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Packaging and Shipping Guidelines

Heavy duty products

Zaki Issa

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Jyväskylän ammattikorkeakoulu
JAMK University of Applied Sciences

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Abstract

The aim of the study was to develop packaging instructions. Packaging guidelines must be designed in a way that it will be easy for the packager to follow the given instructions. This study investigated packaging material requirements and specified the packaging methods that must be implemented on the packaging instruction.

The key objective of the research was to combine the packaging and shipping process guidelines for different types of products. The aim was to avoid damage on the packaged goods during storing, handling and transporting.

The research method in this study was mainly based on the EU standards requirement for wooden materials used in the packaging industry and on the Eurocode 5 for wooden materials used in the construction industry. In addition, the existing data for packaging requirements, particularly for heavy duty products, which were also based on the EU and Eurocode 5 standards were applied in this research

The study managed to develop and specify wooden materials that can be used in packaging. Moreover, it proposed methods for securing the packaged goods at the bottom of the cases, crates or pallets and securing equipment. It also conducted experiments in the JAMK Logistics Laboratory to assure that the wooden materials and securing methods were reliable.

From the packaging requirement perspective, the study reached a successful outcome, but the challenging part was to investigate the mechanical and physical properties of wood. However, it has been approached the thesis results based on the experimental investigation of wooden material in which implemented into the packaging instruction.

Keywords/tags (subjects)
packing, packaging and shipping instruction, packing requirement, packaging guidelines

Miscellaneous (Confidential information)

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1 Introduction

1.1 Research purpose and questions

The aim of this study was to develop packaging instruction for the case company. The idea was implementing packing methods that would well-functioning and instructional for the company and their contract manufacturer. This study investigated the packaging requirements for heavy duty packaging. Hence, the packaging guidelines had to be specified and developed in way that the packaged goods would be safe to store, handle, and most importantly, resist hazards during the shipping processes regardless of the mode of transportation.

Sammet Dampers Oy's production is outsourced to several contract manufacturers. Furthermore, the company is aiming to outsource its warehousing and distribution services to third-party logistics providers. The third-party logistics providers concentrate on warehousing materials.

The company has outsourced the commercial components to a 3PL provider. The 3PL provider's responsibility is to manage the goods in the warehouse, i.e. receiving, storing, picking, packing and shipping them. In this section, warehouse processing is divided into two areas. The first part is to concentrate on packing instructions and the packaging-shipment process, which is the main objective. The other part is to go through briefly the warehousing process, in other words, receiving, put-away, storing, picking, shipping and inventory of the materials. In addition, this would include proposing location labeling and technology used in the warehouse.

The company has also outsourced manufacturing to a contract manufacturer. The contract manufacturer handles the manufacturing process for the company in order to meet the customers' demands. Thus, the final production is variable, which has an impact on the packing design and shipping processes.

The objective of this study was to combine the concept of packaging and shipping guidelines for Sammet and examine how to implement the packaging instructions for the contract manufacturer. Therefore, the packaging materials should facilitate all

transportation models that provide an efficient handling of products in the packaging and shipping process.

To do so, the main research questions were formed in terms of how to procede in the study.

1. What are Sammet's requirements and constraints in developing the implementation of the packaging instructions?
2. Does the company business utilize the implementation of the packaging guidelines?
3. How should different modes of transport be considered in the packaging design?

1.2 Limitation

As the main theme in the study was to concentrate on packing and shipping requirements and conduct a feasibility study of packaging materials, this study did not investigate thoroughly the target company's business operations and its warehouse operations. In addition, wooden material is used in the packaging industry, but this study did not focus deeply on the mechanical properties of wood. Thus, the aim was rather to focus on developing the required instructions for the packaging methods of the company. Furthermore, a model (including documentation) of the shipment of a selected item was planned, created and tested.

1.3 Company background

Sammet Dampers, founded in 1984, is an industrial damper developer and supplier in Northern Europe. Sammet specializes in isolating and controlling dampers, which are designed for heavy industrial use. The two main functions of industrial dampers are isolating and controlling gas flow. Sammet manufactures many different types of dampers for both functions. In addition, the company offers complete damper renewal services that include damper renewal plans, project management, manufacturing, field work on site and installation services. Furthermore, the company helps out with damper modernizing projects or simply provides spare parts. (Company - Sammet Dampers, n.d.)

Sammet Dampers provide for power and energy plants, waste burning plants, flue gas clean-up systems, ventilation systems, which are their target market, by enhancing the product development in the early stage, which could result in a beneficial outcome for both parties. However, Sammet Dampers manufacture different types of dampers, which are tailored according to the customer demand. As shown in Figure 1 and mentioned earlier, the company's approach to their target group is to deliver products efficiently and utilize customer feedback.

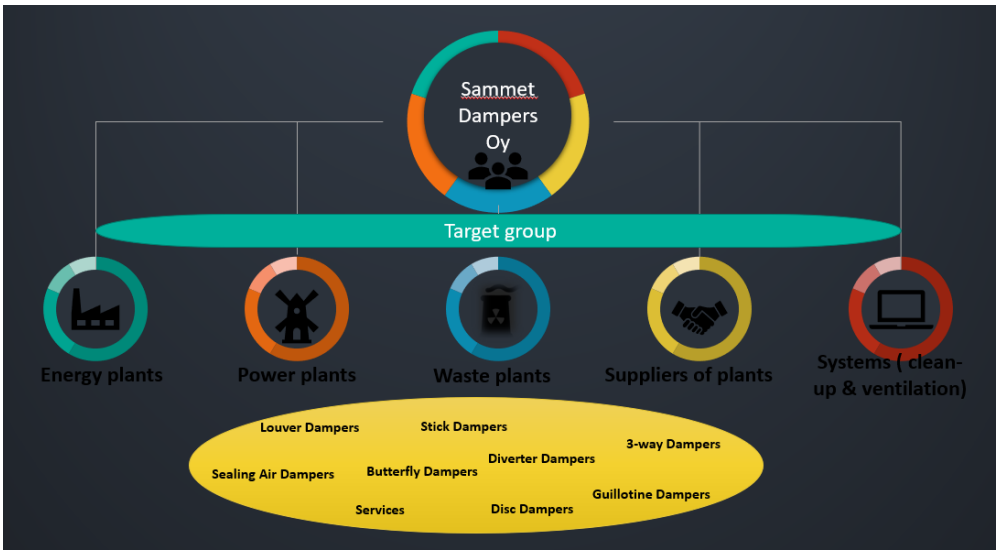


Figure 1. Sammet Dampers business idea.

According to asiakastieto.fi, the company's revenue in 2018 was 5.3 € million and in 2017 it was 7.6 € million. Since 2013 until to now the company's staff average number has been 13.

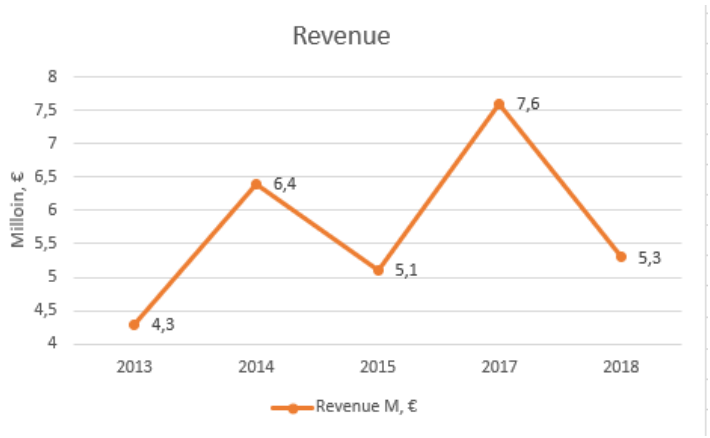


Figure 2. Sammet Dampers Oy Revenue since 2013. (Sammet Dampers Oy taloustiedot, n.d.)

