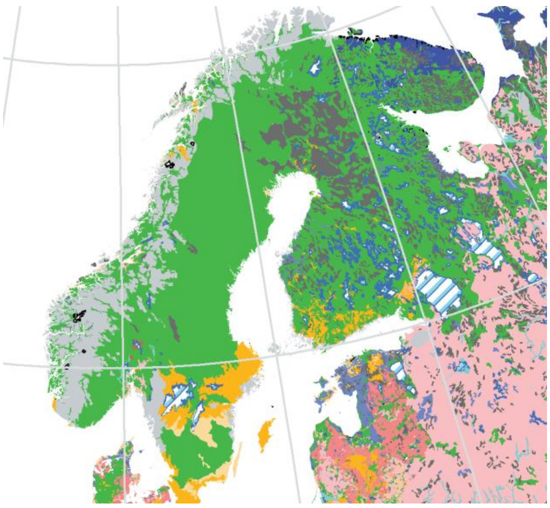

Figure 2. Soil mapping in Finland and used only part of the original figure (European Soil Bureau Network European Commission 2005, p.87).

Research problem research is how to improve welding place in construction site and what measures can be taken on steel pipe piles before delivery to the construction site? Aim of this research is to identify requirements of welding place in construction site and propose future developments actions for continuation welding. Another aim of the research is to utilize the most efficient welding process at the site and transfer part of the welding currently performed at the site to the supplier of steel pile pipes.

1.3 Objective

The subject of the research is the requirements of the welding place in construction site and preliminary preparations made with steel pipe piles before delivery to the construction site. Welding temperature, welding process and welding bevel affect the formation of the final weld joint. The hypothesis is the determine continuation welding place and preliminary preparations for pipe steel piles prevent to interrupt for pipe steel piles drilling process. (SFS EN 5817:2023; RIL-254-2-2016, p.164-165; SFS EN 3834-4:2021.)

Based on earlier research the major problem in welding steel structures are residual stresses and distortion. The welding current, arc voltage and welding speed have a direct effect on heat input as well as on the occurrence of welding distortions. However, can be stated that the problems caused by welding distortions are minor because the material thickness of the steel pipe pile is large. Due to the large material thickness of steel, welding distortions are small. (Pandey AK. and Pandey PM. and Pandey S. 2021, p.836.)

The bigger problem observed in previous studies is therefore the residual stress of the continuation welding of steel pipe piles. Residual stress is created in a continuation weld joint when the corner of the pile penetrates the ground and then the part returns with an upward movement. In the downward movement, the pile is elastically compressed. When the compression wave is released in the corner of the welding pipe pile, the pile tends to return to its original length, a compression reaction occurs in the soil and the pile bounces and vibrates until the pile has reached its final position. (Costa, Danziger and Lopes 2001, p.410.)

Hypothesis it can be assumed that preliminary prepared steel pipe piles and determined continuation welding place in construction site will reduce site interruptions during drilling process. The research questions of this research are the following:

1. How can improve to welding place in construction site?

2. What preliminary preparation can be done before the steel pipe piles are delivered to the construction site?

3. What problems follow from the interruption of piling work?

Interviews are a useful method of data collection in this research because they involve direct linguistic interaction with several people and give the data collector flexibility in obtaining data. Interview were chosen as the data collection method because of the limited knowledge available on the topic of the study, in interview the depth of information that can be gained, and the ability of the interviewee to better bring out silent knowledge that would otherwise be difficult to elicit. Interviews are a form of thematic interviews in which experts answer questions on pre-defined topics. The order of the questions and topics can be changed during the interview, and each expert is given the opportunity to give his or her own answer to each question. (Hirsjärvi S. and Remes P. and Sajavaara P. 2009, p. 204-205, 208-209.)

As a method of data collection, the interview involves direct interaction with the researcher. Interviews have the advantage of flexibility in data collection and are the main method of qualitative research. The interview was chosen as the data collection method because people are allowed to express their views freely and are treated as subjects in the interview situation. The interview is conducted in an area that has been little researched or where there is limited information available, there is a desire for depth, to clarify the interviewee's answers and the result can provide more information than the interviewee expected to be told. Interviews as a data collection method can also provide results in a variety of ways and in many different directions. (Hirsjärvi et al. 2009, p. 204-205.)

In this research focus is continuation welding place in construction site and preliminary preparation pipe steel piles. The purpose of the study is to find out what the continuation welding site of the construction site should be like and what kind of preparation the steel pile pipes arriving at the welding site should include. The study also shows the cause-and-effect relationships of the continuation welding place and steel pipe pile preparations to drilled piling. This research increases scientific knowledge and practical examples to the knowledge of continuation welding of pipe steel piles on construction site. (RIL 254-2-2016, p. 238.)

1.4 Limitations of research topic

The topic of the research is limited to the research of the continuation welding of pipe steel piles on construction sites. On construction site pipe steel pile continuation welding includes the vertical and horizontal welding process, the temporary welding site that is moved and built around the pipe steel piles, and the pipe steel pile preliminary preparations before to continuation welding. The benefits of topic delimitation are time saved during the research, the possibility to carry out the research because the topic is delimited, and the research problem is kept separate from everyday problems. (Hirsjärvi et al. 2009, p. 81-85.)

2 Research methods

This research methods are literature review and Delphi expert interviews. The purpose of the literature review is to search and retrieve information on guidelines and regulations for the continuation welding of steel pipe piles. The Delphi expert interview is intended to find a solution and to provide new information to the research problem as well as to the research questions.

2.1 Literature review

In literary review will be utilized to previous studies and search for new inform for welding place in construction site of pipe steel piles. In literary review will be utilized from scientific databases, standards, and from the literature on the subject. The literature review summarizes the relevant content of scientific publications on continuation welding of steel pipe piles. The purpose of the literature review is to obtain a knowledge base on the topic under investigation, based on which a Delphi expert interview can be conducted. (Salminen A. 2011, p. 9.)

2.2 Delphi interview

To answer research questions a Delfoi expert interview is organized, where information is collected about the requirements of the welding place in construction site and requirements of the steel pipe piles preliminary preparations to the construction site. The welding coordinator, project manager and the project manager of the steel pipe piling works are selected from the customer's personnel as experts. (Kuusi, Bergman & Salminen 2013, p. 254-256.)

Delfoi is a study of the future, and in previous studies alternative possibilities for future development were investigated using the renewing Delfoi method. From Delphi's research styles will select to like-minded vs dissension because it is a sensitive issue that only the company wants to know. With the help of Delfoi, a panel of the experts is combined where different parties work, and they can find a common vision on the matter. In figure 3 the steps of the Delphi method are shown in the flowchart. (Metodix, 2020.)

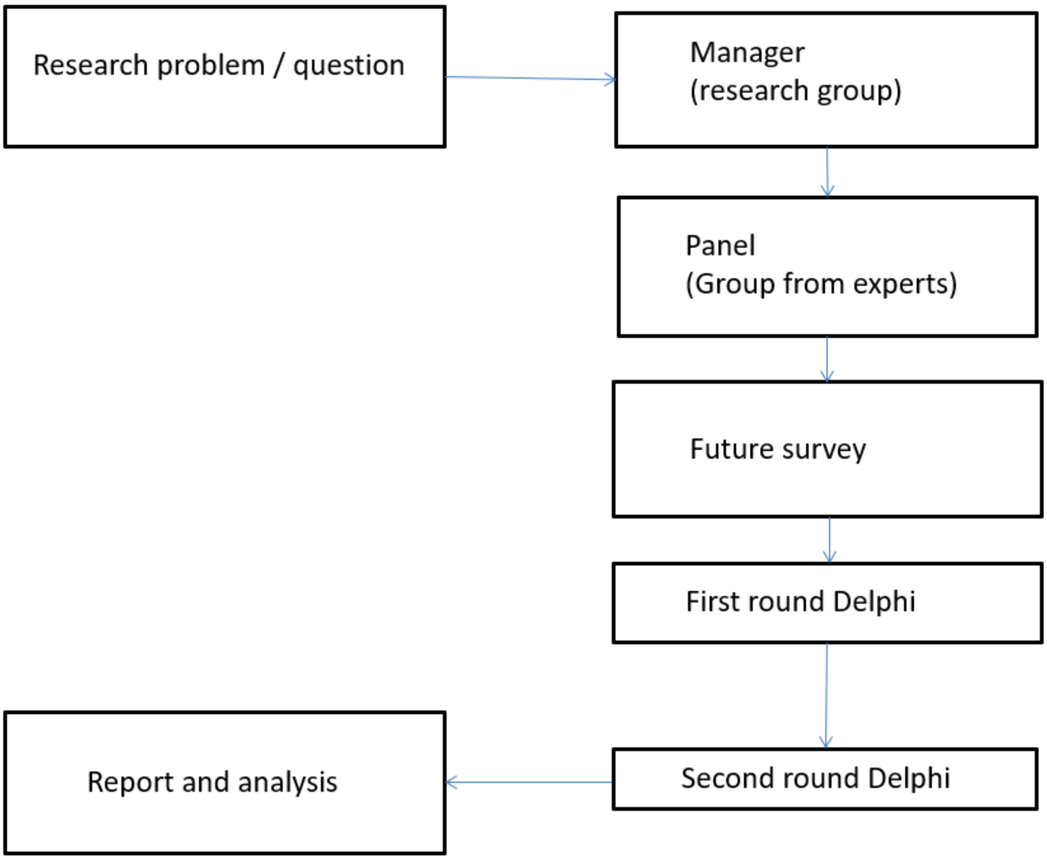

Figure 3. The steps of the Delphi process (Metodix, 2020).

The Delphi interviews will be used to formulate a set of future arguments to which each expert will respond independently. Based on the future answers, a future table is created, which allows to formulate future scenarios for the continuation welding of steel pipe piles. Based on future scenarios format three levels future actions. (Kuusi, Bergman & Salminen, 2013, p.143-144.)

3 Drilling pipe piles and materials

A ground investigation is carried out before piling work starts on the construction site. The purpose of the ground investigation is to identify the layers of soil on the site and to provide sufficient information about the ground and water conditions on the construction site. The drilling methods for pipe steel piles are top hammer drilling and down the hole drilling. Steel pipe piles used for drilling are usually made of steel and vary in length and diameter depending on the site. Drilling equipment usually includes a drill rig and an excavator or crane.

3.1 Ground investigation

A ground investigation is used to verify soil formations and stratification. The ground investigation will provide information on other infrastructure in the area (cables, pipes, wires) and will also identify any vibration-sensitive areas in the area. The geotechnical class of the area is determined based on the SFS-EN ISO 1997-2 standard. There are three geotechnical classes GL1, GL2 and GL3. (RIL 254-2-2016, p. 35-36; ISO EN 1997-2:2007.)

Geotechnical class 1 is carried out by means of a ground investigation method, including a ground survey by an expert and, as a minimum, a borehole or pressure borehole. Geotechnical class 2 is carried out by a drilling method that reaches the assumed depth of the bore pile. In addition, drilling in this category should be carried out if the intention is to drill piles into rock. In geotechnical class 3, ground investigations are carried out in accordance with SFS-EN 1997:1 and it may be necessary to carry out separate investigations in addition to those specified in the standard. Separate investigations may be required for large foundations and if pressurized water is detected during the ground investigation, this should also be measured. (RIL 254-1-2016, p. 36-40.)

3.2 Drill piling

Piling equipment can be drilled into a hole in the ground and drive the pile to the correct depth. Hydraulic and pneumatic hammers are used to drive piles into the ground. The drilling method is using down hole hammer or top hammer methods. In drillable piles, a casing shoe or ring crown is installed on the inner surface of the pile by welding. The suitable drilling equipment for pipe steel piles is top hammer drilling and down the hole drilling. In bored pile machine presented in Figure 4. (RIL 254-2-2016, p. 206-209, 210-211, 220.)

Figure 4. Bored pile machine Llamada P160TT (Ilmi solutions).

The down hole drilling hammer is used pneumatic, and water powered. The downhole drilling hammer includes drill rods and a hydraulic rotation unit. A guide socket attaches the drill rod to the downhole drilling hammer and the other end of the drill rod attaches to the ring bit. The purpose of the rotation unit above the pile is to rotate the drill rods inside the pipe. The maximum possible diameter of the steel pipe pile can be up to 1000 mm with a down hole hammer. (RIL 254-2-2016, p. 211.)

The top hammer is usually operated hydraulically and pneumatically. The percussion rates for top hammers are 1600-3400 strokes per minute for pneumatic and 2000-4000 strokes per minute for hydraulic. The drilling unit includes drill rods that enter inside the pipe steel piles and a rotary unit that operates hydraulically. The diameter of the drill pipe can be up to 200 mm with a top hammer drilling rig. The impact of the percussive drilling rig is usually applied to the end of the drill rod, which rotates simultaneously and from there to the casing shoe. In figure 5 presented top hammer drilling and down the hole drilling. (RIL 254-2-2016, p. 210.)

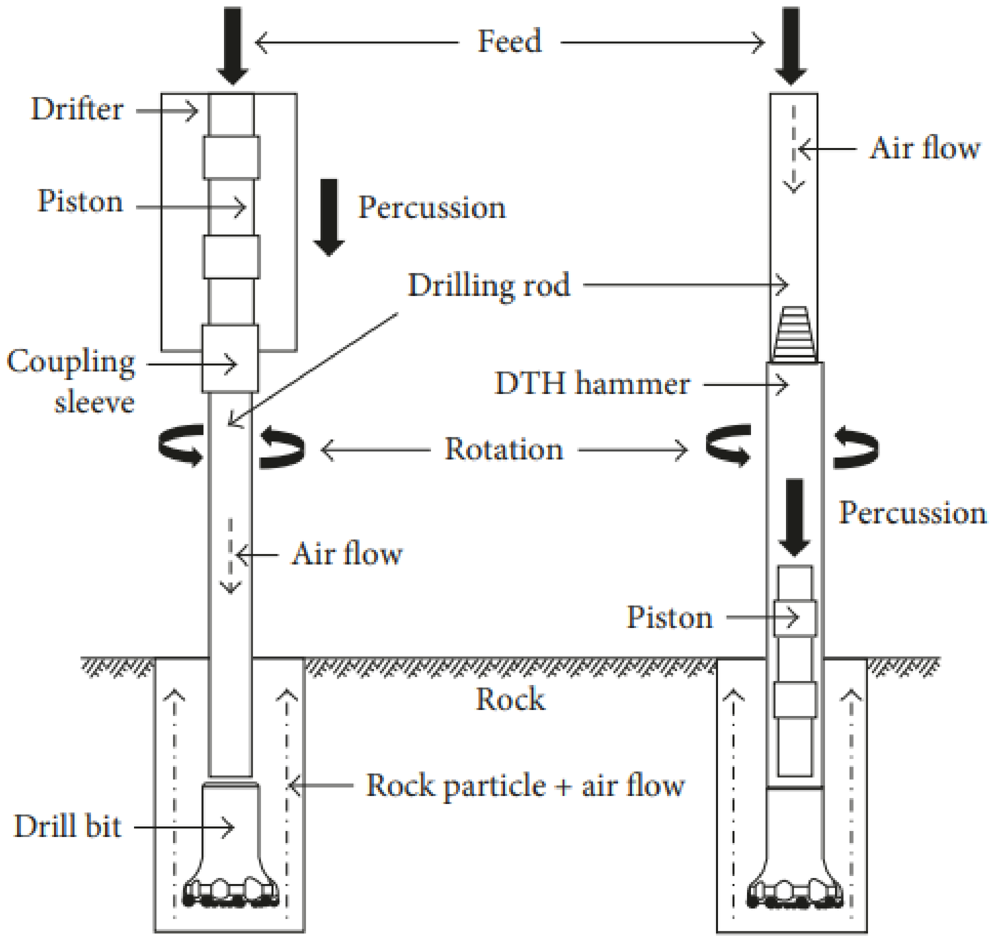

Figure 5. Left-hand side top hammer drilling and down the hole drilling (Kim D. and Kim J. and Lee B. and Shin M. and Oh J. and Cho J. and Song C. 2020, p.2).