1.4 Research methods

A research method is a manner of approaching the research subject, and the methods are often divided into two categories, such as quantitative and qualitative research. Thus, choosing the appropriate method depends on the type of research according to the purpose of the study. However, the main target of the research method is to support the study. (Introduction to quantitative research 2010.)

1.4.1 Quantitative research

Quantitative research defines statistics and generates numerical information by gathering quantifiable data. A systematic investigation collects data from existing information which could be later illustrated by using graphics and tables. Thus, quantitative research sets boundaries to the study by explaining and representing samples and phenomena based on data and seeking answers to *What? Where? How much? How often?* (Heikkilä 2009, 16-17.)

However, quantitative research analyzes the link between two different variables within a population. Quantitative research recognizes the value of numbers by yielding precise measurements as well as yielding measures and data compatible with a statistical analysis. Hence, the quantitative research methods are either descriptive or experimental. (Organizing Your Social Sciences Research Paper: Quantitative Methods 2018.)

Descriptive research seeks answers to, for example to *what, who, what kind, where and when.* Additionally, it usually relates partly to research that has been conducted before. Descriptive research demands extensive data in order to be reliable and deliver accurate results. (Organizing Your Social Sciences Research Paper: Quantitative Methods 2018.)

Experimental research is way of conducting a study with a new method, for example, investigating a sample group of population, which in this case was an appropriate way to approach in this research, as the chosen item was experimented with a new

procedure of how the packaged item could clinch on the packaging material. (Heikkilä 2009, 21; Organizing Your Social Sciences Research Paper: Quantitative Methods 2018.)

There are different methods sections in a quantitative study, and they must describe how every aim of the study will be accomplished as well as provide enough detail to make it understandable for the readers. Thus, a quantitative study seeks answers to the following questions: *How did the data emerge*? Or *Where did it come from*? And *How were the procedures used for the selected item*? Additionally, the tools and methods used in the data collection must be explained. Moreover, one must also tell whether the data was pre-existing or collected, and lastly, the data must be analyzed by using mathematical techniques and explanations given on what kind of software was used to handle the data. (Heikkilä 2009, 21; Organizing Your Social Sciences Research Paper: Quantitative Methods 2018.)

1.5 Qualitative research

Qualitative research provides understanding of a subject or topic and its behavior and the reason behinds decisions. The key objective of qualitative research is the faculty of comprehending, in other words understanding, but not the determination of quantity. Therefore, qualitative research methods are suitable when improving a procedure or operation, searching alternatives or digging deep into social problems. (Heikkilä 2014.)

1.6 Experimental research

The main target of the experiment of this research was to test the chosen wooden material's physical resistance. The outcome of the test would be used in the packaging construction. The first part of the experimental wooden board and beam were screwed together by a log bolt, and tension force was applied to the log bolt in order to learn how much force the wooden materials could sustain with the log bolt. The second part consisted of two wooden beams joined together by a bolt and eye nut. Tension forces were applied on the eye nut from two different directions.

2 Warehousing

The term ‘’ warehouse’’ means a store where any types of goods and materials are processed. The various main activities within the warehousing function are shown in Figure 3. (Kumar & Vyas 2018.)

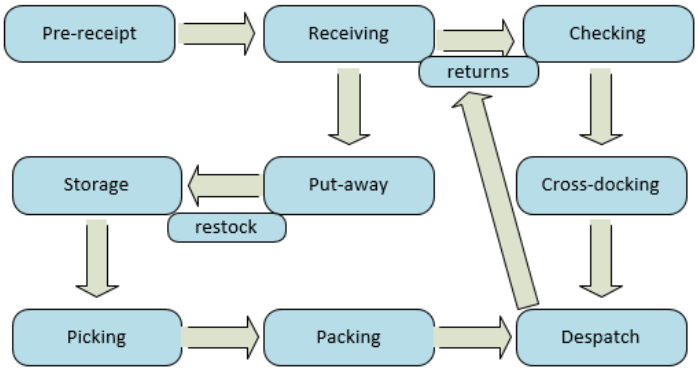


Figure 3. Warehouse processes adopted from Gwynne 2011.

2.1 Receiving

Goods-in or in-handling is a crucial process within the warehouse. Considering that the right product has been received in the right quantity and in the right condition at the right time is one of the mainstays of the warehouse operation. (Gwynne 2011, 45.)

2.2 Put-away

Put-away is the process of taking products off the receiving shipment and putting them into the most appropriate location. (What is a put away strategy? N.d.) In order for the put-away process to work effectively, the implementation of the system must be based on detailed information about the goods and materials, for example, physical dimensions and weight. The put-away process has an impact on the inventory, and therefore, the workers can see through the information system the availability of a storage location. Additionally, the information system could also be used for pick-list design. (Karasek 2013.)

2.3 Storing

Storing operation is the process of storing goods in a warehouse regardless of the types of the racking system. Therefore, when goods are identified, checked and prepped for storage in a multi-stage process, they are stored based on their movements in the warehouse and in order to optimize the distance covered by the order picker. Moreover, fast-moving goods must be stored in a suitable location, in other words, incoming goods must be stored by using the XYZ principle. (Effective storage strategies – The basis for successful warehouse management 2015.)

2.4 Location labeling

There are different methods used in warehouses in order to label locations. Labeling must be planned in such a way that the items are easily identified. A successfully managed warehouse labeling system assures that the order pickers and forklift drivers can collect and put away the items. Most of the warehouses use location labeling letters or numbers, or combinations of both and barcodes are used. (Fernando 2019.)

2.5 Picking

Order picking is the process of collecting items in the warehouse to fill orders requested by the customers. However, order picking is the costliest activity in a warehouse on a daily basis and it has a direct impact on customer service, because of it is labor-intensive and can be difficult to plan. Therefore, the costs are estimated to be as much as 55% of the total warehouse operating expenses. (Gunasengaran 2017.) There are different picking technologies used in warehouses, such as voice picking, pick-to-light, put wall, put to light and RF scanners. (Picking technologies. N.d.)

2.6 Packaging

Packaging is way of protecting products regardless type or size. However, packaging has impact on the whole supply chain especially in logistics, therefore, the purpose is

to protect the products against physically or chemically damages during handling and shipping processes. (Järvi-Kääriäinen & Ollila, 2007, 9.)

There has been used different packaging combination in terms of protecting products, which can be easily and effectively handled throughout all the processes. Transport packing has impact to shipping process, considering package must be sized accurately to maximize truck load. (Järvi-Kääriäinen & Ollila, 2007, 11.) Additionally, packaging system must be provided, not only to achieve a successful supply chain, but also associated with aspect of logistics and productions. (Regattieri and Santarelli 2013.)

Packaging system consists of three different levels.

Primary package is the product package based for purpose of the end consumer.

Secondary package binds together the primary packages.

Tertiary package binds together more secondary package to make easier handling, storing and transporting. (Järvi-Kääriäinen & Ollila, 2007, 11.)

The aim of the packaging system is to be well functioning, since it has interface with different industrial policy, considering with their specific requirement of how packages must be designed and what packaging materials must be used. Therefore, the packaging materials must assuage several purposes, i.e. physical protection, hygiene, containment or agglomeration and information transmission. (Regattieri and Santarelli 2013.)

Packaging in logistics: Logistics is not only warehousing and transporting, but collaborating with purchasing, production and marketing departments, for creating a strategic competitive advantage. In addition, services which put into practice come under logistics such as distribution, production, purchasing, and flow of materials, information and cash. (Logistics. N.d.) As earlier statement mentioned, packaging takes a major part of the whole logistics processes in terms of achieving efficiency transportation. Furthermore, packaging materials must provide enough stiffness to handle heavy duty items which is going to investigate in this study.

3 Packaging material and requirement

3.1 Wooden material

Wooden materials must comply with requirements and standards of EN 12246 for quality classification of timber used in pallets and packaging, EN 12248 for Sawn timber used in industrial packaging, EN 12249 for sawn timber used in pallets, EN 338 for structural timber-strength classes, EN 1912 for structural timber-strength classes-assignment of visual grades and species, and EN 13986 for wood based panels such as plywood and OSB (Oriented strand board). (Packaging guidelines 2010.) However, there are few standardization activities at national level which have been realized by the DIN (German Institute for standardization) in Germany. In addition, there are EN standards at European level and ISO standards at international level which are published by the International Organization for Standardization. (Fasteners. N.d.)

DIN: National standards have been largely replaced by either international or European standards. DIN standards are still valid for products which are not available in ISO or EN standards.

ISO: International standards are meant to standardize technical regulations worldwide and make it easier to exchange goods and reduce trade barriers.

EN: the purpose is to harmonize technical rules and laws within the single European market which was established on 01.01.1993. (Fasteners. N.d.)

Pallet: is the most common platform used for goods transporting, storing, and handling. EURO pallet is the most common standard pallet and is basically made of wood. However, choosing the suitable pallet for goods would be based on the items dimension and weight, which in this case is to customize a pallet. There are different ways of securing cargo on pallet such as lashing, fastening items on pallet with bolts and screws, locking, blocking and shrink wrapping. (European Best Practice Guidelines on Cargo Securing for Road Transport. N.d.)

Crates: Crates are basically used in load-bearing packaging, which designed based on product type to carry the entire weight of the packaged goods during transportation,

storing and handling. Crates and boxes are made of wooden materials, such as cut-timber (spruce and pine), plywood and OSB. Most importantly, all above mentioned wooden material must have the resistances and strength to handle the packaged goods, and more respectfully the crate or boxes components must be chosen according to the standards and comply with requirements. (6 Constructing boxes and crates. N.d.) (ISPM 15 Regulation of wood packaging material in international trade. 2018.)

However, securing items on pallet requires to consider what types of wood material is used to ensure the goods secured within package, and shipping process is efficiency easy to handle, regardless the modes of transport. The most common wooden material is timber, which is used in Europe over 25 million cubic meters every year in pallets and packaging. (Downloads. Fact and Figure. N.d.) Thus, wooden materials which is used packaging should be looked as an integral part of any international transaction with variables such as legal and environmental all taken into consideration. (Common Basic Rules in Export packaging 2006)

Most importantly, packaged goods are fastened on the pallet with bolts and screws to secure the cargo and it require an enormous insight to investigate the wooden properties. Thus, certain wood species is used not only in packaging industry, but also in construction such as sawn timber which its structure meets the requirement minimum in wooden material in terms of resistance against such things as moisture, along the way of transportation process. (Sawn wood. N.d.)

Therefore, to hand-pick the best suitable wood species in this case is to sort the woods in terms of strength, and thereby to go through sawn timber, plywood and OSB as it used in wooden packaging. As the technology nowadays is in advance, nearly all sawn timber is sorted using modern highly developed mechanical strength sorting methods such as measurement software which measures by computer vision, X-ray and ultrasound. Sawn conifer timber strength sorted into strength classes as it shown in table 1 according to EN 338, in other word European standard about sawn timber's strength classes which are appropriate to the characteristic values of temperate hardwoods. Additionally, it also set a value for the softwood classes for shear

strength and tension strength perpendicular to grain. (Sorting sawn timber in terms of strength. N.d.)

Table 1 Sawn timber strength classes according to EN 331

All sawn timber strength classes	
C14, C16, C18, C20, C22, C24, C27, C30, C35, C40, C45, C50	
Strength classes are grouped	
Visually or mechanically	Only mechanically
C14, C16, C18, C20, C22, C24, C27, C30	C35, C40, C45, C50
Strength classes in accordance with INSTA 142	
T0, T1, T2, T3	T0=C14, T1=C18, T2=C24, T3=C30

Table 2 Material properties (EUROCODE 5, 2009)

Strength classes		**Sawn timber**		
		C18 (T1)	**C24 (T2)**	**C30 (T3)**
Characteristic strength (N/mm^2)				
Bending	$f_{m,k}$	18	24	30
Tensile	$f_{t,0,k}$	10	14,5	19
	$f_{t,90,k}$	0,4	0,4	0,4
Compression	$f_{c,0,k}$	18	21	24
	$f_{c,90,k}$	2,2	2,5	2,7
Shear	$f_{v,k}$	3,4	4,0	4,0
Stiffness properties (N/mm^2)				
Modulus of elasticity	$E_{0,\,mean}$	9000	11000	12000
	$E_{90,\,mean}$	300	370	400
Mean shear modulus	$G_{\,mean}$	560	690	750
Density (kg/m^3)				
Density	ρ_k	320	350	380
Mean density	ρ_{mean}	380	420	460

3.2 Jointing methods

As mentioned earlier, some of the goods will be fastened on the pallet or bottom cases, therefore, there are different types of jointing methods to implement the wooden packaging for different purposes. In general, jointing materials which are used in crates and boxes assembling, and item fastening show in table 3 must be used according to EN/DIN/ISO standards in table 4. (5.5 Nails. N.d.) (5.6 Bolts. N.d.)

Table 3 Jointing methods for crates and fastening

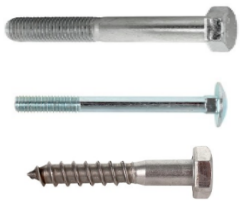
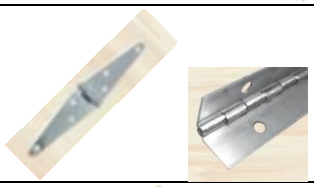
Items	Purpose	Picture
Hexagon & lock head bolts	For end beams and items that must be fastened on the bottom case	
Nuts	For end beam and items	
Washers	For end beam and items	
Screw & wire nails, & nails for pneumatic tools	For joints between cases components	
Strap and piano hinges	For holding together (side and end wall, and lid)	
Klimp fastener		
Snaps		

Table 4 Bolts, nails and screw standards

Standards	
Hexogon head bolts	EN ISO 4016
Cup-head square-neck bolt	ISO 8678
Wire nails	EN 10230-1
Nails for use in automatic nailing machines	DIN 1143
Timber structures – Dowel-type fasteners - Requirements	EN 14592:2008+A1:2012

There are also dowel joint module methods used in constructions (see figure 4). Steel dowel modules are mainly installed into the wooden beams and concrete. The idea is to drill the steel module into pallet to attach the items by screwing with log bolts so that the items are secured on pallet. Therefore, in order to avoid the steel modules pulling off the sawn timber beam, it requires the measurement must be done accurately and considering the sawn timber's mechanical properties. These joint methods are used in construction industries and have not yet been standardized on how to implement the system into the packaging industry. (Moses 2014.) (Anchor Shield, N.d.)

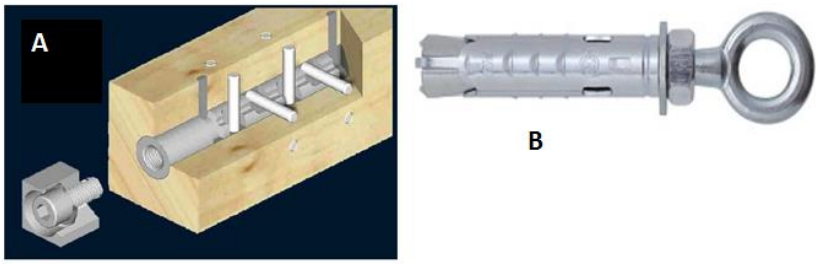


Figure 4 A. Advanced fastener for glulam. B. Anchor shield fastener for concrete

3.3 Packaging film

In the shipping process, packaged goods are exposed to act in temperature and humidity during transportation. Suitable film must be applied on the good based on the transportation mode. There are different protection methods used in packaging such

as vacuum packaging, vapor barrier, barrier bagging, PE film and VCI film/bag. In addition, desiccants packets must be placed inside the bag before wrapped it which absorb the moisture. (Heavy Machinery Packaging. N.d.)