The drilling methods are eccentric and concentric drilling. In the eccentric drilling method, the eccentric drill bit is an integral part of the pilot bit. During eccentric drilling, the reamer makes the drill hole in the pilot bit larger than the diameter of the pipe. The casing shoe pulls the steel pipe pile into the ground because the casing shoe is attached to the drill bit. The soil is moved away by a flushing agent, either out of the outer surface of the pipe or out of the inner diameter of the pipe. At the target depth, the drill bit is closed, allowing the drill rods, drill bit and hammer to be removed from around the pipe. (RIL 254-2-2016, p. 211.)

In the concentric drilling method, the drill bit is attached to the lower end of the pipe to be drilled by means of a ground ring. The drill may be a wing bit, or a reamer bit attached to a pilot bit. After drilling, the wing bit is left in the ground at the bottom of the drilled pipe and the pilot bit is lifted out of the pipe. The wing bit is used when drilling into rock and the wing blades remain off the rock by blade length. In Figure 6 is presented steel pipe pile with casing and ring bit. (RIL 254-2-2016, p. 212-213.)

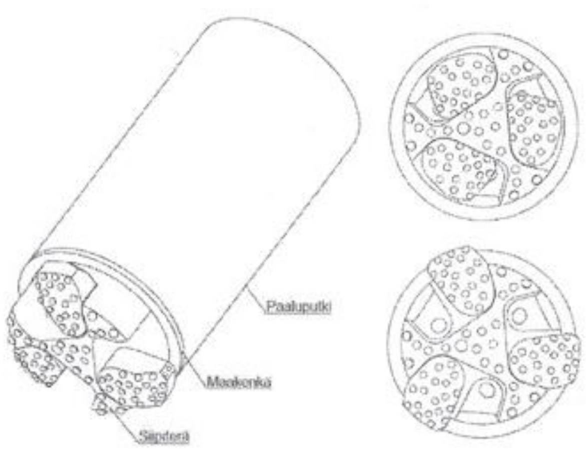

Figure 6. Casing shoe and ring bit (RIL 2016-2, p. 213).

3.3 Pipe steel piles

The material requirements for steel pipe piles used in drill piling are defined according to the standards SFS-EN 10219-1 and SFS-EN 10210-1. Steel pipe piles manufacture hot or cold-formed steel. Commonly used materials of pipe steel piles are presented in Table 1. Pipe piles are piles that do displace the ground, and they are drilled into the ground using drilling piling machines. The diameters of the steel pipe piles drilled into the ground are usually larger than 300 mm. A material certificate must be submitted for the manufactured steel pipes. (RIL 254-2-2016, p. 16,139,153-154; SFS-EN 10219-1:2006; SFS-EN 10210-1:2006)

Table 1.Mechanical properties of standard material pipe steel pile (SSAB 2023, p.4).

Steel grade	Carbon equivalent	Chemical composition, max.				Mechanical properties				
										Impact strength
	CEV max.	C	Mn	P	S	f_y min	f_u	A_{5min}	T	KV min
	[%]	[%]	[%]	[%]	[%]	[MPa]	[MPa]	[%]	[°C]	[J]
S355J2H	0.45	0.22	1.6	0.03	0.03	355	470-630	20	-20	27
S440J2H	0.45	0.16	1.6	0.02	0.02	440	490-630	17	-20	27
S460MH	0.46	0.16	1.7	0.035	0.03	460	530-720	17	-20	40
S550J2H	0.47	0.12	1.9	0.02	0.02	550	605-760	14	-20	27

The purpose of a pile pipe is to transfer forces to the ground and limit deformations. Piles can also contain loads that are transferred directly or indirectly. Types of piles include earth displacement piles, bored piles, and small piles. Displacement piles are installed without bored and without removal of earth material by hammering, compression, vibration, or a combination of these. The materials used for soil displacement piles are steel, ductile iron, concrete, wood, or a combination of these materials. Bored piles are installed by drilling, bored or by means of a protective tube. The material of the piles which are not driven into the ground is reinforced concrete or steel. (RIL 254-2-2016, p. 15-16; EN 12699:2015; EN 1536:2011; EN 14199:2015.)

Steel pipe piles can be extended by mechanical joining or continuation welding. By mechanical joining, steel pipe piles can be extended up to a diameter of 270 mm. Pipes of larger diameters are extended by continuation welding. The standard lengths for steel pipe piles are 6 m, 12 m, and 16 m. The steel pipe pile is cut by oxyfuel cutting or grinding after drilling. In figure 7 are presented parts of steel pipe piles. (SFS-EN 10219-2, p. 7.; SSAB 2023, p.5, 42.)

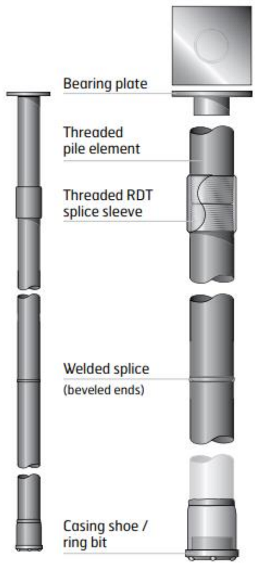

Figure 7. Parts of steel pipe pile (SSAB 2023, p.9).

Steel pipe piles delivered from the factory usually have welding grooves ready for welding. For steel pipe piles supplied from the factory. It is possible to get welding bevels of generally 30° and a root size of 1.6 mm. The inner and outer surfaces of the steel pipe piles are cleaned at 50 mm before centering the ends of the piles. Root support is recommended to be used on the inside of the pipe steel pile. The angles of the bevels used in steel pipe piles are between 30° and 60° and the shape of the bevelled is V-groove or ½-groove. The parts of the welding groove are shown in Figure 8. (RIL 254-2-2016, p. 240; SSAB, p.42.)

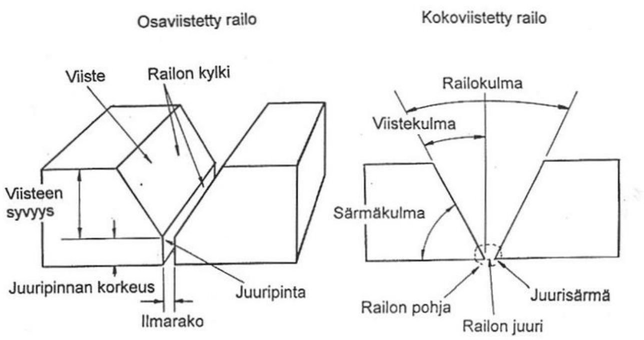

Figure 8. Left part bevelled groove and right whole bevelled groove (Lukkari 2002, p.25).

4 Continuation welding

The temporary welding place will be mobile on site, as the work site will change due to the location of the new drilled steel pipe piles. The welding method for steel pipe piles on site will be FCAW and SMAW. Steel pipe piles can be welded in vertical or horizontal position. The welder performing the continuation welding must be qualified for the task and the continuation weld is checked visually or by NTD after welding.

4.1 Welding Place

Before welding starts, a temporary fire workplace is set up on site. The temporary fire workplace on the construction site shall meet the requirements of EN 5900 and a hot work plan shall be drawn up. The hot work plan shall describe the hot workplaces, the storage of welding consumables and the welding conditions for the workers. The conditions of the welding place shall be in accordance with the hot work plan and the welding place shall be adequately lit and the surface shall be level. The welding place must also be protected from wind and rain. When the air temperature falls below +10 C, the ends of the steel pipe piles shall be heated to +50-100 C before further welding is started. The safety of the welder is ensured by an earthing cable, which is attached directly to the workpiece and is the same length as the welding cable. The metal surfaces of the grounding points must be cleaned. (RIL 254-2-2016, p. 238-239; SFS EN 5900:2016.)

On the construction site, the fire permit is approved by the contractor, based on a hot work plan. The firework permit designates the person who will carry out the fireworks and they must hold a valid firework card. The fire permit shall indicate the subject of the fire work, the fire work processes, the fire risk assessment, the fire extinguisher equipment, and the fire safety measures. The fire permit is valid for the period indicated in the permit and after the fire work, a post-fire safety watch is required to prevent fire. (Destia hot work plan 2022.)

4.2 Welding methods and filler materials

SMAW and FCAW are used as the welding process at the construction site. SMAW is used in variable weather conditions and FCAW requires standardized conditions on the construction site. Is possible to use for a combination of SMAW and FCAW, whereby the first welding layer of the gap is made with a SMAW and then the remaining welding layers with FCAW. (RIL 254-2-2016, p.164.)

In SMAW, known as metal arc welding, an arc burns between the material and the stick. The welding stick consists of a core wire and a coating. The coating burns more slowly than the core wire in the welding process and thus acts as a protection for the welding process with the help of gas and molten slag. Solder melt is formed when the core wire melts and transfers to the metal as molten droplets. In SMAW welding parts are presented Figure 9. (Lukkari, 1997, p.88.)

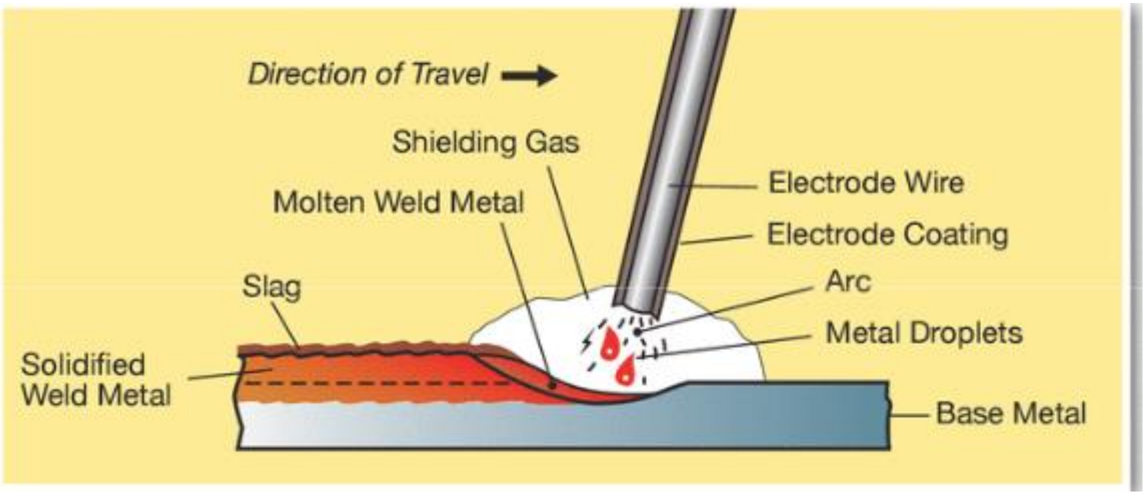

Figure 9. Stick welding process (Hobart Institute of Welding Technology 2012, p.1).

In SMAW for welding bead use 2.5 mm stick. A stick in diameter 3.2 mm can be used for filler beds. SMAW filler material is in accordance with the requirements of the standards ISO 17632-A and EN 499-94. Welding consumable classification is ISO 2560-A E 46 4 B 32 H5, and model is Conarc 49C. Welding consumable suitable structural steel welding types

S185, S235, S275 and S355. SMAW specification presented in Figure 10. (RIL 254-2-2016, pp. 240; Rapid welding)

Figure 10. Specification of Conarc 49 welding stick (Rapid welding).

Sizes Diam. x length (mm)	Current range (A)	Current type	Arc time (s)*	Energy E(kJ)	Dep.rate H(kg/h)	Weight/ 1000 pcs. (kg)	Electrodes/ kg weldmetal B	kg Electrodes/ kg weldmetal 1/N
			- per electrode at max. current -					
2.5 x 350	55 - 80	DC+	55	99	0.78	19.6	84	1.65
3.0 x 350	70 - 110	DC+	53	193	1.2	30.4	58	1.77
3.2 x 350	80 - 130	DC+	65	217	1.2	37.9	45	1.69
4.0 x 350	120 - 160	DC+	75	348	1.6	54.2	30	1.61
4.0 x 450	120 - 160	DC+	100	444	1.7	70.4	21	1.47
5.0 x 450	180 - 240	DC+	90	632	2.6	105.6	15	1.60
6.0 x 450	250 - 330	DC+	106	976	3.5	136.9	10	1.33

* stub end 35 mm

In FCAW the arc burns between the workpiece and the filler wire, and the filler wire welding process is protected by a protective gas. The shielding gas is usually a gas of argon or mixture carbon dioxide. In FCAW, the molten material transfers to the workpiece as droplets. In FCAW use 1.2mm diameter stuffing wire. FCAW process presented in Figure 11. (Lukkari, 1997, p. 228-229; RIL 254-2-2016, p. 240.)

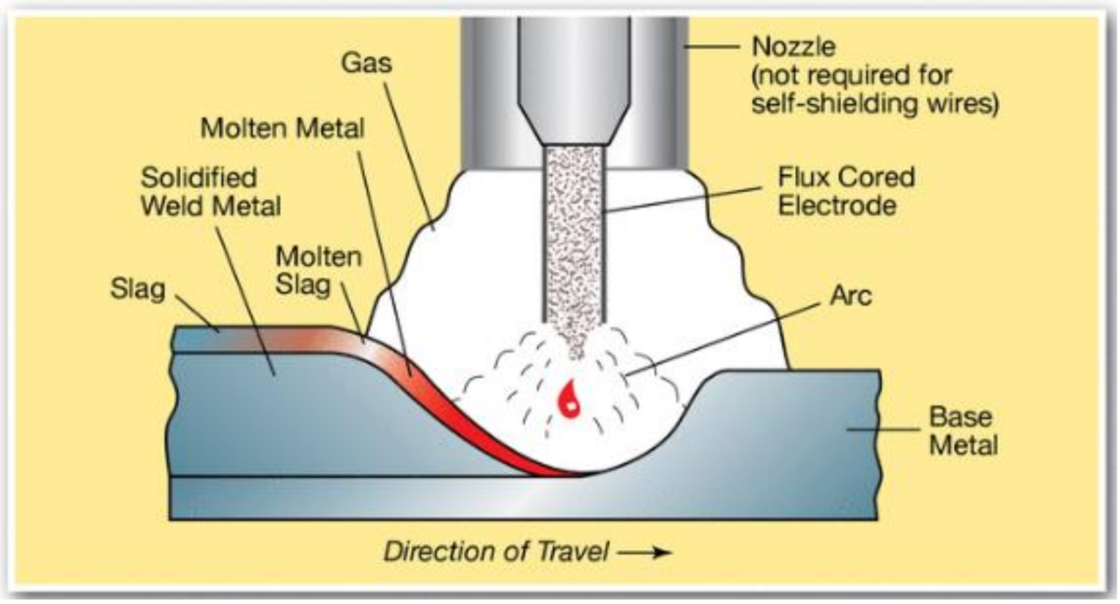

Figure 11. Process of Flux cored arc welding (Hobart Institute of Welding Technology 2002, p.1).

The FCAW used for welding is inside the coil and feed is partially mechanical. The welding current is direct current, and the filler wire feeders are usually constant speed. In FCAW consumable classification EN ISO 17632-A: T 46 4 P M21 1 H5. Core flux type is Filarc PZ6113. In FCAW specification presented in Figure 12. (Esab; Hobart Institute of Welding Technology 2002, p.9; Lukkari, 1997, p.228-229.)

Figure 12. Specification of Core flux PZ6113. (Esab)

Deposition Data				
Diameter	**Current**	**Voltage**	**Wire Feed Speed**	**Deposition Rate**
1.0 mm	100-300 A	22-35 V	4.5-23.0 m/min	1.2-6.2 kg/h
1.2 mm	150-350 A	23-35 V	5.8-20.7 m/min	2.1-7.5 kg/h
1.4 mm	150-350 A	22-34 V	3.3-11.6 m/min	1.8-6.3 kg/h
1.6 mm	150-450 A	22-36 V	2.8-12.4 m/min	1.8-8.1 kg/h

4.3 Continuation welding of pipe steel piles

The welding process of the steel pipe piles is done several times on the construction site. Continuation welding of steel pipe piles can be performed in vertical Figure 13 and horizontally in Figure 14 positions. During vertical welding, the steel pipe pile is attached to the drilling rig. During continuation welding in the horizontal plane, the pipes are not attached to the drilling rig. The welding process includes two different welds, which are a continuation welding and a casing shoe welding. The casing shoe welding on the inner surface of the pipe and on the end of the pipe that welding toward the ground during drilling. Ends of the steel pipe piles are welded together by butt welding. (RIL 254-2-2016, p.163, 220.)