4 Securing cargo for different modes of transport

4.1 Packaging methods

Packaged goods must be secured effectively in order to avoid hazards during transportation. Therefore, packager and carrier must consider in early stages that the least requirement of securing packaged goods are met and must be used the appropriate packaging material, and methods. Table 5 briefly illustrates the issues which effect product during securing, packaging and transporting. (Learning Material. N.d.)

Table 5 Common causes on securing cargo according to EN 12195-1

Road transport	Sea transport	Rail transport	Air freight
Acting forces			
• Acceleration • Deceleration • Centrifugal force • Gravity • Vibration	• Roll • Pitch • Yaw • Sway • Surge • Heave	• Longitudinal and horizontal forces • Transverse horizontal forces • Centrifugal force • Gravity • Vibration	• Acceleration • Deceleration • Yawing • Lift
These forces may cause sliding, tipping and wandering			
Securing methods			
• Blocking • Locking • Lashing	• Blocking • Locking • Lashing	• Blocking • Locking • Lashing	• Blocking • Lashing
Different types of lashing			
• Top-over • Loop • Spring • Straight/ Cross	• Top-over • Loop • Spring • Straight/ Cross	• Top-over • Loop • Spring • Straight/ Cross	• Net • Straps

During transportation, there are various forces which have an effect to the cargo. The force acting on the cargo is the mass of the cargo (m) which is expressed in kilogram (kg) or ton (t), multiplied by the acceleration (a) which is measured in m/s^2:

$$F = m * a$$

F *Force*

m *Mass*

a *Acceleration*

Acceleration considered during transport are the gravitational acceleration (a = g = 9,81 m/s^2) and acceleration caused by transport conditions such as by braking or rapid change of traffic lanes by a road truck. These accelerations are expressed as product of the gravitational acceleration (g) and a specific acceleration coefficient (c).

To avoid cargo movements, the cargo must be secured in longitudinal and transverse direction according to the worst combination of horizontal and corresponding vertical accelerations. The following figure is shown the acceleration coefficients which are key to calculation securing forces. (IMO/ILO/UNECE Code of Practice for Packing of Cargo Transport Units. 2014.)

Road transport					
Securing in	Acceleration coefficients				
	(c_x)		(c_y)		vertically down (c_z)
	forward	rearward	Sliding	Tilting	
Transverse direction (c_y)	-	-	0,5	0,5/0,6	1,0
Longitudinal direction (c_x)	0,8	0,5			1,0

Rail transport					
Securing in	Acceleration coefficients				
	c_x		c_y	minimum vertically down c_z	
	sliding	tilting		sliding	tilting
Transverse direction	-	-	0,5	0,7	1,0
Longitudinal direction	1,0	0,6	-	1,0	1,0

Sea transport				
	Acceleration coefficients			
Sea area	Securing in	c_x	c_y	minimum vertically down c_z
A	Transverse direction	-	0,5	1,0
	Longitudinal direction	0,3	-	0,5
B	Transverse direction	-	0,7	1,0
	Longitudinal direction	0,3	-	0,3
C	Transverse direction	-	0,8	1,0
	Longitudinal direction	0,4	-	0,2

Figure 5 Acceleration coefficients for modes of transport

4.2 Securing equipment

There are different types of Securing equipment used in transportations. However, web lashing and chain are the most common lashings used in terms of securing cargo, which can only transfer tensile forces. Lashing maximum allowable tensile force is displayed as LC (lashing capacity), in addition, breaking strength is indicated in units of force, either kilo-Newton (kN) or deka-Newton (daN). (Cargo securing for road transport. 2014)

Web lashing: According to the EN12195-2, web lashing is man-made fibres which is attached with ratchet system (figure 20) to tension the lashing, either by dragging or pushing on the handle of the ratchet. In terms of securing the cargo during transportation, the ratchet must always be blocked. (Cargo securing for road transport. 2014)

Chain: Chains are mainly used for lashing cargo to secure them during transportation, and it must be manufactured according to EN 12195-3 standard. Chain lashing is recommended mainly on heavy duty, because under a normal load it doesn't stretch

and neither sensitive for the sharp edges. (Cargo securing for road transport. 2014) (Cargo securing to prevent cargo damages on road. N.d.)

4.3 Determining securing forces

The number of lashing needed will be depend upon: the weight of the load, friction between the load and surface, rating of the lashing, angle of the lashing relative to the surface, how many tensioners are used. The different types of lashing methods which is used in securing cargo are; top-over lashing, loop lashing, spring lashing and straight lashing. However, this research is going to investigate the straight/direct lashing, particularly on tipping perspective which is explained later in this research. Thus, all the lashing methods must be calculated according to EN 12195-1 standard. (IMO/ILO/UNECE Code of Practice for Packing of Cargo Transport Units. 2014.)

EN 12195-1 standard	
Combination of materials in the contact surface[a]	**Friction factor, μ**
Sawn wood	
fabric base laminate/plywood	0,45
grooved aluminium	0,40
shrink film	0,30
stainless steel sheet	0,30
Plaine wood	
fabric base laminate/plywood	0,30
grooved aluminium	0,25
stainless steel sheet	0,20
Plastic pallet	
fabric base laminate/plywood	0,20
grooved aluminium	0,15
stainless steel sheet	0,15
Steel and metal	
fabric base laminate/plywood	0,45
grooved aluminium	0,30
stainless steel sheet	0,20
Concrete	
sawn wood battents	0,70
sawn wood battents	0,55
Anti-slip mat	
rubber	0,6 [b]
other material	as certified [c]

[a] Surface, dry or wet but clean, free from oil, ice, grease.
[b] May be used with f_{μ} = 1,0 direct lashing
[c] When special materials for increased friction like skid-inhibiting mats are applied, a certificate for the friction factor μ is required

Figure 6 Friction factor for combination of materials in the contact surface according to EN 12195-1 and key to securing forces

5 Implemention of a reseach

The company did not provide an existing data to analyze for packaging instruction, rather, the research method which implemented in this study is mainly based on EU standards requirement for wooden materials used in packaging industry and Eurocode 5 for wooden materials used in construction industry. In addition, an existing data for packaging requirement, particularly for heavy duty products which also based on according to EU and Eurocode 5 standards is adapted in this research.

Since, there was no existing data to investigate, mainly in the packaging instruction, the research approach started by getting acquainted with products in which net weight wise could vary from 300 kg to 4500 kg, and this demand to develop and specify a packaging and shipping instruction. In addition, the research is familiarized with wooden materials, and securing methods and equipment.

The key objective of this study was the implementation of the new packaging and shipping guidelines for a Sammet. Hence, for the company point of view, the instruction approve that the goods are secured during transportation, and contract manufacture put into action with help of the packaging guidelines.

5.1 Calculation securing forces and securing methods

In terms of calculation securing forces, the formula methods used in securing cargo must comply with EN 12195-1. This standard is specified for securing cargo on load carrier. As in this study, packaged goods must be secured on the pallet or bottom of cases. The formula methods and securing equipment of how to calculate lashing capacity and anti-slip mat is adopted from the standard and shown in result section, additionally, the web lashing which is applied on the packaged goods and bottom of the cases must comply with EN 12195-2 which is also implemented in this research.

5.2 EU standards for wood used in packaging

EU standards are specified wooden materials requirement which is used in packaging. Hence, every standard which concerns wooden materials is adopted and implemented in this research. Wooden materials which implemented in this research is chosen based on strength and specified existing data for packaging requirement.