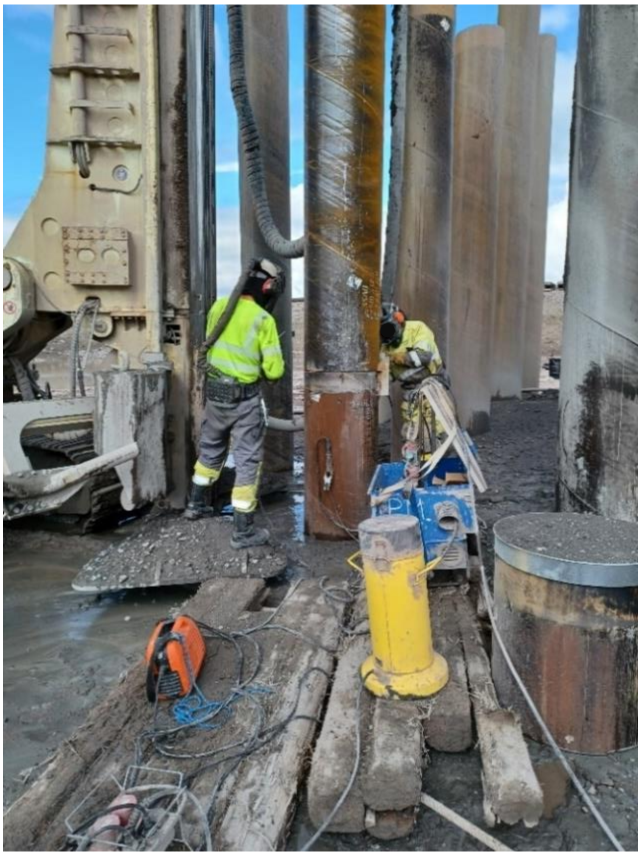

Figure 13. Continuation welding vertically.

Figure 14. Continuation welding horizontally.

The joint preparation is carried out before continuation welding. Joint types are with or without backing. Preliminary joint preparation of V-groove without backing in presented Figure 15 and with backing in Figure 16. Continuation welding is overlay welding and includes root passes and several filling passes. Overlay welding is started by root passes, which are made by the SMAW process. Next comes several layers of filling passes and until the V-groove is filled. Filling passes process doing FCAW process. The weld sequence of continuation welding is presented in Figure 17. (Destia WPS 2023; SSAB, p.43.)

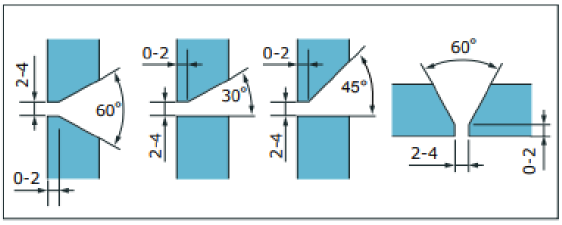

Figure 15. V-groove joint types without backing (SSAB 2023, p.43).

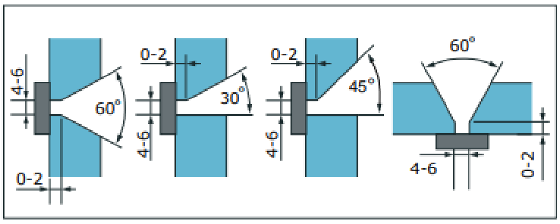

Figure 16. V-groove joint types with backing (SSAB 2023, p.43).

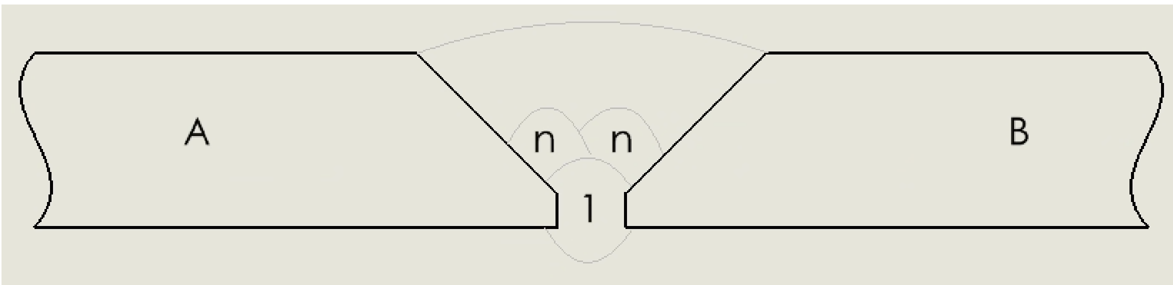

Figure 17. Continuation weld sequence (Destia WPS 2023).

The welding classes required for the joints of steel pipe piles are specified in the standard SFS EN ISO 5817, and the welding requirements welding process and inspection for steel pipe piles are from the SFS EN ISO 3834-4. The piling class is determined based on the class of consequence. The higher the piling class, the more inspections are performed on continuation welds. The welding inspection must meet the requirements of SFS EN ISO 3834-4. (SFS-EN ISO 3834-4:2021; SFS-EN ISO 5817:2023; RIL 254-2-2016, p.164.)

The welding seam can be inspected with a non-destructive NTD method and visual method. The welding categories of pile joints are shown in Table 2. An alternative method for inspection of continuation welds is an experimental method suitable for mechanically welded continuation. Welded continuation can be experimentally verified by means of bending stiffness and bending strength. (RIL 254-2-2016, p.163-164.)

Table 2. Welding classes of continuation welding (RIL 254-2-2016, p. 164).

Piling class	Consequence class		
	CC1	CC2	CC3
PTL3	C	C	B
PTL2	C	C	C
PTL1	D	-	-

In piling class 1, the continuation welding of steel pipe piles is visually inspected. In piling class 2 is sufficient visual inspection in other consequences classes, except CC3 required an ultrasound inspection. In piling class 3, in addition to a visual inspection, is commonly between 10-15% of the continuation welds to be inspected by NTD-methods. The inspection quantities of welds for piling classes are shown in Table 3. (RIL 254-2-2016, p.165.)

Table 3. Percentage of inspected weld joints (RIL 254-2-2016, p.165).

Piling class	NTD inspection as a percentage of continuation welds		
	CC1	CC2	CC3
PTL3	-	10	15
PTL2	-	-	10

Welders must be qualified in accordance with EN 9606-1. After completing the butt-welding test, the welder can weld all butt welds except pipe branches and filled welds. The welding consumable is selected according to the steel pipe piles with a softer or lower alloy content in the butt joint of steel pipe piles of different strengths and materials. (EN 9606-1:2017 p. 14; RIL 254-2-2016, p. 165)

The inspection of the continuation welding of steel pipe piles is carefully planned and cause as small interrupt to the construction site as possible. Larger steel pipe piles usually contain 1-2 continuation weld and smaller steel pipe piles may have several continuations to be inspected. A continuation weld can be inspected with the steel pipe pile in the vertical or horizontal position. The continuation welds to be inspected are attempted to be inspected from horizontal steel pipe piles, because vertical steel pipe piles are attached to the drill rig and inspecting can cause interference with the drilling process. The welding NTD inspector will submit an inspection report to the contractor. Figure 18 shows the NTD-inspected continuation weld. (RIL 254-2-2016, p. 162-166.)

Piirustus nro / Drawing no. -	Rev. nro -	Perusaine / Base material S440J2H		Nimellismitat / Nominal dimensions Ø406x12,5
Liitos ja railotyyppi / Type of joint and bevel V	WPS nro. -	Pinnan laatu / Surface Condition Hitsattu	Lämpötila / Temperature 3 °C	Lämpökäsitelty / Heat treated Ei
Tarkastusohje / Inspection procedure EN 10160	Rev. nro -	Laatuvaatimus / Quality requirement EN ISO 11666/ 2 (Paalutusluokka PTL3)		Tarkastuslaajuus / Extent of examination 100%
Tarkastuslaite / Inspection apparatus USM 35	Kalusto nro / Equipment no. 203	Näyttöherkkyyden tarkistuskpl. / Reference calibration block S20	Kalusto nro / Equipment no. HT-89	Tarkastustekniikka / Inspection technique Pulssikaiku
Etäisyysasteikon tarkistuskpl. / Range calibration block Kappale 2	Kalusto nro / Equipment no. 5-89	Kaapeli / Cable Koaksiaali 2m		Kytkentäaine / Couplant Geeli

Luotaimen No / Probe no.	Tyyppi / Type	Kiteet / Elements	Värähtelijän koko / Element dimension mm	Nimelliskulma / Nominal angle °	Taajuus / Frequency MHz	Perusvahvistus / Gain of calibration dB	Luotausvahv. / Scanning gain dB	Vaimennus / Attenuation dB	Siirtymäkorjaus / Transfer loss dB	Mitta-alue / Range mm	Aaltolaji / Wave mode
3224	MSEB4	2	2x10	0	4	47,0	47,0	-	-	0-80	L
3255	MWB	1	8x9	70	4	55,5	61,5	-	-	0-90	T
3254	MWB	1	8x9	60	4	44,5	50,5	-	-	0-60	T
-	-										

Luotaussuunnitelma / Scanning plan
-

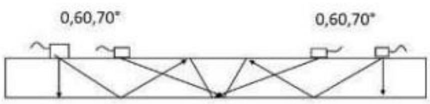

Figure 18. Accepted NTD-inspection. Destia NTD inspection report 2021.

5 Quality and explore the future

The quality of the continuation welding of steel pipe piles is measured by the total welding time indicator. The total welding time of a steel pipe pile can be used to measure the lead time of one continuation weld. Qualitative methods are discussed in the section on quality research methods. The explore the future section introduces perspectives and baselines for future research.

5.1 Quality and productivity

The quality requirements for continuation welding of steel pipe piles come from standard EN 3834, which defines quality requirement level for welding. EN 15607 is one part of the EN 3834 series of standards. The standard EN 15607 includes the development and acceptance criteria of the welding procedure specification WPS for different metals. The WPS welding procedure specification for steel pipe piles is based on EN 15609-1, which includes the quality requirements for fusion welding for metals. WPS ensures that welds are made according to quality criteria. (SFS-EN 15607:2019; SFS-EN 3834-4:2021; SFS-EN 15609–1:2019.)

Welding procedure specification for WPS steel pipe pile continuation welding has been developed for the SMAW and FCAW welding processes by means of a method test, which is specified in EN 15609. The welding procedure specifies the welding positions, welding type, welding parameters, materials to be welded, shape of the groove and joints, material thickness and size of the pipe diameter to be welded. (Destia WPS 2023; EN 15609.)

The total welding time indicator includes weld preparation, arc time, post weld activities time, processing time of workpiece and production auxiliary time. Total welding time can be calculated as shown in equation below. (Stenbacka, 2011, p.66.)

$$\textit{Total welding time} = t_{wp} + t_{at} + t_{pwa} + t_{pt} + t_{pat} \qquad (1)$$

Where t_{wp} is weld preparation (s), t_{at} is arc time (s), t_{pwa} is post weld activities time (s), t_{pt} is processing time of workpiece (s) and t_{pat} is production auxiliary time (s) (Stenbacka 2011, p.66).

Weld preparation (t_{wp}) = Weld preparation, which is done before welding starts. Weld preparation time may include preparation of welding equipment, cleaning of the welding groove and installation of grounding cables.(Stenbacka 2011, p.66.)

Arc time (t_{at}) = The arc time is the time during which the arc burns in the welding process. The arc time varies between SMAW and FCAW. Arc time is affected by the groove, welding position, welding parameters and the object to be welded. (Stenbacka 2011, p.67.)

Post weld activities time (t_{pwa}) = The time when the arc is not burning, and the workpiece is not being processed. The postweld activies can be the time taken to replace the welding consumable, shielding gas, welding rod and nozzle remove slag and clean the nozzle. (Stenbacka 2011, p.67.)

Processing time of workpiece (t_{pt}) = The time required to handle a workpiece, which may be moving a steel pipe pile with an excavator or moving or turning a workpiece with a drilling rig (Stenbacka 2011, p.67).

Production auxiliary time (t_{pat}) = Time in the welding process that is not directly related to the welding work. Auxiliary time can be exit from the welding place during the welding process, setting and removal of auxiliary pieces and defects repair. Auxiliary time should be kept to a minimum. (Stenbacka 2011, p.67.)

$$A = s^2 \times tan\left(\frac{\alpha}{2}\right) \times s + i \quad (2)$$

Where A is cross sectional area (mm^2), s is plate thickness (mm), α is groove angle (°) and i is root gap (mm) (Stenbacka 2011, p.73).

$$M = A \times L \times \rho \quad (3)$$

Where A is cross sectional area (mm^2), L is weld length (mm) and ρ is density of filler material (kg/m3) (Stenbacka 2011, p.73).

$$t_{arc} = \frac{M}{T} \quad (4)$$

Where M is deposition metal mass (kg), and T is Deposition rate (kg/h) (Stenbacka 2011, p.67).

$$C = 2 \times \pi \times r \quad (5)$$

Where r is radius of the circle (mm) (Valtanen Esko 2019, p.18).

The total welding time of a steel pipe pile continuation weld is measured by the total welding time of a single continuation weld. Calculation of a single continuation welding grooves 30°, 45° and 60° presented in Table 4. Duration of welding phases presented in Table 5 and Figure 19. The calculations have been compared to the actual welding times taken with a stopwatch at the construction site. Comparison presented in Figure 20. The total welding time indicator includes for SMAW and FCAW at the maximum current by the WPS. Deposition rate SMAW and FCAW presented in Figures 21 and 22. (Destia WPS; Stenbacka, 2011, p.66.)

Table 4. Calculation parameters for continuation welding.

CALCULATION PARAMETERS FOR CONTINUATION WELDING						
Welding method	FCAW	FCAW	FCAW	SMAW	SMAW	SMAW
Angle of groove	30°	45°	60°	30°	45°	60°
Cross-sectional area (A)	66,87	89,71	115,21	97,86	89,71	115,21
Filler metal (M)	1	1,34	1,72	1	1,34	1,72

Table 4 continues. Calculation parameters for continuation welding.

CALCULATION PARAMETERS FOR CONTINUATION WELDING						
Welding method	FCAW	FCAW	FCAW	SMAW	SMAW	SMAW
Maximum profit of filler metal (T)	5	5	5	1,2	1,2	1,2
Effective arc time (min and s)	11 min 59 s	16 min 5 s	22 min 58s	49 min 59s	67 min 3s	86 min 6s

Table 5. Duration of welding phases.

WELDING METHOD	FCAW	SMAW
Description of welding phases	Time (min and s)	Time (min and s)
Effective arc time groove 45°	16 min 5 s	67 min 3 s
Weld preparation	10 min 51 s	8 min 56 s
Post weld activities time	2 min 31 s	2 min 4 s
Processing time of workpiece	17 min 3 s	39 min 42 s
Production auxiliary time	2 min 4 s	11 min 54 s
TOTAL	49 min 11 s	130 min 15 s

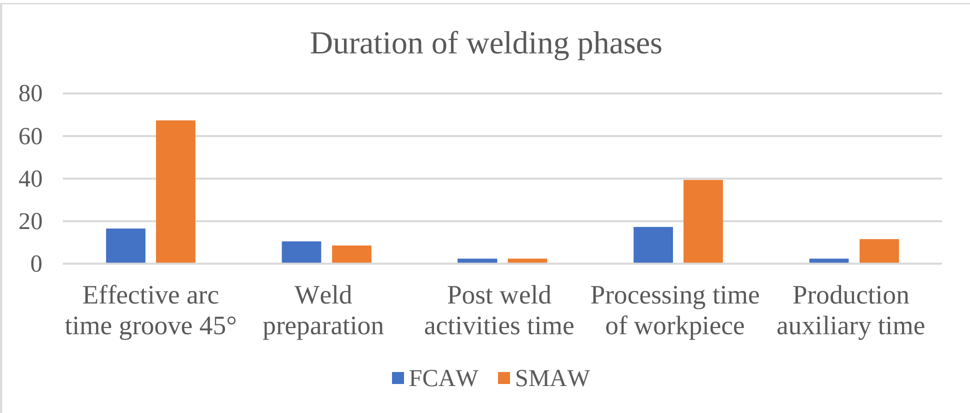

Figure 19. Duration of welding steps groove 45°.