5.3 Eurocode 5 standard for construction industry

Eurocode 5 mainly specified a wooden material which is used in designing construction. This research benefits from Eurocode 5 sawn timber, plywood and OSB property which is used in the packaging. As the packaged goods shipped overseas, the packaging materials must with stand the hazards and humidity experienced during transit. In addition, the Eurocode 5 specifies the sawn timber bending value which is also used in this research in order to determine the bending stress.

5.4 Determining the bending

As the packaged goods are secured on the bottom of the case, bending must be considered when lifting goods by crane. In this research, bending moments are calculated based on worst case scenario method, as if calculated in reliable way, the calculation method must be proceeded according to Eurocode 5 standard. In other words, the calculation processes must be consulted with engineering department.

5.5 Product data

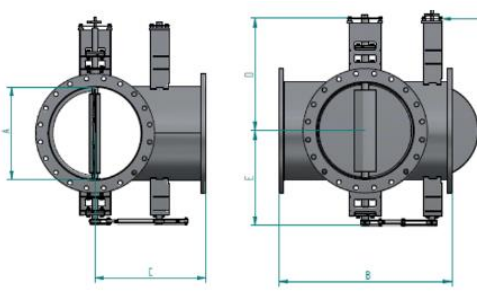


Figure 7 Illustrative 3-way damper dimension

	Dimensions (mm)					Weight (kg)
	A	B	C	D	E	
DN700	699	1510	800	1057	509	819,6
DN800	801	1610	840	1135	593	951,8
DN900	902	1700	880	1358	648	1138,7
DN1000	-	-	-	-	-	-
DN1100	1108	2000	1080	1493	766	1551,5
DN1200	-	-	-	-	-	-
DN1300	1308	2290	1260	1546	833	1836,3
DN1400	-	-	-	-	-	-
DN1500	-	-	-	-	-	-
DN1600	-	-	-	-	-	-
DN1700	1708	2790	1350	1808	1085	2592,2
DN1800	-	-	-	-	-	-
DN1900	-	-	-	-	-	-

Figure 8 Dampers dimension and weight sheet

6 Research results

6.1 Packaging requirement and material

The packaging methods that were suitable for this study were customized pallets, crates and cases. The packaging materials consisted of wooden expendable pallets, crates, polyethylene (PE) film, volatile corrosion inhibitor (VCI) bag/film, bolts, screws and load straps. However, choosing the packaging materials had to be based on the product characteristics as the packaged items were heavy and some of them had to be fastened on the pallet. This meant that the packaging materials had to withstand the transit regardless of the mode of transportation. All wooden materials used in packaging must be heat treated and marked according to the international standard ISPM 15. Used wooden material would not be accepted for crates and cases, and rot, tears and knot spots are not allowed.

Table 6 Marking example according to ISPM 15

Marks				
IPPC	**XX – YYYY** **ZZ**	XX	Country code	
		YYYY	Manufacturer number	
		ZZ	Treatment code and type	
			HT	Heat treatment
			MB	Methyl bromide
			DH	Dielectric heating

6.1.1 Methods of packaging

Wooden packaging standards

Table 7 Wooden packaging EU standards

Standard	Description
EN 12246	Quality classification of timber used in pallets and packaging
EN 12248	Sawn timber used in industrial packaging
EN 12249	Sawn timber used in pallets
EN 338	Structural timber. Strength classes
EN 1912	Structural timber. Strength classes. Assignment of visual grades and species

Solid timber requirement

Table 8 Solid timber requirement

items	Grading class	Strength class	Moisture content during transformation
Boards	S7 or T1	C18	Semi dry
Boards used in crates and cases	S10 or T2	C24	Semi dry
S = Stands for German standard T = Stands for Nordic countries standard			

Wooden boxes-based products requirement

Table 9 Wooden boxes-based products requirement

Wood based products	Technical specifications	DIN standard	EU standard
OSB/3 & OSB/4	Performed well to loading bearing & resistant to high air humidity	DIN EN 300	EN 300
Plywood	Glue must be resistant to all climate and humidity influences	DIN 68705/BFU 100	EN 13986
Hardboard (hard wood fibre board	Resistant to high air humidity levels	DIN EN 622-2	EN 622-2

Wooden packaging material which consists of pallets, crates must comply with requirements of ISPM 15.

Crates and cases: They are made of cut-lumber or sheet material veneer products. The most suitable wooden materials for cases are made of either plywood or OSB (Oriented Strand Board), and for crates it is made of cut-lumbers. Therefore, OSB or plywood must be used in boxes' side and end walls to protect the packaged goods during transportation as it has high resistance of humidity, and a high shearing modulus, with the respect of considering the requirements of EN 300: OSB/3 and OSB/4

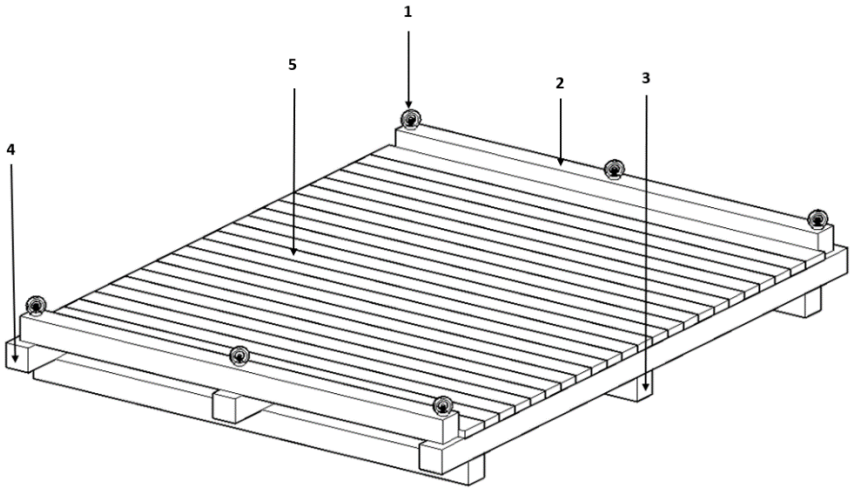


Figure 9 Wooden crate construction

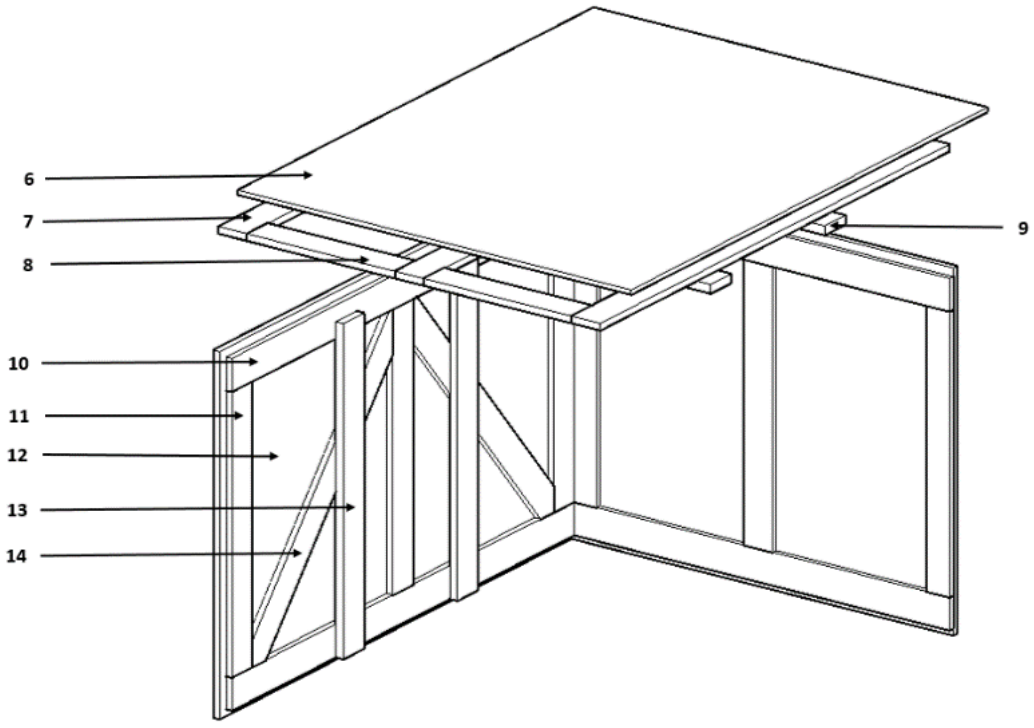


Figure 10 Boxes' construction

Table 10 Key to figure 9 and 10

Bottom		The lid		Case sides	
1	Bolts and eye nuts	6	Plywood or OSB	10	Lateral battens
2	End beam	7	Battens	11	Header battens
3	Transverse runners	8	Lining	12	Side wall (OSB or Plywood)
4	Longitudinal runners	9	Top cross boards	13	Lid support
5	Boards			14	Diagonals

Table 11 Components used in crates and cases

Wooden materials	Net weight	Crates and cases constructtion parts			
Sawn timber **(1)**		Side/end walls	Bottom case	runners	Battens
	0 – 500 kg	**1,2,3**	**1,2,3**	**1**	**1**
Plywood **(2)**	500 – 1000 kg	**1,2,3**	**1,2,3**	**1**	**1**
	1000 – 2000 kg	**2,3**	**1**	**1**	**1**
OSB **(3)**	2000 – 3000 kg	**2,3**	**1**	**1**	**1**
	Over 3000 kg	**2,3**	**1**	**1**	**1**

6.1.2 Packaging materials and fasteners

Types of jointing: Jointing elements which applied into wooden materials are hexagon-head bolts, cup-head square-neck bolts, screws nails and threaded bolt, and with support of washers. The diameter of the bolt must be at least Ø10 mm with the minimum 8mm thick timber, and if the thicknesses of the timber above 8mm, the bolt diameter must be at least Ø12 mm. In terms of assembling the bottom of the case, nailing principle shown in figure 10 must be considered. Strength classes for all bolts must be 8,8.

Table 12 Requirements of bolts and washers

The diameter of the bolts	Ø M12	Ø M16	Ø M20	Ø M22	Ø M24
Washer thickness (mm)	6	6	8	8	8

Installing joint elements

Table 13 Cases and crates assembling principle

Parts		**Types of joints**		
	Nails	Screw nails	Log bolt	Bolted joints & washers
Bottom boards & runners	X	X	X	
End beam & longitudinal runners				X
Plywood or OSB & battens	X	X		
Side and end walls	X	X		
Item supporter		X	X	X
Item fastened on the bottom board			X	X

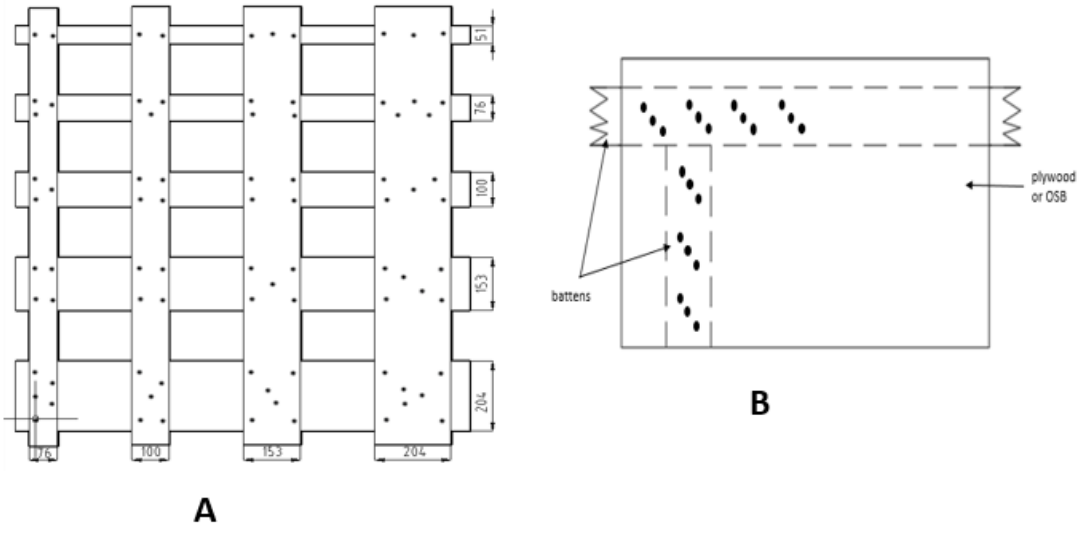


Figure 11 Nailing principle A) Boards and runners B) Boards and veneers

Packaging film: During the transportation goods must be protected not only from dusts and moisture, but also the packaging film must withstand the mechanical stress. Packaged film must be used according to the mode of transport.

Table 14 Films which are used in packaged goods

Transport route	**Film type**		
	PE (polyeth-ylene)	VCI (volatile corrosion inhibitor)	Aluminum barrier foil
Road	X	X	X
Rail	X	X	X
Sea A			X
Sea B			X
Sea C			X
Sea A = The Baltic Sea Sea B = The North & Mediterranean Seas Sea C = Unrestricted area			

6.2 Packing process

6.2.1 Sea transport

Wooden crates would be customized based on the item's measurements and weights. Wooden package must be made from a new and heat-treated material according to ISPM 15. Used crates and boxes are not allowed.

The item must be placed to the bottom before or after installing side and endways, but at least one of the ways (side cover) must be open to operate the packaging. At first, packaging film must be wrapped to the sensitive area part of the item and the entire item must be lined with required film. Furthermore, the item must be fastened with bolts or bolt screws all the way through to the bottom runners. If the item cannot be fastened on the runners, additional beams/runners must be added on top of the bottom case (figure 15)

Table 15 Crates materials for minimum thicknesses requirements

Items	Min. thickness (mm)			
	0-500 kg	500-1000 kg	1000-3000 kg	above 3000 kg
bottom boards	22	30	30	32
Transverse runner	50	80 x 100	100 x 100	120 x 120
Longitudinal skids	50	80 x 100	100 x 100	120 x 120
Item supporter	50	100	100	100
End beams	50 - 100	80 x 100	100 x 100	120 x 120
Plywood/OSB	9	12	15	18
Inner battens	22	-	-	-
Outer battens	22	-	-	-
board for side and end walls	24	24	26	26