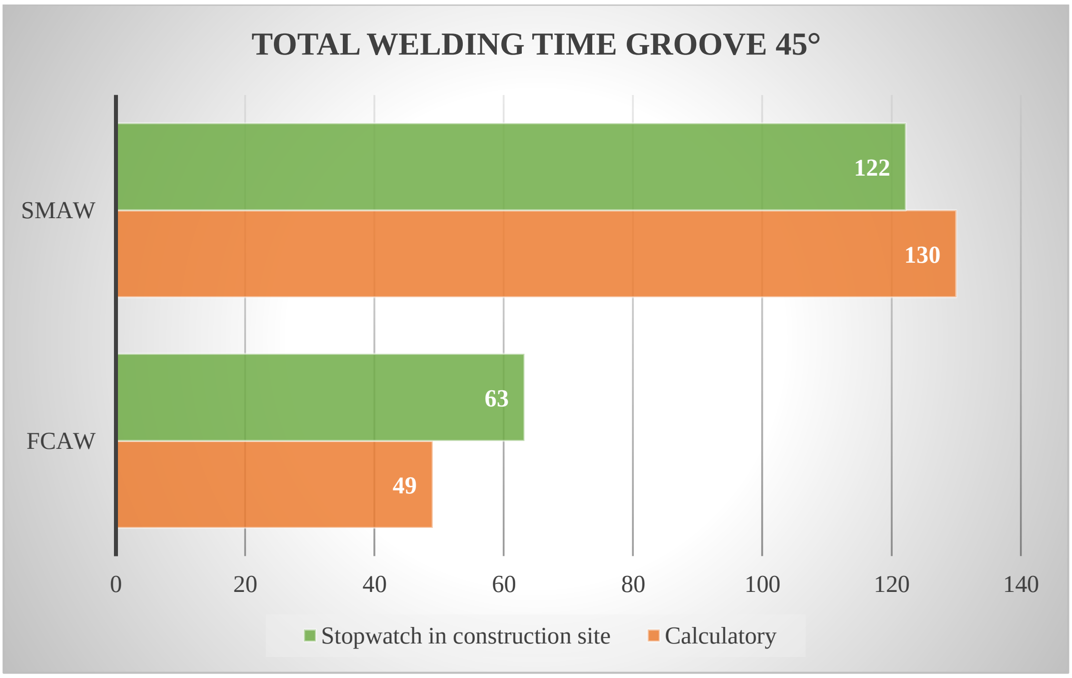

Figure 20. Total welding time (min).

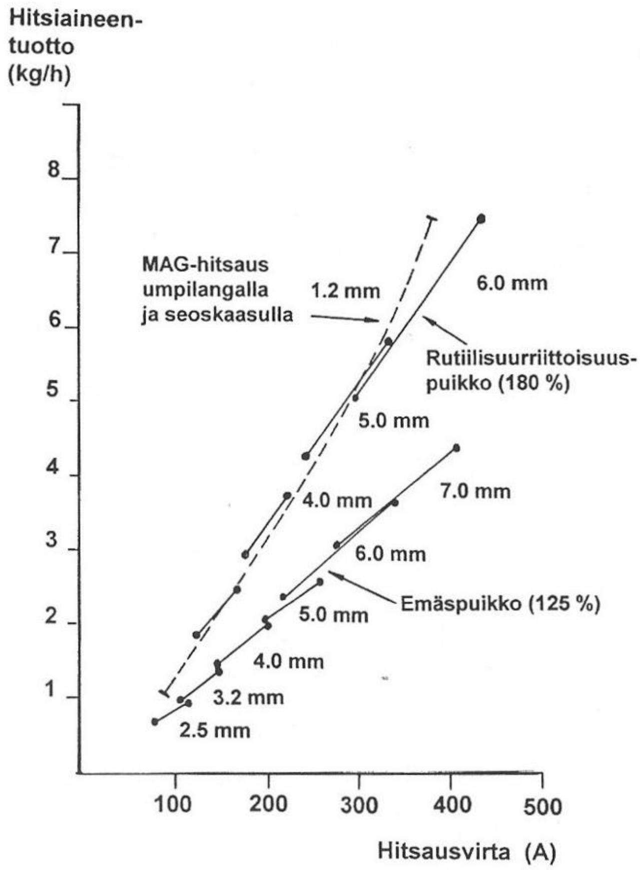

Figure 21. SMAW filler material deposition rate (Lukkari 2002, p.89).

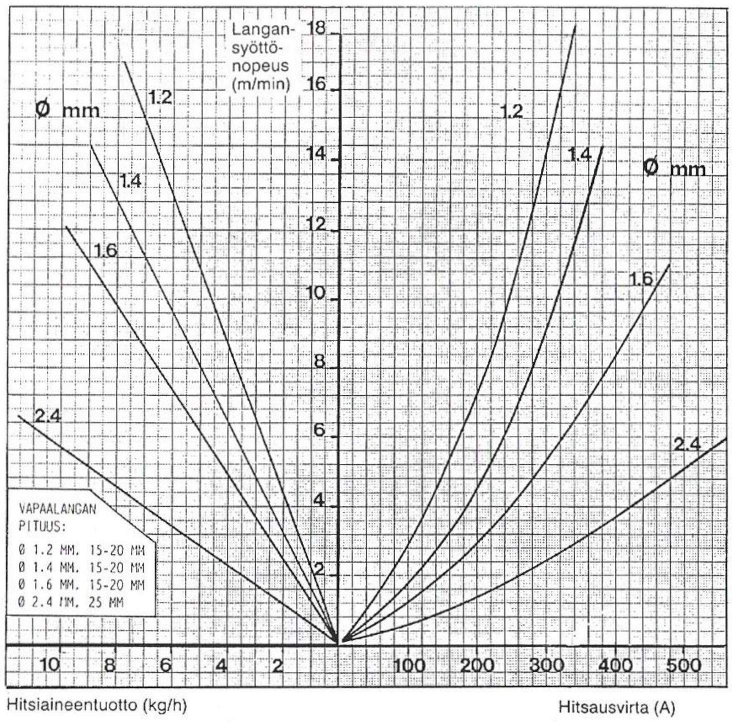

Figure 22. FCAW deposition rate (Lukkari 2002, p.244).

5.2 Qualitative methods

The philosophy of research science is based on empiricism. Empiricism is observation based on experience and the senses. Experiential observations of the subject under study are generalized to cover the phenomena of the subject. The researcher can find explanations for the solution and the difference between qualitative and quantitative research is easier to explain. In this study, a flowchart of empirical research and background commitments has been used, as shown in Figure 23. (Hirsjärvi et al., 2009, p. 161; Marki P. 2004.)

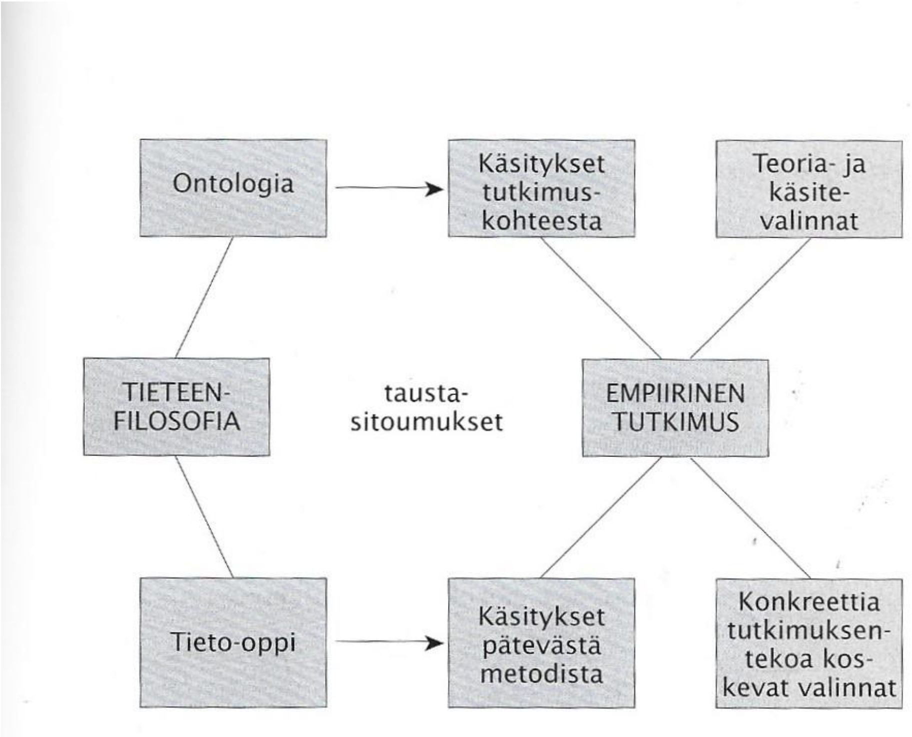

Figure 23. Future research of empirical and background commitment (Hirsjärvi et al. 2009, p.131).

Ontological based on questions about the nature of reality, while epistemology seeks to answer which methodology would be best for conducting research. In this study, the theoretical and conceptual choices relate to the continuation welding of a steel pipe piles at a construction site. The specific research choices are justified, methodologically feasible and targeted to the subject under study. (Hirsjärvi et al. 2009, p. 161.)

Denzin & Lincon: “Qualitative research is the implementation of research practices under natural conditions, from which different interpretations can be drawn. Qualitative research has no theory, no paradigm and its methods are not entirely own.” Hirsijärvi etl: Qualitative research is a description of real life, where information is collected about events happening at the same time and events shape each other, so it is not possible to break down reality into parts. (Metsämuuronen 2008, p.9; Hirsjärvi et al. 2009, p. 161.)

“The term reliability refers to the reproducibility of results”, meaning that if another researcher were to carry out the same study using the same methods, the results would be similar. Validity refers to the ability to measure the right things using research methodology.

The reliability and repeatability of qualitative research is ensured by using existing qualitative methods such as literature review and Delphi interview. The information from the Delphi interviews will be linked to existing knowledge through a literature review. The measure of validity is the total welding time, which the study identified as a qualitative problem at the construction site. (Hirsjärvi et al. 2009, p. 231-232.)

The total welding time is first calculated using the manual calculation method of the welding task time. After the manual calculation, a measurement of one continuation weld is performed on the construction site using a stopwatch. The results obtained are compared with each other to ensure the accuracy of the results. The same steel pipe pile size, welding parameters and materials are used for the manual calculation of the total welding time and during the measurements. The results obtained are expressed in hours and minutes to two decimal places. (Stenbacka 2011, p.66.)

The Delphi expert interview will make use of a small panel of participants. There are three experts per client company and the conclusions will change if the panel size is changed to a panel of more than 20 people. In terms of sensitivity, in small panels, the majority views are not generalized to expert panel views to avoid error. Two rounds of Delphi interviews will be conducted to saturate the survey results. The first round of Delphi will provide the knowledge base of the research problem and the second round will refine the analysis method to identify future development needs. Two rounds of interviews are sufficient to obtain a saturation, as a future table and future scenarios can then be generated. (Kuusi, Bergman & Salminen 2013, p. 251.)

5.3 Investigate of future

Malaska: The future cannot be perceived through senses and memories. The future exists as an experience of consciousness and is a characteristic of every human being. Future knowledge is determined based on factual knowledge and vision. Niiniluoto: Self-understanding and practice have been scientific concepts for futures research. The basic function of science has been described as the truthful informative presentation of the facts and regularities of the world. Scientific knowledge arises from argument statements of private and general facts. The use of current knowledge for future research does not transform the present into the object of research. (Kuusi, Bergman & Salminen, 2013, p. 14, 22-23.)

Futurology, foresight, and futures research are terms used in futures research. Futurology is defined as the basic assumptions of the philosophy of science and as a fundamental part of futurology, playing with the possibilities of the evolution of phenomena. The term foresight refers to the scientific study of the future. To anticipate is to see things before they happen. Foresight is used in the planning process of future research. (Kuusi, Bergman &Salminen, 2013, p. 18–19.)

The creation and exploitation of future knowledge must consider the chains of knowledge access and understanding. “In his doctoral thesis, Timo Sneck has created a diagram of the chains of future-oriented knowledge creation and exploitation”. In this study, the diagram is used to generate future-oriented knowledge, to understand and present the nature of knowledge, to hypothesise and to present tacit knowledge in delphi interviews. Benefits of future knowledge is presented in Figure 24. (Sneck, T. 2002. p.39.)

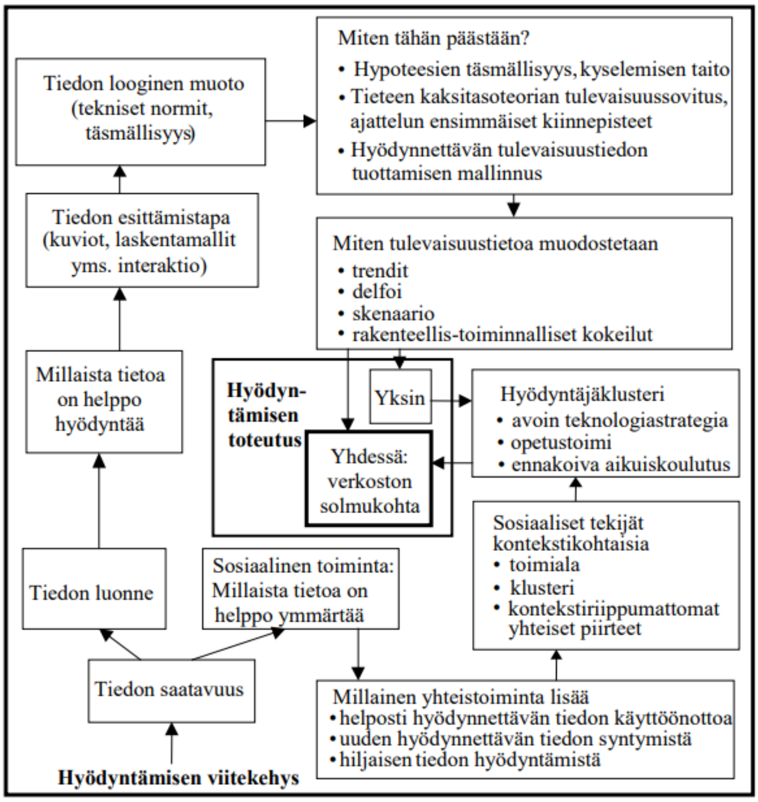

Figure 24. Benefits of future knowledge. (Sneck 2002, p.39.)

6 Formation of the research

The formation of research introduces the structure of the Delphi interview, the selection of the expert panel and Delphi interview rounds 1 and 2. The Delphi interviews are analysed using thematic analysis and then the future arguments are created. Based on the answers to the future arguments, a future table was compiled and based on the answers to the future arguments, future scenarios were derived.

6.1 Introduction of Delphi interview

The Delphi method originated from the Rand Company's research into military technology in the 1950s. The Delphi method is used to gather expert opinions and assess the potential for future developments. The three main features of the Delphi method are anonymity, iteration, and feedback. Anonymity aims to allow experts to express their views depending on their background and role. During a new iteration round of interviews, experts can comment again on their statements. Getting feedback from other experts/panellists and thereby correcting one's own opinion. (Kuusi, Bergman & Salminen 2013, p. 248-249.)

The original purpose of the Delphi method was to produce a consensus among the panellists. The Delfoi panel has been used to raise sensitive issues, set change in motion, and create optional futures. Millet and Honton: Today, the Delfoi method aim to not produce a consensus opinion but future scenarios which are viewed from many different perspectives. Argumentative Delphi is based on the Turoff 1957 argumentative Delphi method. In Argumentative Delphi, solutions are sought for different theses and points of view. In this study, the arguments after the Delphi interview are the arguments of the future, which have been collected from the thematic analysis of the Delphi interview material. (Kuusi, Bergman & Salminen 2013, p.252–253, 260–261; Moilanen & Räihä 2001, p.53-54.)

Typical errors of the Delphi process include scattered answers, inability of experts to assess future scenarios too far into the future, ambiguous question wording, economically beneficial scenarios, and events in the recent past. In a changing environment, people can feel anxious and the attempt to predict the future is made in a safe environment for experts. (Kuusi, Bergman & Salminen, 2013, p. 259.)