6.2.2 Types of crates and cases construction for goods up to 1000 kg

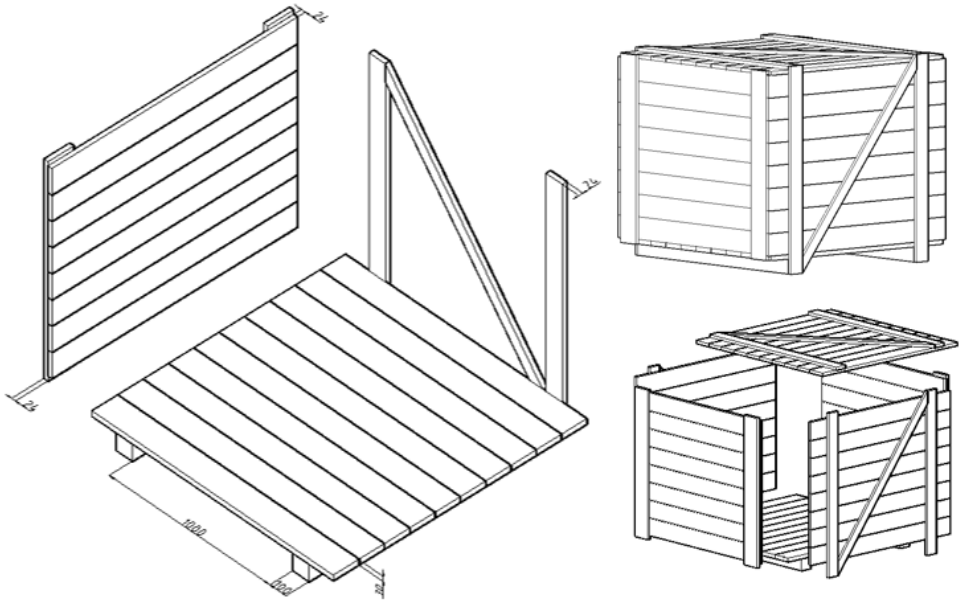


Figure 12 Crate construction

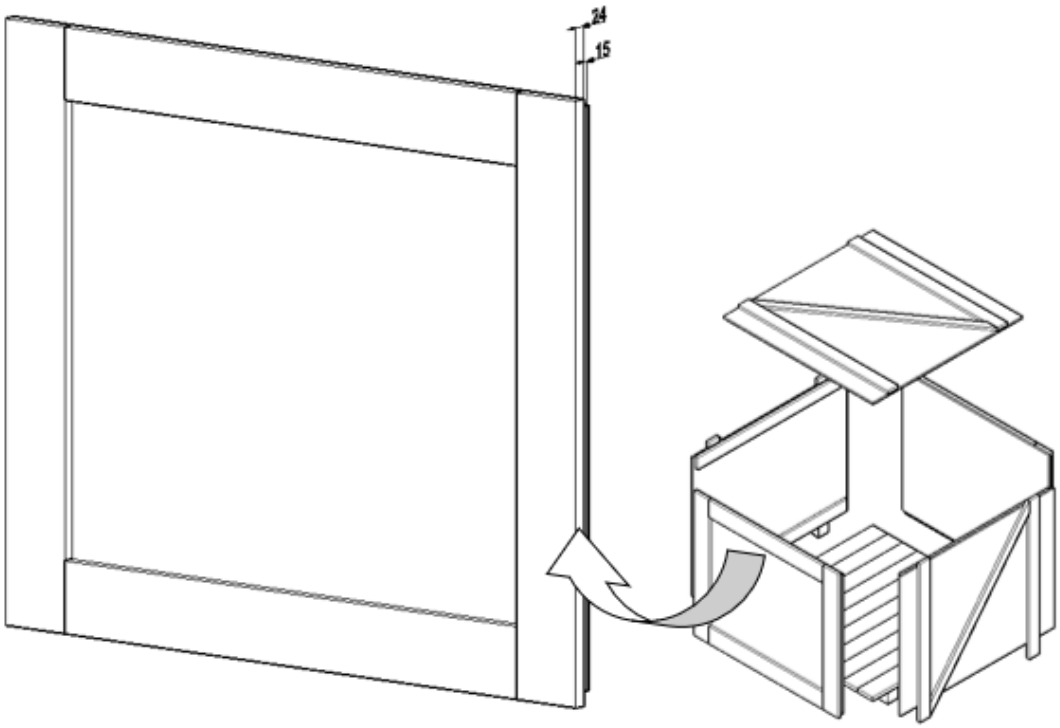


Figure 13 Case construction

The bottom of the crates must be provided with four-way entry for lifting.

Table 16 Crate parts description

Parts	Description
Bottom board	Bottom board must be nailed to the transverse skids
Transverse skids	
Battens on the outside	Holds together for the cases and crates
Battens on the inside	Provide support when assembling side and end walls
Side and end wall boards	Boards must be mounted horizontally or longitudinally
lid	Boards must be nailed of each side of the crate
	Plywood or OSB must be nailed of each side of the case

Goods that cannot be fastened by screw or bolt through to the bottom must be provided additional support to secure the goods from tilting, slipping and falling. Therefore, different securing methods must be applied (Figure 18) considering the size and weight of the goods. Types of securing methods such as blocking, locking, lashing, cross or longitudinal bars, bolts and eye nuts must be provided according to the type of product.

Table 17 Additional support requirements

Inner parts	Min. thickness (mm)	Description
Cross bars	30	Secure the cargo from tilting or falling. Must be nailed or screwed to side wall.
Longitudinal bars	30	Secure the cargo from tilting or falling. Must be nailed or screwed to end wall.
Battens	22-30	To support the bars and the lid
Additional bars on the top of the bottom	22-30	According to the product type
Bolts and eye nuts	M12	To secure the goods by lashing

6.2.3 Types of crates and cases for goods above 1000 kg

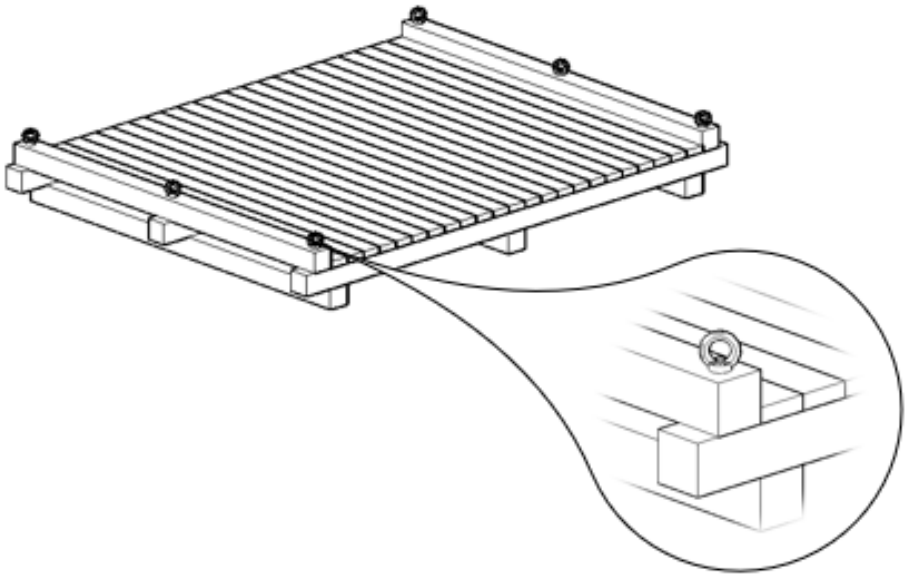


Figure 14 Bottom case

The bottom case (figure 14) is the main instruction where the items will be fastened with bolts. Therefore, the wooden materials must have enough thickness and width to avoid loosening bolts and screws. Above all, the wooden materials must comply with requirement standards mentioned in table 7 and 9. Therefore, runners, boards and end beam must be strong enough to withstand lifting with cranes and forklifts.

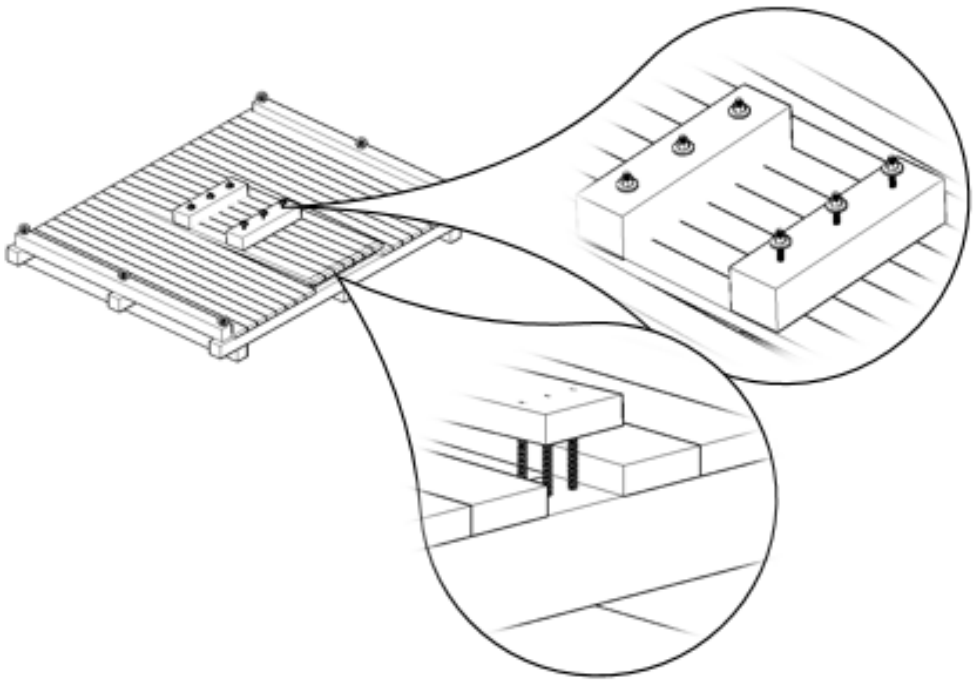


Figure 15 Bottom case added additional parts and screwing instruction

As the product type differ from one another and require different way of securing methods, items must be secured according to the requirements. Therefore, packaged goods that cannot be fastened on the bottom of the case, additional boards and longitudinal runners must be secured with screw nails (figure 15).