The research will be interview-based, to bring out the " silent knowledge" of the experts as much as possible. The Delphi interview round of the study will be conducted in a Teams video call and the Delphi interview manager will record the interviews. The interview questions will be evaluate using a Swot risk analysis before the actual interviews take place. The interview is transcribed and analysed using the thematic analysis method The time functions of the theming method were the past, now and the future. The native language of the experts participating in the interview study is Finnish. The interviews are conducted in English, because the customer company is international, and English is used daily. (Kuusi, Bergman & Salminen, 2013, p. 253; Tuomi & Sarajärvi 2009, p.92-93.)

6.2 Experts for Delphi interview

The Delphi panel is selected from a pool of experts. The quality of the experts is more of a determining factor than the number. In a small panel of experts, care must be taken not to turn the majority opinion into a general opinion. For expert panellists, it is important to be aware of how they make their choices based on their own perspective of the future. (Kuusi, Bergman & Salminen 2013, p.251, 254-256.)

The experts are selected from the customer`s company based on the research problem. The criteria for selecting the experts were quality, which is why the number of experts selected was lower than in a normal Delphi study. The welding technology expert is responsible for welding in the customer company and could have an insight into future developments in welding technology. The project manager has the best knowledge of the management and leadership of piling projects and could bring future development ideas for the project and the leadership of the piling project on site. The project manager has the best knowledge of practical piling operations and will bring practical knowledge from the site to future research. Bringing in practical knowledge strengthens the validity of the theory and enables the further development of the site piling process in the right direction. Experts were selected using in selection Table 6. (Kuusi, Bergman & Salminen 2013, p. 254.)

Table 6. Expert panellist selection table. (Kuusi, Bergman & Salminen 2013, p. 257)

Interest/ Expertise	Head of welding unit and welding coordinator	Project Manager	Project Manager
Welding technology	Konsta Hölttä		
Management and leadership of piling projects		Miro Mykkälä	
Development of practical procedures for drill piling and steel piles, and the organization of the work			Alexei Kesonen

6.3 Delphi Round 1

The researcher is unfamiliar with the subject and the purpose of the first Delphi round is to establish a knowledge base about the problem to be studied. In the first round, there are seventeen questions. The questions in the Delphi first round aim to answer the current situation on the construction site and to find future trends in the research problem. In the first Delphi round, attention is also paid to the layout of meaningful questions and to ensuring that all questions in the interview round are understood correctly. (Kuusi, Bergman & Salminen 2013, p.256-258.)

SWOT analysis is made up of the word's strengths, weaknesses, opportunities, and threats. SWOT analysis is used to assess the future of companies. In this study, SWOT analysis is used to assess the risks of Delphi interview rounds. In the first round of interviews, the internal strength is seen as the issues related to the interview conduct and recording. An internal weakness is the experience of the experts in the expert interview and the scheduling of the interview. External strengths are the framing of questions for the next round, the creation of future scenarios, getting future opportunities in a resource-efficient way and development models for future follow-up. Threats are perceived to be the tendency of respondents to seek a common opinion, the method not working in practice, the number of experts interviewed being too small and the risk that experts answer too narrowly to the interview questions. SWOT analysis presented in Figure 25. (Kotler and Keller 2006, p. 52–53.)

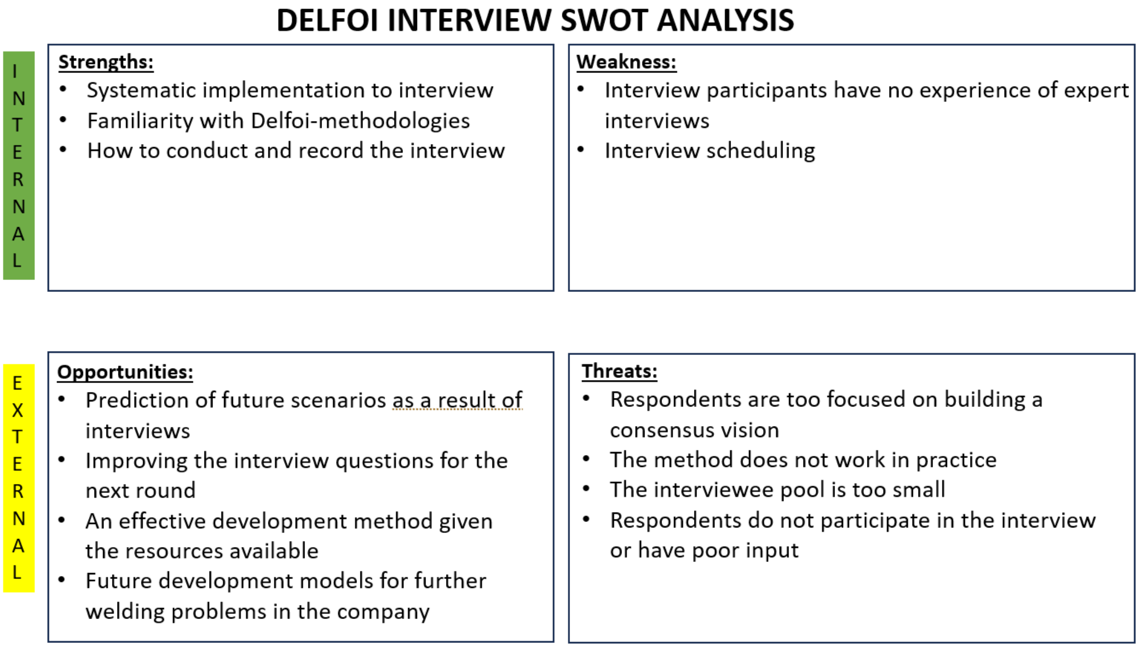

Figure 25. SWOT-analysis Delphi interview round 1 (Molarius et al. 2007, p.12).

The seventeen questions of the first round of the Delphi interview are presented below, followed by a summary of the experts' answers. The questions of the first round of Delphi were refined based on the SWOT risk analysis in Figure 25 and research questions.

<u>What kind of mental image for continuation welding of pipe steel piles?</u>

Depending on the welding work. Construction sites mostly use piles in soft soil situations. Types of pile pipe and continuing. Location of construction site. Near the sea, work at the north and welding on site conditions under the sky pretty much. Welder location on welding situations on construction site. The weather situations and air conditions. Snow, winter, rain, and waves. What time of the year. Welding conditions and quality. Welding covered and hard work.

<u>What is today's continuation welding of pipe steel piles?</u>

Hard work, better solutions, and welding work is easier for the welders. Different solutions make it better, faster, keep up and quality. Lots of ways are improved by mechanization or automatization. For the welder himself, the challenging welding process and lots of work is to do. Completely manual. Depending on characteristic of welding and job. Small pipes could be used by couplers. The coupler use helps for quantities because no need weld and can purchase less pipe materials. Couplers cost much because of the weight of the metal and commonly welding could be done cheaper. Quality problem, site properties and design. Quality inspection by NTD. Important are the sizes of pipe and site location. Differences properties, quality and standards for Sweden, Finland, and Norway.

What are welding methods and welding equipment for continuation welding?

Welding processes are sticking welding 111 and flux core welding 136. That's like we are commonly using at the moment. Equipment that we use in the open air has mostly been produced for working inside of the hall. Equipment is produced in good condition and workers need all the time to check that everything works on the construction site. Mostly problems with electricity, water, and time loss on construction sites. Stick welding easier variables conditions and MIG/MAG solution equipment mostly difficult for bad weather conditions. Winter is affecting it, and it would like to blow away this gas. Sometimes only stick welding because the weather is bad, hurry and don't have time to make covers enough. Small pile is not effective to start make cover and using only stick welding. Use welding tents and covering plates. Welding tents are used for welding railway applications.

Whether mechanized welding has been used for the future welding of pipe steel pipe piles?

I have never heard about it, and we haven't done it. Ring bit or some lock for the pipe wall could be done by mechanized welding only in hall. The problem could be mechanized welding needs good cover from the dust, weather conditions and much time to install this mechanism around pipe. Drilling rig keeping the pile, is not too much space around pipe piles and installation conditions could be hard. Robotized workers can help ups for welding. There are mechanized applications for welding pipes in general.

Where are welding equipment and welding consumables stored on the construction site?

Containers and vehicle cars. They are not driving gas balloons, but they have all equipment. Small jobs have no place to keep equipment on site. Job could be performed mostly easily on site and fastly.

What are pipe steel materials?

Depends on the designer and different steel materials. Normal structural steel and some higher strength variance. Commonly 355 or 440 and sometimes need more capacity. Purchased mostly from stores in Europe. S355 in Finland and Scandinavia of SSAB quality. Quality also grows to S440 and S460. Also 550 if you are about it is asking. Smaller pipe diameter starts 140 mm and goes up like 1200 mm. Wall thickness of pipe smallest 8 mm and normally 12.5 mm. The biggest pile wall thickness has been 22 mm.

How to prepare steel pipe piles for continuation welding?

Usually bevel from factory, but sometimes prepare bevel on construction site. When the bevel is ready done preparing are clean up and start welding. Winter times we must heat up. Bevelling equipment on construction site. Most welders like to use the normal hand tool to make. The vibes are done by supplier already. Sometimes they can't make it if you have a long pile, and they are not able to bevels. The shorter piles are taken out and they have some kind of flowerpot, which is doing this bevel. Every time we can affect this decision, we want these bevels from the factory because the quality is also better.

What other operations related of welding are carried out on steel pipe piles before drill piling?

Usually use casing shoes which are welded on second end of the pile. The drilling pilot is contacting the casing shoe. This way we hit the pile bottom and get it and go down like this way we push the pile in the ground. Usually welded casing shoe on site. Sometimes already like factory welded casing shoes. Depends on the resources of the factory. When we need to continue pipe piles, we need to install piles on. The helper machine, with the clamps, needs to install the drilling rods inside of the pipe and then install the pipe and the rods just lift them up. Install it on top of the drilled pipe and they need to check all lines and angle, it could be vertical. Furthermore, dust and dirt coming on. Need to have water inside, so you need to wash this welding contact firstly and then to and then to install it correctly one to another and then make this welding happens. Free workers' jobs like there are drillers who are moving the drilling rig mast and there is a helper with the excavator with the clamps. Need to have good communication and weather conditions.

What preliminary operations related welding can a steel pipe piles supplier make before they deliver the pipe piles to the construction site?

Bevels can be done beforehand. Depends on everything. The system is done because these pipes are big, long, 12 meters, 15 meters or longer than if the needs like everything needs to work. Pipes are made in not good condition soil or in hard soil or when you need to be reinforced. Delivery needs co-operated with supplier. Depends on welding, because if you don't have materials, you can't weld anything, and the job stays. Casing shoes installation of the end of pile but nothing else.

<u>What kind of continuation welding place in construction site?</u>

Place is all the time change. Don`t have constant welding place. Mobile you jump from one place to another. Protect from weather, snow, and rain. Containers or tents could be installed nearby. If the weather is sufficient, can weld in the open air without any protection. Small diameter pipes, making one continuation taking like 30 or 45 min. Then the drilling goes on and then the next pipe. We are constantly moving at the site and by location are changing. Next part could be like 5 meters from the earlier one.

<u>What are the requirements for the welding place in construction site?</u>

Depends on how fast to do a job like. Usually there is no need for standard requirements. Depending on the weather situation now on the side and rain, snow, and sun shining. Mostly problem are wind and rain. Pipe installation vertically needs lot of space because pipe is 12 m long. Need flat and good area to make this happened safely and welding place it's mobile. We change it all the time and the situation need to be controlled. The weather, mostly requirements, electricity and the materials need to be nearby. Welding horizontal piles try to make some kind of tent. Some cover if we know that we are going to use this same place, that's like an only. Long work site and we know that there is going to be a horizontal welding. Extending piles, then we are making like some kind of tent for around it. Can weld in the cover of from the weather. But for requirements, it depends on the weather. The weather is great, we don't need cover. Process to protect from rain, wind, and the weather in general. Safe, and ergonomic. Play for the welders to work. Logistics, tools, piles. Everything goes well, like smoothly and the product of activity is there also. Should be easy to get electricity for equipment.

<u>What deviation in welding quality cause in continuation welding?</u>

Depends on what we are, which we are. Drilling procedure and it costs. The pipe installs by drilling. If we speak about piling drill piles, then mostly if the pipe is welded not properly.

Gets broken on this welding continuation while drilling. Quality control and need to be proceed on site, there are a several norms. They have a preliminary continuation program plan, how the job needs to be performed and all welders know. Before site it could be discussed what kind of continuation need to be done and is a needed some more additional checks for welding quality than just need to be performed. The deviations in welding must prepare this weld again and fix it, and this also takes a lot of time. Currently all the other crew are waiting for this welding and always aim to do the welding according to plan. We make sure that we don't have any deviations because lose a lot of time in preparing the welding scheme. Defects in welds are moisture in the process due to the weather conditions. The wind can blow and shield gas during the process and ruin the world. Mistake by the welder because it's all manual work and faulty equipment. Welder is not following the but in procedures specification and fault in base material.

<u>What is the lead time for continuation welding?</u>

Depends on the size of pipe. Depends on the size, diameter, and thickness of the bar. Tick bar to do more welding and it takes more time. For the past size, it could take 10 minutes or 10 hours even. The equipment, material, weather conditions depend on everything. Sometimes we use two welders for the bigger piles.

<u>How many continuation welds can be made on steel pipe piles per day?</u>

Big differences, but it is small piles. We have dashed these diameters of the pipe like the common diameter for smaller pipes. For example, in big cities where drill pipes on like from 140 millimeters to let's say 300 mm 23 millimeters pipe. But when we need to make something bigger from 400 millimeters, so 1 to 1.5-meter pipe. The diameter of the pipes grows and the thickness of the pipe. Usually, 12 or 10 millimeters could be thicker as well. Need to make more welding lines and taken on time. Small diameter pipes one hour can go for a while from 1-1 continuation, but for the big diameter it could be 10 hours for the one pipe continuation. Design and site and weather conditions as well. If you don't have electricity on site, which is mostly the bigger problem on site, can do 0 pipe continuation because you don't have electricity and that's the first problem that needs to be solved on site. The weather and all the situation with pile sizes and everything, and but if I want to say some numbers so example 800-millimeter piles. If we have, we reach about 2 piles in a day and two bars. They have like two welding seams. In one day, we can weld two big piles and smaller ones. For example, 400 millimeters can reach five or six welds. It depends on a lot what kind of site working site. Do we have to move the thrilling rig the time or can we just move boom a little bit and we can read the second point.

How many steel pipe piles are they target to be related usually per day?

Depends on the size of piles. because of different pipes like the bigger size of the pipe and the heavier pipe. More material needs to be operated. The bigger pipes need bigger equipment, more space, bigger machines, and bigger welding needs to be done for continuation. For the small pipes it is good to calculate 60-65 meters per one working shaft. Only theoretical because side is different, every pipe conditions is different and dealing with machinery with equipment. Many situations could go wrong on machine can be broken on stuff. Depends on location, how long piles are and how big of piles are. Many things can affect and could even say there is no similar work site. Depending on when we calculate the project or start planning to do this work, we have some kind of theoretical answer. Depends on the project. Example 400-millimeter piles we about 20-meter piles. We can reach up to like 10 piles per day, but we can also read 5 piles a day.

What problems can continuation welding cause for drill piling?

A bad welding and, in a drilling, we can destroy this seam and it gets loose. We must leave the whole pile up and do a welding again. Problems in welding like the weather condition bad, we make mistakes and welding welder takes more time to do. All the crew is waiting for him like they don't have any other option to do there, they can't do any other work now. They or everyone is waiting for this one guy, you know he's doing the welding. Welding will be a bottleneck, then it holds all operations. Welding wrongly, it's not possible like gets broken in some place and a possible option to lose drilling equipment. In this situation, we have a pipe with real pipes using down to haul drilling technology. Expensive drilling equipment at the bottom of the pipe. If something happened with this welding while drilling for example, that could also cause problems for the drilling equipment and can lose drilling equipment which is money. Lift this equipment up, for example. Need to change the place of the pipe and some design costs as well because it's the change to design. Welding, for example in different soil properties, could be a problem.

The clay and the pressure because this drilling mostly. We use compressed air for drilling, for using this down to haul hammer. Welding is their drilling equipment is not working because to push air down. Close their compressors while welding and then if the soil properties are bad and the pressure is high water pressure down to on the pile. A problem that clays, or dirt goes inside of the drilling company. Equipment hoses and after can see the problem that all our equipment is full of clay for example. Welding takes a long time then the air holes are full of clay. Air can pass through and if air can't pass through then the down to hall hammer is not can be worked. Need to open the welding again and then you need to lift the equipment up. Need to open everything and then you need to clean. Need to put it back and you need to install the pipe back and you need to make a welding again there is million different problems that could be.

What future challenges for continuation welding?

All the piles are getting bigger and thicker and takes more time to weld. How many welders can we wait around the file is one kind of challenge possible future because for now designers are all the time planning bigger and bigger piles. In all kinds of businesses is to make things faster, cheaper, and safer. Is not enough quality control for this work and there is a not the standards change regarding different countries. Different companies, different workers, different welders. They do everything a little bit by them all and I think it is a really good solution. Need to check only. The exact amount of welding piles. For example, in Finnish sites construction sites, you need to check only some, some exact amount of this, but so this means that if you checked like 5 then then all other 45 could be welded as they as they want. Differences in the welding quality. It's there, I think, to get better qualities. One big challenge for every company that does welding is to get professional welders to make the top. It is hard work and in hard weather conditions and sometimes we have welders that are just. Thinking about causes that they can't weld like they're complaining things, and we need in future more welders on this market like we are already looking for people from Europe that we could hire.

A thematic method was used to analyse the Delphi first round interview data. The thematic method involves a dialogue between theory, empirical research data, methodology and previous research. In the analysis, the resulting text from the interview transcription is transformed from views and themes into the categories of time functions past, present and future. The time functions past, present and future have been chosen because of the research problem and the prediction of the future. The past time function tells us how things were before, the now time function tells us how things are now, and the future time function seeks answers to the question of how we want things to be in the future. The thematic method presented in Table 7. (Puusa, Juuti and Aaltio, 2020, pp. 157.)

Table 7. First Delphi round thematic analysis.

CLASSIFICATION OF THEMES		
PAST	NOW	FUTURE
• Weather conditions • Bevelling equipment and welding covered • Casing shoe welding on site • Deviations lose lot of time in welding • No constant welding place • Problem utilize mechanized welding • Completely manually welding. Methods 111 and 136. • Hard work • Location of site and welder • Problem electricity, water and time loss on site	• Better solutions for welder and manually welding • Challenging welding process, lot of work and hard work • Coupler for small piles • Quality problem, site properties, design and inspection (NTD) • Sizes of pipe diameter and wall thickness • Differences properties, quality and standards for different countries • Problem electricity, water and time loss • Welding equipment produced for working good conditions • Tents and covering plates • As a Storage at the site for container and vehicle car • Pipe material normal structural steel and some higher strength variance • Bevels from factory and casing shoe welded on site • Important good weather conditions • Deliver supplier. No material no welding • Pipes are made in in not good condition soil or in hard soil • Welding place change all time • Small piles welding 30-45 min and big piles even 10 hour • More additional checks for welding • Deviations in welding: prepare and fix weld again and takes lot of time • Pipe welding vertically and horizontally • Currently all the other crew are waiting for this welding. Welding will be a bottleneck, then it holds all operations. • Welding plan • Defects moisture, shiel gas, mistake manually welding work and faulty equipment • Welding leadtime depends on the size, diameter, and thickness of the pipe • Steel pile target per day only theoretically (depend construction site, piles and machines). Times vary daily • Bad welding and, in a drilling, we can destroy this seam • Wrong welding possible losing drilling equipment. Lose money. • Down to haul hammer clogged if welding takes a long time	• Improved mechanization or automatization • Ring bit or some lock for the pipe wall done by mechanized welding on hall • Robotized workers can help ups for welding • Casing shoe welded from factory • Mobile welding place • Protect from weather conditions • Reduced total welding time • Flat and safety welding area on site • Materials need to be nearby • All the piles are bigger and thicker. Takes more time to weld. • How many welders can we wait around the file. • All kinds of businesses is making things faster, cheaper, and safer • Not enough quality control for this work. Not the standards change regarding different countries • Different companies, workers, and welders • Differences in the welding quality. • Big challenge professional welders • Hard work and weather conditions • In future, welders will be hired from Europe

In the first Delphi interview's thematic analysis, the experts saw the addition of automation and mechanization as part of the continuation welding of the steel pipe pile on the site as future development targets. Casing shoe and ring bit can be pre-welded at the factory, and a movable welding place would be useful for continuation welding, because the target changes all the time. The continuation welding should be able to be protected in different weather conditions, the total welding time should be reduced and the continuation welding place on the construction site should be flat and dry. Steel pipe piles should be obtained close to the continuation welding place on the construction site, larger and thicker steel pipe piles require more time for continuation welding, there are not sufficient requirements for the quality of continuation welding, quality requirements vary in different countries and companies and between different welders. Finding skilled welders to do continuation welding was seen as a development target. Continued welding on the construction site is hard work and professional welders must be hired from Europe.

6.4 Delphi Round 2

The second round of Delphi will use the analysis from the first round to refine future questions from experts. The questions are related to the research problem and the refining questions are selected by theming the issues of the future time function of the analysis experiment. The second round of Delphi interviews will include a total of nine questions. (Kuusi, Bergman and Salminen, 2013, pp. 125, 143; Tuomi & Sarajärvi 2009, p.92-93.)

Before the second round of the Delphi interview, the SWOT risk analysis is updated. The SWOT risk analysis will be updated with Delphi second round questions in Finnish and English. This way, the experts will understand the meaning of the question in the second round of the Delphi interview. In Delphi second round SWOT analysis presented in Figure 26. (Kotler and Keller 2006, p. 52–53.)

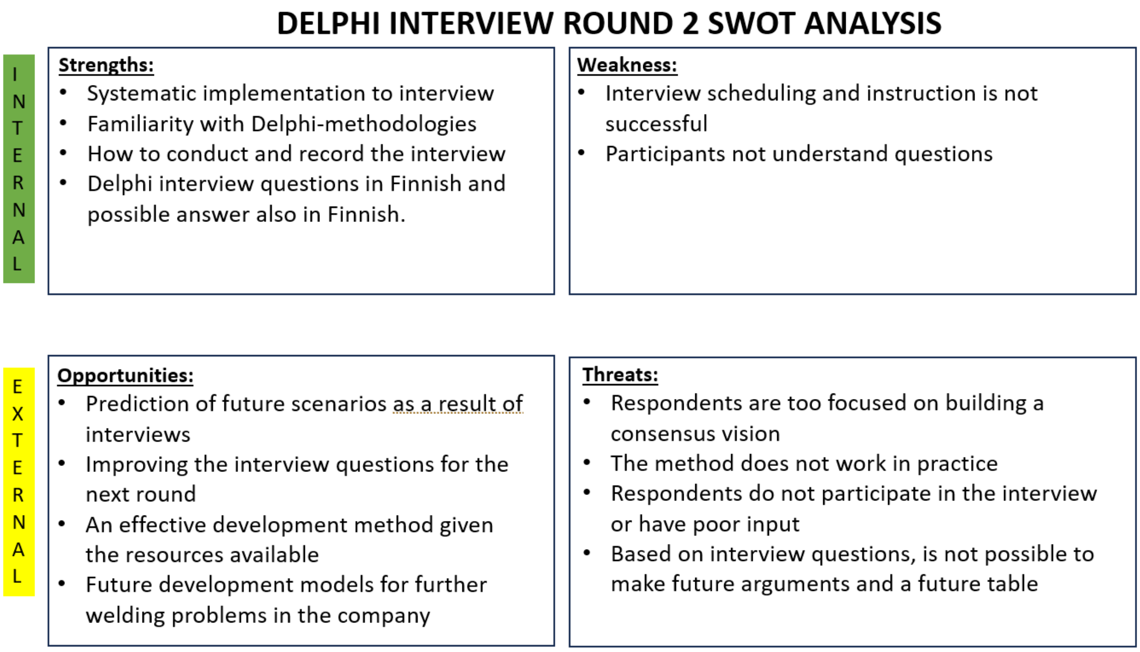

Figure 26. SWOT-analysis Delphi round 2 (Molarius et al. 2007, p.12).

The nine questions of the second round of the Delphi interview are presented below, followed by a summary of the experts' answers. The questions of the second round of Delphi were refined based on the SWOT risk analysis in Figure 24 and research questions.

<u>How can the welding conditions be standardized in continuation welding at the construction site, so that the weather conditions do not affect the execution and quality of the welding?</u>

Need some kind of cover for pile. For the welding like a block, a better condition, like rain and wind. The cover must be fire resistant. Difficult question regarding the different site conditions the in like addition. Sometime problem is also the base. If we speak about excavation pits or something like that, we mostly work on clay soils or is it under the beneath the zero level or beneath the ground water level. Base soil materials that they could be water also and the water it's sometimes hard to pump away and it's also caused problems and risks for welding but some cover and like everything needs time. The best way is probably to plan each work set exactly regarding the weather regarding the conditions of the site. Team work on site with four men and crew workers doing the job. Closed space where wind and wind and rain won't have effect. Temperature maybe effect material. Pile continuation, need to be preheated when temperature drops below 0 C.

<u>How to increase mechanization, automation and robotization on site continuation welding?</u>

Most problems are like these conditions because all these mechanisms, mechanization, automatization, robotization, it needs clean, and stable weather conditions and mostly on our side. Do we need motion automatization or robotization for jobs like this? Like hard industry, where, working inside then it it's probably a can be profitable and show good performance. Like we have welders, and we have this condition, I think there we can spend time more to adjust this robot on place and clean place. It will be good conditions for this robot to perform the job, but it will be faster just to weld. I think maybe something probably needs to come from this drilling rig technology. Like some additional hand or something like that which is connected to the machine and it's just clean and does all the work automatically. Small robot that needs to be installed on place with the workers, then it's the same job as welded. How big would like to install this machine or robot on the pile because the pile location is always changing. It must be like a very light and easy to install the pile or is somehow with the machine or some somewhere and I think maybe in future when robots are like a smaller and easier to install. Maybe we could use it, but in the end, I didn't care at the time to set up, the system takes longer than the welding. Maybe big files or some kind of automatic welding machine could be helpful. I don't see a good solution for this. Profitable solution for high level of mechanization or automatization? At least in the future, there will be some sort of development were, where it will be viable. At the moment if we think about robotization

Gobots (yhteistyörobotti). Gobots are very light and somewhere between manual welder and full-scale robot. Some sort of maybe solution? But I don't know, maybe some other kind of mechanization at this point could pay the most. Most viable way to proceed?

How can the continuation welding place on the construction site be made flat, and how electricity and dry conditions can be made possible at the welding site?

Usually, we use an excavator to remove like a thrilling soil which comes next to the pile. Removed the soil from there so that the welders can come next to the pile. If you are working in the city center, we usually have electricity. Straight next to us, and sometimes when we are working somewhere remote. We have generators generating electricity pretty much. You know, a couple of meters from the machine and the dry. Places are sometimes a problem if there is a lot of water, but usually we try to pump it away. It's the main railway station, so there is like a 5-minute interval for the trains and there are these trains are like these bridges are 10 meter one from another. All the time there is this train.

As usual we have only equipment, different excavator sizes, we have pumps, we have different pumps. We have production materials we have; we have different drilling rigs; we have different pile lengths. This is like we need to check equipment that we can use. We need to check the excavator equipment that can go inside. We need to check whether conditions, we need to check water and all the things. Usually, the best way is just to plan the work well. Like when you have plan, when you have seen the place, when you make good decisions and that’s the good result for good result like you need to the plan the work is the best and figure out, but we are still closed in different solutions that are on market we can't build a new machine. Work only with equipment that we need and that we can use or rent or hand.

Of course, there is this worker just clay that can it goes it's broken all the time like you can feel it many times but there is no space too much for taking big machines. It’s not they're big machines can’t drive in the big machines we can’t bring any crushed rocks. Like efficiently to displace it. I mean if you have any robot to install here at this pipe that could be tricky. Tricky solution of course, but like planning, planning, and planning and cooperation is the best way to have a good result. Build some portable welding module. For example, a container where the welding would take place and the model would be easy to. Install and stabilize in different kind of conditions.

<u>How do we get the other on-site welds (casing shoe, ring bit) on the steel pipe piles done before pipes delivery to site?</u>

The main part here is the timetable. Usually, we try to push it like a casing shoe ring bit welding is at the factory. If it's just a possible in if they got the time on the factory, but sometimes suddenly we have new works at it and we need to pass there as soon as possible They don't have a factory, might not have resources to weld those so fast, we have to take the piles without casing shoes or ring bits to the side and to the welding at the site. It's about planning. Like, what is the timetable of the project when we don't know where it is and how we can prepare for it?

From my point of view, I think last times for my last site it's better just to take this service from factories. There is a like we have only two pile suppliers in Finland right now. SSAB and with factories in Finland and then we have a Scandia steel like, and they use materials from around the Europe, Turkey and Italy and they based on Baltic countries. They have this kind of solution, and they have this kind of service. Regarding, this procedure on side because on site. Usually, you need space and I mean mostly there is not too much space on the side for rotating this pipe. Pipe pile standard length is 12 meters, and these shoes or ring bits drill bits are small but still you need to have a machine to rotate these pipes. You need to welder. You need electricity. You need to save and like a good foundation.

If it's an option, if it's like it's even safer regarding our situation. It's even safe to take this from factories. There is also the option to use like if there is bad schedule on factories with welding this, it's all. Firstly, could be delivered to some welding areas like welding companies. Welding companies can make this welding work. You just need to deliver first piles to this to this smaller welding company and then they do the job and then you have a second transportation on site it it's a little bit expensive but still it's the performance on site will be easier. Planning in advance is the most important one. Developing the cooperation with current suppliers, all they make everything as smooth as possible. Tackled the schedule issues. Also, probably one option would pay to find new suppliers and develop co-cooperation with them.

<u>How do we make the continuation welding site mobile? How do we get the pipe and welding materials close to the mobile continuation welding site?</u>

I think we need this machine. We need workers like when trucks. Pipe standard length is 12 meters and truck like something like 24 tons, I think they can transport in one track 25 tons of materials. Arrive on one track, so you need to unload the truck. You need to keep these materials on site and then wait. If we are talking about piling you the location is moves all the time because if we are making like house or hall or factory or peer there, is you need to that like the piles goes around on in line with the foundations of the building you need to have a rolled, you need to have an equipment for transportation these materials. It's the planning, the foreman, the crew, and the scheduling of work. Most of these questions are solved only with the planning and discussion with the main contractor or with the client or only with the team.

These containers can be transported from place to place if we have a big crane, we can use crane or if we don't have crane, we can order hiab on site. We use our excavator to move containers with materials in place and like it's for piling, we need excavator. Who left these piles for the drilling equipment machine for the drilling rig. Anyhow, we have excavators, but we need to think logistics. We need to think about roads and safety regarding. Make sure that we have everything next to our welding place. We can move to container. There we can have everything next to this place. I don't see this any kind of problem and we usually have when we are doing trading work, we have excavator there which can lift piles and all the materials which is needed the next to the pile location and all the welding materials are stored in the container. Close to the site like a close to the welding place. Container that would include all the necessary equipment and basically be that.

Welding place itself, it could be more whether excavators in cranes or trucks. Probably better planning is as important. An option to really calculate all needed welding materials and purchase it on side like in one order you got all your materials, all your needed materials on side. Probably sometimes it could help with just four men or welder, or we need. No need to call the supplier anymore and order something. If something like of the materials like I feel and on side, then we can just take it from our container we have everything we need on site spare parts like materials at that could be like this some kind of welding container with equipment and it's continuing need to be packed as 100%. What well there could be need there could be spare part that could be spare machine welding machine that could be different electrodes that could be different materials inside so it's probably helps except like yeah and also for working sites which situated far away from civilization like if we work some somewhere on the north or near to I don't know maybe in some close area it's hard to get any material on place so that that could be solution.

How can we reduce the overall continuation welding time and how can we get the continuation welding done faster, cheaper, and safer on construction site?

Usually, in bigger piles we add more welders for the welding, that way we can shorten the welding time and that will be like a the problem comes is it good to have to ask for welder at the site, that we can do the welding faster if he doesn't have more work like if we and if he's there only for the welding like this seam and it takes about like a couple of hours maybe and after that he doesn't have anything to do. They're come some money questions like is it efficient to have two welders at the side like a big pile? Alone welding to a big pile extension, it takes so long time that the boss from the machinery and all the other people on the crew is so much bigger that it must be like 2 welders next to the pile. Cheap as possible and safety.

Of course, we take the safety very well, like we think about all the safety stuff. Like we have a possible extent extension like fire extinguishers next to the welding place. If we have good roles on side if we have space for work if we have our pump are working and we have. From welders some container or some something that stops? They're mostly all of this will help. We'll have it many times, and it will be fast, easy, and good quality, but one of these is not. Solved on site then. Then we have a problem. There is not a problem to make a welding. The welding is itself. It's not a big deal. The preparation for the welding is that's the job on site and if you have everything, plant and if you have everything, every all materials near you then it will take. Take as much time as it really needed for good welding performance.

Something means then that's the problem starts and that's you. Unusually, Problem on construction site. That's something is missing, like whether is not checked or the roads good. Welder, there is not on place or there are not materials. We have the problem. Think there is cooperation planning and that will help with it, and this solves this problem. I think the most important thing is to have everything planned, right. Planning in advance and so that everything is. Ready at the site and can be done. Don't easily. Well, maybe one point. I'll do we increase the speed? I would be the. Maybe find some alternative welding processes or if there would be a way to increase the mechanization. Regarding the processes, In the future, laser welding? Maybe, but probably not now. Then of course submerged arc welding is. One options, but probably also see it wouldn't work here now at least.

<u>How can we prepare for the welding of large steel pipe piles and for welding the wall thicknesses of thick steel pipe piles in future?</u>

The first thing what comes to my mind is that we need more welders at the site. I think we are having like a it takes so long time when the pile thickness is getting bigger and bigger. We have a more seem to weld so fast option. I would say that, OK, we need more welders, and I don't know like. I think there is a need for standards. Need to be. I welding coordination there needs to be planned. But I think welding as a profession, I think it's important and it will not. It will not leave us all, so we need to train more workers and we need to plan jobs. We need to develop equipment, we need to develop, develop the whole industry. I think that's a solution, just doing a good job every day will help. I'm kind of new to procedures. We'll be developed. Developed for this. Or this welding then? It should be thought in any such way that all possible sizes are considered.

<u>How will we get hired professional welders to do continuation welding and what is the welding need on construction site in the future?</u>

I didn't care, and for now it has been a problem for us to get like a Finnish guy for the side as welders. There aren’t so many. The good welders are already working somewhere. Commonly we are trying to get people from Estonia somewhere in the Europe that. Well, that's one possible solution and I think in future I hope the welding. Welds are not needed so much that we have professional welders that are fast, and they are good at their work so we can possibly have a less welders at the site in future.

I have four points. First would be competitive wages and working conditions to attract the existing professional welders from other companies and other industries maybe. The second one would be racing the young students who are in the with the working summer jobs and raising them. I'm mentoring them as professionals for the future. And another point is cooperation with occupational Institutions. Maybe other educational institutions to find young talent. The last one would be the use of a foreign workforce. Sometimes problems in our piling industry really depend on possible works.

Future works, we would like to keep like needed a quantity of workers. But if we don't have any work for them, it's a problem for doing business, because if they are all cited on our hall, then it could be the problem. But I think we need to, we need to find talented, talented people. I am interested in this profession and give them options and possibility to grew up to possibility to have a good salary possibility to work in good company and safe company and we need to give them an interesting work. I think it's the normal human resources work and like my cooperation, I think it's the, it's the interesting profession and it will there will be work on it.

<u>How can levels of the quality and inspections to continuation welding for steel pipe piles be increased between different companies?</u>

I think there is like right now there is a thank you for each company have own welding like plan or welding. I procedure we. Which are accepted by some welding coordinator or some specialist, but I think there is also a law and there are a manufacturer standard and advises how this continuation needs to be performed. I think if we were speaking about company, I think we need to like to be professionals in what we are doing, we need to understand the quality standards.

I think it's good to start and probably for example for our piling, I think for us it could be really important to train our foreman’s and maybe our welders put them together and just like right now I see it will be really good to just sit, sit down and have one day of some welding course for example to check the details to have some visitors with and that that could be performed like after each big site or that could be performed 1 yearly because we have a lot of welding, we have a lot of welders, we have a lot of equipment and then we can all the time grew up with our with our knowledge and with our professional skills let's say.

We have NTD and the inspection for the piles depends on. I think class and I it's a like we have is it like a 10 to 15% of the welds has to be checked. On the side, the quality is good, and I think that's a good solution. So, like a company. Who is checking these welds and it's not only like a welding company which is doing the welding. They are, of course, inspecting to see what they weld, but we also have a different company which checks and reports the results of the welds. Of course, the main thing is the training of employees. One thing how to. The increase maybe the level of he expects us would be to. Also, here would be to have for example, use machine learning in NDT inspections which is nowadays possible. In the future, more. Maybe it's too early for this now, but maybe later.

We need to have some kind of structure, structured way how to look at them. Welding and you know and NDT, me and how everything can be done according to the. Law and law and standards and so on. And I think the most reasonable way to do this would be to take some sort of welding quality management system. To use in this case would be ISO 3834 to and work according to that. I think it's a good idea. I think we have. We have it, but I think that like what I like so on site, and I think there is a like we need to have our formats, our side personal all to the same level. I mean that we need to that's that could be important to get like a training with and of course possible developments and possible materials, new materials like that that will really help for to get to get everybody to the same level. There are some people now. Some people are most experienced, some people are less experienced, but like this. With this we can like a like couple times in year we can like a little bit develop our knowledge and skills together that that will be good solution.

The second round of Delphi interviews was also analysed using a thematic method. After the thematic analysis, future arguments were developed from the future themes. The results of the thematic analysis of the second round of Delphi interviews are presented in Table 8.

Table 8. Second Delphi round thematic analysis.

CLASSIFICATION OF THEMES		
PAST	NOW	FUTURE
• The excavator removes the poor soil that comes next to the pile. • Welding place problem is water and try pump away. • We have equipment, different excavator and pumps. • Equipment on hand. • Factory, might not have resources to other site welds so fast.	• Need cover, block, better condition, like raining and wind, fire resistant cover material and temperature. • Problem the base and base soil material water is hard pump away. • Cover prepare need time and wind and rained won't have effect. • Preheating when temperature is below 0 C. • Excavator to removes poor soil which comes next to the pile. • Teamwork, good roles, planning work well and right, co-operation. • Plan->See place->good decisions -> good results. • Increase MH, AM, and RB problem is clean and stable conditions. • MH, AM, RB hard industry profitable and show good performance. • How would like install this robot on the pile because the pile location is changing? • City center, we have like an electricity and remote use generators couple of meters from the from the machine. • Lots of traffic could be near the site. • Need to check equipment, machines and weather conditions. • Equipment on hand and rent. • Not too much space on construction site. • Main part is the timetable other on-site welds. • Casing shoe and bit ring weld on factory if factory is time. • What is the timetable of the project when we don't know where it and how we can prepare for it? • Two pile supplier in Finland which offer other weld services. Welds are good quality, easier, safety and performance. • Casing shoe and ring bit welds on site need space, machine, welders, time and electricity. • Need two delivery if want utilize subcontractor to welding other site welds. Need trucks or excavator or crane move pipe materials on site. • Pipe standard length 12 m and one track in 25 t materials. • Most of these questions solves discussion with main contractor or client or team. • Material and welding equipment need to be next continuation weld place. (Container) • Bigger pile more welders. • Safety aspect very well and Every time try push to cheaper option. • Continuation weld is not problem. Problem is welding preparation. • Welder, there is not on place or there is not materials. Follow problem. • Large diameter and thickness of pipe. Need more welders. • Problem is Finnish welders not available. Try welders from Europe. • Each company have own welding like plan. Accepted welding coordinator also a law and there is a manufacturer standards and advises how this continuation needs to be performed. • NTD and the inspections for the (Count: between 10-15% of continuation welding of piles) • Already some kind of format (WQM	• Different conditions on site. • Plan work, teamwork, scheduling, material movements • Faster filling weld seam MH, AM and RB. • Do we need a motion automatization or robotization for jobs like this? • Can spend time to adjust this robot on place and clean place • In good conditions, the robot performs the welding faster • Future applications for robot in drilling rig technology. Connected to the machine and do all work automatically. • Small robot that need to be installed on place with the workers. • In future when robots are a smaller, light, and easier to install. • Robot useful maybe biggest sites. • At the time to set up/install robot cannot longer than continuation welding • Will be some sort of development where robot will be viable. (Gobots). Somewhere between manual welder and full-scale robot. • MH at this point could pay the most. Most viable way to proceed? • No space to install MH, AM, Rb around of at this pipe. • Build some portable welding module. • a container where the welding would take place and the model would be easy to install and stabilize in different option. • Developing the cooperation with current and new suppliers (other site welds) • Roads need check material transportation plan. • Calculated welding materials and needed spare part put all equipment on container. • Welding materials and spare ready calculated on container and moved this near to next welding place. • Increase welding speed alternative welding process. Laser welding or submerged arc. • Increase mechanization. • Welding coordinator, need to train more workers and we need to plan jobs. • Develop equipment, welding procedure, and materials. • Need more professional welders which are fast and their good work. We can have a less welders at the site. • Competitive wages and working conditions to attract the existing professional welders from other companies, racing the young students in summer jobs, cooperation with educational institutional and foreign workforce. • Would like to keep like needed a quantity of workers. • Need talented welders, good working conditions and benefits. • Understand the quality standards. • Train employees (crew, foreman, and welders). • Train continuation knowledge of welds inspection. Machine learning in NDT inspections. Structure welding and NDT, me and how everything can be done according to the law and standard. • Welding quality management system (ISO 3834) • People experience same level.

In the second round of Delphi interviews, the experts saw the different conditions in the continuation welding of the construction site, the design of the continuation welding work and the delivery of steel pipe piles to the construction site on time as the future development points of the theming analysis. Mechanization, automatization and robotization can add a faster welding speed, but do they require more time to set up on the job site than the current manual continuation welding method. A continuation welding robot could be a part of a drilling machine in the future and what could be the most effective solution at a continuation welding site. In the future, robots will be easier and faster to install on the construction site. The biggest benefit of a continuous welding robot on large construction sites, portable welding module inside container. Calculation of welding material and confirmation of construction site roads in terms of material delivery. A more efficient welding process is laser welding and submerged arc welding. Welding coordinator to plan and implement development proposals. Development of steel pipe piles, materials, and welding equipment. More skilled welders. For advanced continuation welding foreign workforce, cooperation with educational institutions and training young experts. Better understanding of the quality standard for continuation welding. Machine learning in continuation welding inspections. Getting on the same level with the advanced welders working on the site and other site personnel.

6.5 Future arguments

After the Delphi second round, experts answered future arguments true or false. These future arguments are used to create a future table of the answers. From the future table, future scenarios are drawn up based on the experts' answers. Based on the Delphi interview rounds and the thematic analysis, the issues in the future timetable are set as future scenarios. The future arguments are answered independently by each expert. The future arguments are the points of future development raised by the experts in the interviews. (Kuusi, Bergman and Salminen, 2013, p. 144.)

There were sixteen future arguments. Based on the answers to the future arguments, a future table is created. The statements of the future arguments are based on the second round Delphi interview. The number of responses to the future arguments is presented as a percentage. In future arguments presented in Table 9 and number of responses is presented as a percentage. Future arguments confirm whether experts really agree or disagree about future development targets.

Table 9. Experts answer for future arguments.

NO.	QUESTION	TRUE	FALSE
1	Automation, mechanization and robotization will be used more the continuation welding of steel pipe piles at the construction site in future.	67 %	33 %
2	The weather conditions at the construction site will continue to affect the quality and execution of the future continuation welding.	100 %	0 %
3	Is possible to reduce the total welding time of continuation welding of steel pipe piles by means of welding preparation, more speed welding, with the welding method that best suits the weather conditions, and training of welders.	100 %	0 %
4	The need for dry conditions, flat area and electricity for the continuation welding site can be ensured in the future by determining the requirements for the continuation welding site on construction site.	100 %	0 %
5	Professional welders can be better hired to continuation welding tasks on the construction site, when the continuation welding get easier utilizes mechanization, automation and robotization.	67 %	33 %
6	The quality of continuation welding and inspection activities can be improved by training the welders, and the inspection activities at the construction site by preparing internal instructions for future welding.	100 %	0 %
7	In the future, the welding of the casing shoe and the welding bevel of the steel pipe pile can always be done before the delivery of the steel pipe pile to the site.	33 %	67 %
8	Can prepare for the welding of large steel pipe piles and for welding the wall thicknesses of thick steel pipe pile.	100 %	0 %

Table 9 continues. Experts answer for future arguments.

NO.	QUESTION	TRUE	FALSE
9	The risk of being a bottleneck in continuation welding can be reduced by determining the requirements of the continuation welding on construction site, bringing pipe and welding materials close and protecting continuation welding from the weather.	100 %	0 %
10	The right conditions for continuation welding, timely inspections of continuation welding and the right welding method reduce time loss and quality errors in piling work.	100 %	0 %
11	The automation, robotization and mechanization equipment for continuation welding must be easy to install on construction site or be attached to the drilling or excavation equipment.	100 %	0 %
12	Teamwork (welders, supervisors, other subcontractors + suppliers) is key role to the success of continuation welding on construction site.	100 %	0 %
13	Collaboration between educational institution can enable new professional welders to be recruited for continuation welding work on construction site	100 %	0 %
14	Weld shields can be used to reduce the quality of the subsequent weld and the impact of weather conditions on the weld.	100 %	0 %
15	The welding site on site is made flat by a machine (excavator) and electricity is brought to the welding site by generators or directly from the power unit/line.	100 %	0 %
16	A mobile welding place is made possible through cooperation with the supplier and the machine operator, Pre-calculations of count for welding and pipe materials, and a secure welding site.	100 %	0 %

6.6 Future table

The futures table method can be used to identify different future scenarios. The futures table has been chosen for this study to help visualise the future and create a picture of the future. The sectors of the futures table have been selected as the most relevant for the research problem and the arguments for the future. The second column of the table first shows the current situation, followed by four columns with four possible futures. The future table shows the future that emerges from the experts' responses in the form of a dashed line. The future table is presented in Table 10. (Kuusi, Bergman and Salminen, 2013, p. 137–144.)

Table 10. Future table with scenarios (Kuusi, Bergman and Salminen, 2013, p. 144).

Sectors	Current status	A	B	C	D
Other on site welds	Carried out in the factory and on the site	Always welded at the factory	Welding on construction site and in the factory	Developing the cooperation with current and new suppliers	Only welding construction site
Automation, mechanization and robotization	Very limited use rather than full implementation	No deployment	Use in part	Used on large constrcution sites	Adopted for robot in drilling rig technology. Connected to the machine and do all work automatically. Extra hand or Cobots.
Affects of weather conditions on further welding	Effects of weather conditions cannot be fully prevented	Cover, plate and fire resistant tent	Robotization, automatization or mechanization	weather conditions continue to affect continuation welding	Alternative welding process laser or
Dry conditions, flat area and electricity	Dry conditions not always possible, electricity can be obtained from compressor or directly from the power grid, flat ground partly	Defining the equipment to be used on site and planning the power supply and flat area.	Planning to work and check equipmnets	Water pump away	
Professional welders	There are currently no welders available in your country.	Foreign workers	Raising young student	Competitive wages and working conditions to attract the existing professional welders from other companies	Co-operation with educational institutional
The quality of continuation welding and inspection activities	NTD Inspection carried out by an external inspector welding quality at an adequate level	Machine learning inspection	Training employee for inspection	Quality standard (welding quality management system and ISO 3834)	People experience same level and co-operation. Welding coodinator.
Steel pipe piles continuation welding for construction site	Steel pipe piles are continuation welded vertically and horizontally.	Increasing the welding speed	Continuation weld preliminary preprations	Decrease total welding time	Training welders.
Mobile continuation welding place	Container is currently partly used to transport welding materials and equipment. container is moved by an excavator	Calculated welding materials and needed spare part put all equipments on container.	Cooperation with the supplier	truck, crane or excavator is used for move materials.	Road must be chech and plan for material delivery.
The risk of being a bottleneck in continuation welding	Materials and welders are, as a rule, close to the welding site.	Welders must be scheduled to arrive on time and materials must be as well prepared as possible for welding.	Material close by welding place	protection and prefabrication of the welding operation	
Steel pipe piles with large diameter and wall thickness	More welders	Need talented welders, good working conditions and benefits	Longer welding time with existing welders or more welders at potentially higher cost	Development welding equipment and welding process	

6.7 Future scenarios

The futures Table 10 has generated three different future scenarios: blue, red, and green. Each future scenario is presented below.

In the future 1 (blue) other welds (ring bit and casing shoe) will always be done at the factory by the supplier. Automation, mechanisation and robotisation will only be used on the largest sites. The impact of weather conditions on further welding will be prevented and reduced using welding shelters and tents. Dry conditions will be made possible by the development of on-site equipment, a flatbed will be made for the excavator and the power for welding will be generated by a compressor or taken directly from the power line in urban areas. Skilled welders for further welding will be provided by foreign labour. The quality and inspection of the submerged arc welding will be improved on site by developing the welders' skills in submerged arc welding inspection. In the future, efforts will be made to reduce the total welding time for the continuation welding process. A mobile welding site will be made possible by a truck, crane, and excavator to bring materials close to the continuation welding site. Avoiding bottlenecks in the post-weld process will be achieved by planning the preparations for welding and the arrival of welders at the welding site. Welding of steel pipe piles with larger diameters and wall thicknesses is prepared for by longer welding times or more welders, which can increase costs.

In the future 2 (red) other on-site welds (ring bit and casing shoe) will be done in the factory at the supplier's site and on site. Automation, mechanisation and robotisation of welding will not be introduced on construction site. Weather conditions will continue to affect further welding on site. Dry conditions will be made possible by the development of equipment for use on site, a flatbed will be made for the excavator and the power for welding will be generated by a compressor or taken directly from the power line in urban areas. In the future, skilled welders will be attracted to sites through increased cooperation with educational institutions. The quality of welding on construction sites will be improved in the future through joint training of people to ensure that everyone is at the same level. The efforts of the current welding coordinator will also play a key role in improving the quality and inspections of welding on the sites. In the case of progressive welding, attention will be paid to the preparatory measures for welding before the actual welding is carried out. A mobile post-welding site is ensured using site roads. The welding process is prevented from being a bottleneck by protecting the welding from the weather and by pre-welding preparations. Welding of steel pipe piles with larger diameters and wall thicknesses will be prepared for in the future by developing welding equipment and processes.

In the future 3 (green) other welds (ring bit and casing shoe) will in the future be done in the factory by the supplier and on construction site. Automation, mechanisation and robotisation will be adopted in drilling technology and will be directly linked to the drilling equipment, which will do all the work automatically. The drilling rig can be equipped with a fixed attachment or cobots. The influence of weather conditions on the downstream welding is reduced by an alternative welding process laser welding or submerged arc. Dry conditions are made possible at the continuation welding site by pumping water out of the site. Professional welders are obtained for the post-welding tasks by raising young summer trainees to become professionals. The future quality of welding and inspections on site will be managed by machine learning. In the future, the rate of welding will be increased. A mobile welding site will be made possible in a container, where welding material and spare parts will be loaded ready for use. In the future, welding will be prevented from being a bottleneck on site by bringing the materials to be welded close to the welding location. The welding of steel pipe piles with larger diameters and wall thicknesses will be prepared for in the future by increasing the number of skilled welders and by providing good working conditions and employment benefits.

During the future development process, the direction of the future was monitored. The Delphi interview goal setting served as a chain of reasoning linking the future scenarios. Three sets of scenarios were created to ensure that the scenarios were sufficiently comprehensive, that the scenarios could be used and that the scenarios could be linked to existing knowledge. (Sneck 2002, p.85)

For the future, the analysis of the future and the present was used as shown in Figure 27. In the table, the direction of progress is represented by a state of creation and a state of ambition, which aim to identify the means and means to achieve the objectives. In the table, the aim is to guide future developments by the impact of phenomena and the factors that cause them. In this study, the creative action is a literature review, and the goal mode is achieved through a Delphi interview. In this study, the development is guided by the questions of the Delphi interview and the future state is achieved by future scenarios. (Sneck 2002, p. 85–86.)

Figure 27. Future analysis (Sneck 2002, p.85).

Tarkastelun etenemissuunta / Kehityksen ohjattavuus	Luotaava	Tavoitteellinen
Kehitys ohjattavissa	Tarkastellaan mitä tavoitteita eri välineillä voidaan saavuttaa	Kehitetään tarkoituksenmukaiset keinot haluttujen tavoitteiden saavuttamiseksi
Kehitys on satunnaista, sitä on mahdotonta ohjata	Tutkitaan erilaisten ilmiöiden vaikutuksia	Arvioidaan mahdollisia vaikutuksia ja päätellään, mitkä ilmiöt voivat olla niiden aiheuttajia

7 Results

As a result of the research, a knowledge base has been obtained, where the continuation welding on the site is currently going, and the knowledge base also provides information on what are the instructions and what are the requirements for continuation welding steel pipe piling. The results of the research corresponded to the research questions and from the results obtained three levels of proposed measures. The proposed measures are linked to the research questions of the study and in a wider perspective they mean actions that the customer can utilize in the future on the construction site in the continuation welding of steel pipe piles.

Previous research has focused more on continuation welding equipment and studying the mechanical properties of the continuation weld. In terms of continuation welding equipment, the results correspond to previous research, but a completely similar study of continuation welding performed on a construction site has not been done before, so a comparison of their results has been made with continuation welding in factory conditions.

As a scientific contribution, new information has been produced about the continuation welding of steel pipe piles on the construction site. A concrete application has been three levels of proposed measures are easy-to-implement measures, measures to be implemented within a year and longer-term measures. The general result is that other construction sites that perform continuation welding of steel pipe piles will continue to take advantage of future continuation welding needs.

Easy-to-implement actions:

Updating WPS to match all materials and wall thicknesses of steel pipe piles for continuation welding. The introduction of a welding shield/tent on the vertical welded steel tube pile to stabilize the welding conditions. All casing shoes and ring bits for new projects are welded by the supplier of the steel pipe piles before they are taken to the construction site. Invest in weld preparation for the continuation welding so that the welder does not have to interrupt the continuation weld and leave the continuation weld site during the welding operation. Investing in the planning of the continuation welding operation, as the continuation welding is the neck of the bottle in the piling operation and should be carried out as smoothly as possible. The planning of the continuation welding operation should take into account the condition of the construction site roads, the availability of steel pipe piling material close to the continuation welding site, sufficient equipment for moving the steel pipe piles (excavator, crane), the availability of electricity for the welding equipment, a dry and flat surface for the continuation welding site and sufficient welding personnel and timely attendance to ensure a smooth continuation welding operation.

Feasible actions in one year's time:

Increasing cooperation with education institutional to train new welders, as there are not enough skilled welders available on the market. Increasing the use of foreign labour for continuation welding. Raising our own young students into skilled welders. Skilled welders to prepare for the continuation welding of large and thick-walled steel pipe piles. Calculate the need for welding materials and spare parts for continuation welding and plan them for new construction sites. The target situation for new construction sites starting up would be to have a container of welding materials, spare parts, and welding equipment ready for use, rather than each site having to do the job over and over again. Organize a training session once a year with the continuation welders and construction site personnel to enable them to update their knowledge to the same level.

Longer time actions:

More efficient continuation welding methods, laser welding and submerged arc welding, will be introduced, thus increasing the welding speed, and reducing the total welding time. Piloting automation, mechanization or robotization equipment on the largest construction sites. Let's add machine learning to continuation welding in inspections and thus improve welding quality. A new welding coordinator will be added to implement new action proposals and improve the quality of the inspection of continuation welding.

8 Discussion

The key findings are the three-level action proposals for follow-up welding on the site in the future. The novelty value of the results obtained in the research can be considered the requirements for the welding place of the continuation welding performed on the construction site, the welding performed in advance and the preliminary preparation for the steel pipe piles before they are delivered to the construction site, and actions that can be taken to prevent the piling work from being interrupted. Compared to other studies, this study provides more information about the continuation welding of steel pipe piles performed on the construction site, while previous information has been limited to continuation welding performed in the factory or under factory conditions.

When looking at objectivity, by implementing the three-level action proposals in the future, disturbances at the steel pipe piling site will probably decrease, and more steel pipe piles can be drilled in one day than before. By improving the continuation welding place on the construction site and assigning the supplier of the steel pipe piles to perform the welding of the steel pipe piles, the total welding time on the construction site can be reduced and enable fewer disturbances in the piling work of the steel pipe piles.

The research was qualitative and quantitative, and it measured the total time of continuation welding of a steel pipe pile on the construction site and calculated the total welding time of a similar steel pipe pile. The calculated time of the total welding time of the steel pipe pile was marked in the form of minutes and seconds, and the results were accurate to two decimal places. A small panel of experts was used in the Delphi interview because the research plan estimated that it would be qualitatively sufficient for future research. Regarding the Delphi interview, there were also differences in the results of the interview and the experts predicted the future from their own perspectives and did not focus too much on seeking a common opinion. Based on the data collected in the study, observations and conclusions can be made about future welding of steel pipe piles at the construction site.

9 Conclusion

Easy-to-implement measures, measures to be implemented within a year and longer-term measures are connected to research questions. Easy-to-implement actions can reduce interruption in continuation welding and speed up the drilling of steel pipe piles, because the casing shoe welding and ring bit are already done beforehand. This also enables the welders on the job site to spend more time preparing for continuation welding and it reduces the bottleneck of continuation welding, because the welds can be performed quickly and with good quality thanks to the continuation welding preparation.

The measures in a year's time will enable a faster introduction of welding places on new construction sites, because based on the research, it has been found which measures enable an efficient continuation welding places and the requirements for the welding place, and the equipment has been determined in advance. Longer-term action proposals provide the customer with information and planning on how the continuation welding process of steel pipe piles can be developed faster and with higher quality in the future.

The conclusion can also be a survey of the knowledge base and the current state of the continuation welding of steel pipe piles on the construction site. The knowledge base can be used in the development of future continuation welding of steel pipe piles and in the preparation of new welding sites and steel pipe piles on the construction site. Futures research has also made it possible for experts to collect tacit information for research and thereby find future development targets, as well as to make tacit information available to others as well.

1. How can improve to welding place in the construction site?

A welding shield/tent on the vertical welded steel pipe pile to stabilize the welding conditions, invest to weld preparation and planning for the continuation welding, steel pipe pile material close to welding place. Utilize efficient welding methods laser and submerged welding. The availability of electricity for the welding equipment, a dry and flat surface for the continuation welding and calculation welding materials and spare parts container.

2. What preliminary preparation can be done before the steel pipe piles are delivered to the construction site?

All casing shoes and ring bits for new projects are welded by the supplier of the steel pipe piles before they are taken to the construction site. Plan the construction site roads and machines available to move pipe steel pipes.

3. What problems follow from the interruption of piling work?

As the continuation welding is the neck of the bottle in the drilling process cause delay for construction site schedule. When welders are not in the continuation welding place at the right time, the drill bit can become clogged. The piling process is interrupted if continuation welding is not completed on time or continuation welding defects must be re-welded or fixed.

The future research targets are the utilization of automation, mechanization and robotization of the continuation welding of steel pipe piles on larger construction sites and the study of machine learning in the inspection of the continuation welding of steel pipe piles.

10 Summary

In summary of the research, it can be said that the continuation welding of steel pipe piles at the construction site is still a little researched topic, and, in the future, it should be studied more. Piling and continuation welding of steel pipe piles is still much to develop and research in the practices of the construction site. This research has been interesting for the author, because he has been able to familiarize himself with a significant topic, which has been little researched, and the results of the research can be useful for the customer in the future.

In the research solutions to the research problem and research questions were found. These proposed solutions enable the development of continuation welding of steel pipe piles at the construction site, and through research it has been possible to bring new information about continuation welding. As a summary of the research, the knowledge base of the continuation welding of steel pipe piles and the proposals for future measures have been collected. The total welding time of continuation welding of steel pipe piles has also been measured in the research in measurements made at the construction site and calculated total welding times.

With the help of the research methods and the expert panel, sufficient information has been obtained about the current welding of steel pipe piles at the construction site and new information that can be used in the continuation in the welding of steel pipe piles. The research has achieved the goals set for it and future research topics have been found for studying the continuation welding of steel pipe piles at the construction site.

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Appendix 1. Questionnaire from futures arguments.

NO.	QUESTION	TRUE	FALSE
1	Tulevaisuudessa automaatioa, mekanisointia ja robotisaatiota tullaan käyttämään enemmän työmaalla tehtävässä jatkothisauskessa.	☐	☐
2	Sääolosuhteet työmaalla vaikuttavat jatkossakin teräsputkipaalujen jatkohitsauksen laatuun ja toteutukseen	☐	☐
3	Teräsputkipaalujen kokonaishitsausaikaa on mahdollista vähentää hitsauksen esivalmisteluilla, hitsausnopeuden lisäämisellä, olosuhteisiin parhaiten sopivalla hitsausmetodilla ja hitsaajien koulutuksen avulla.	☐	☐
4	Kuivien olosuhteiden, tasaisen alueen ja sähkön toteutuminen jatkohitsauspaikalla voidaan varmistaa tulevaisuudessa määrittämällä jatkohitsauspaikkaa koskevat vaatimukset rakennustyömaalla ja kalustoresurssit (kaivinkone, nosturi)	☐	☐
5	Ammattitaitoisia hitsaajia saadaan paremmin palkattua jatkohitsaustehtäviin rakennustyömaalla, kun jatkohitsausta helpotetaan hyödyntämällä mekanisointia, automaatiota ja robotisaatiota	☐	☐
6	Jatkoshitsauksen ja sen tarkastuksen laatua voidaan parantaa työmaalla kouluttamalla hitsaajia, ja hyödyntämällä laatustandardeja (ISO 3834) sekä lisäämällä koneoppimista hitsaustarkastuksiin tulevaisuuden hitsauksissa	☐	☐
7	Tulevaisuudessa maakengän hitsaaminen ja teräsputkipaalun hitsausviiste voidaan aina tehdä ennen teräsputkipaalun toimittamista työmaalle.	☐	☐
8	Halkaisijaltaan ja seinäpaksuudelta suurien teräsputkipaalujen hitsaamisen voidaan tulevaisuudessa valmistautua ammattitaitoisten hitsaajien avulla ja kehittämällä hitsausvälineitä sekä hitsausprosessia.	☐	☐

9	Teräsputkipaalujen jatkoshitsauksen pullonkaulana olemisen riskiä työmaalla voidaan pienentää määrittämällä jatkohitsauspaikan vaatimukset, tuomalla teräsputkipaalu- ja hitsausmateriaalit lähelle ja suojaamalla jatkoshitsauspaikka säältä.	☐	☐
10	Oikeat olosuhteet jatkoshitsauksessa, oikean aikaiset jatkoshitsauksen tarkastukset ja oikea hitsausmetodi vähentävät aikahävikkiä ja laatuvirheitä paalutyössä.	☐	☐
11	Jatkoshitsauksen automatisoinnin, robotisoinnin ja mekanisointilaitteiden tulee olla helposti asennettavia työmaalla tai niiden tulee olla kiinni poraus- tai kaivinkonekalustossa.	☐	☐
12	Työmaalla tehtävän jatkohitsaamisen onnistumisen avaintekijänä työryhmän yhteistyö (hitsaajat, työnjohto, muut alihankkijat + toimittajat)	☐	☐
13	Oppilaitosyhteistyöllä voidaan mahdollistaa uusien ammattihitsaajien saaminen jatkoshitsauksen tehtäviin työmaalle.	☐	☐
14	Jatkoshitsauksen laatua ja sääolosuhteiden vaikutusta hitsaukseen voidaan pienentää hitsausuojilla.	☐	☐
15	Hitsauspaikasta työmaalla saadaan tasainen työkoneella (kaivinkone) ja sähkö saadaan tuotua hitsauspaikalle generaattoreilla tai suoraan voimayksiköstä/-linjasta.	☐	☐
16	Liikkuva jatkoshitsauspaikka mahdollistetaan yhteistyöllä tavaran toimittajan ja työkoneen kuljettajan kanssa, hitsaus- ja putkimateriaalien ennakkoon laskemisella sekä suojatulla hitsauspaikalla.	☐	☐