The number of longitudinal runners and distance between them must be chosen according to the product type. At least two longitudinal runners must be used on the sides (figure 15), and additional longitudinal runners must be also used based on the product type size and where the bolts/log bolts screwed (figure 16).

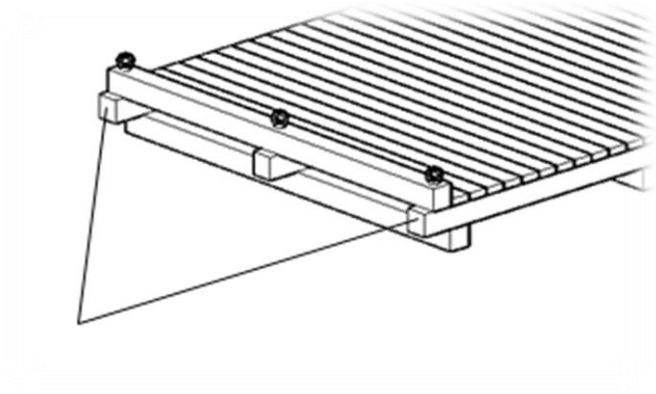


Figure 16 Compulsory runners

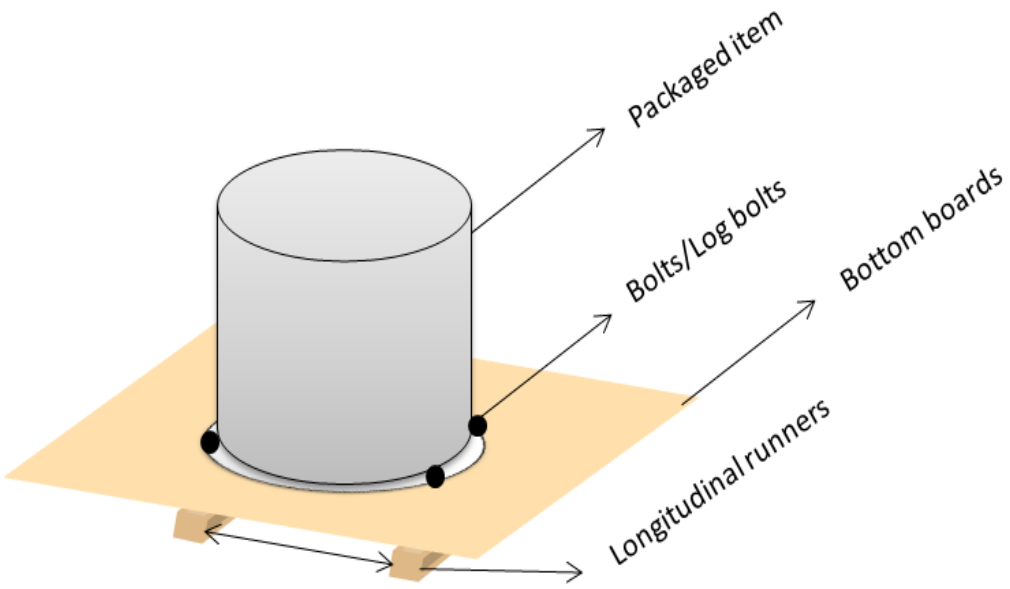


Figure 17 Additional runners based on the net weight of the product

Table 18 Minimum runners and spacing between runners

Item dimension (mm)	**Minimum number of runners**		**Maximum distance between runners (mm)**	
	Longitudinal	Transverse	Longitudinal	Transverse
1000[a)]	2[b)]	2[c)]	800	800
1000-2000	5	3-4	850	300-400
2000-3000	5	4	750	300-400
3000-4000	6	4-5	650	600
4000-5000	7	5-6	500	700

[a)] For packaged goods of net weight up to 1000 kg
[b)] In case if the boards are in transverse direction, runners must be nails with boards on longitudinal direction. Thus, transverse runners would not be necessary.
[c)] In case if the boards are in longitudinal direction, runners must be nails with boards on transverse direction. Thus, longitudinal runners would not be necessary.

6.3 Securing goods

6.3.1 Packaged goods up to 1000 kg

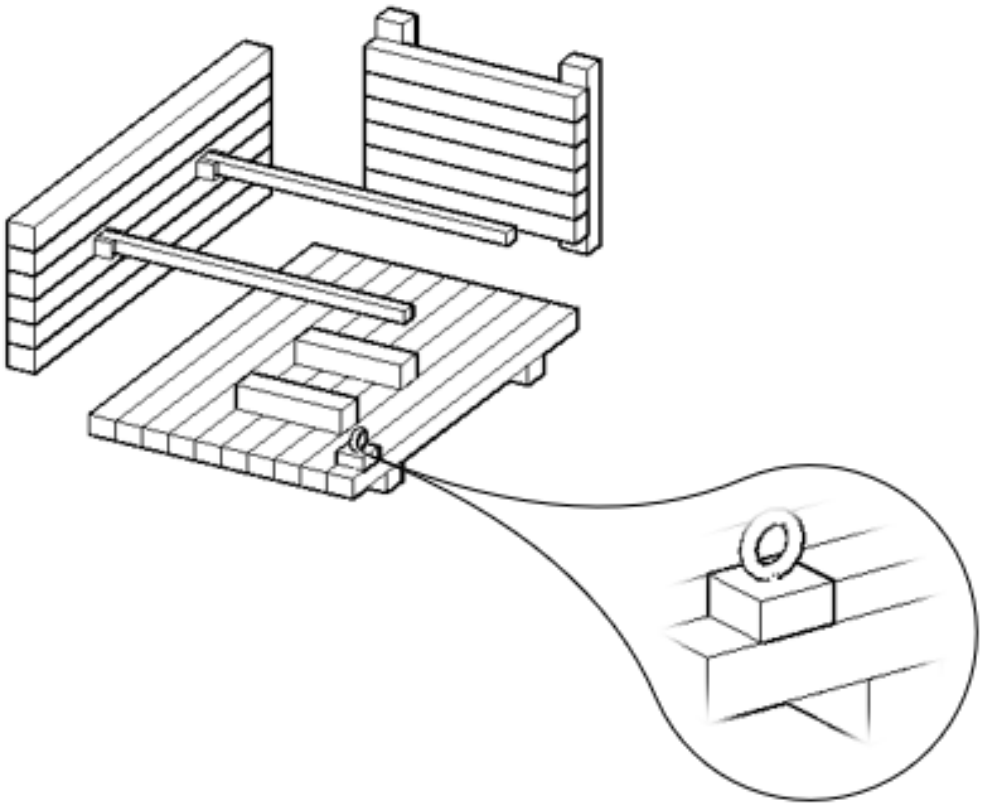


Figure 18 Crate construction with additional support

Goods may be packaged on Euro pallet cases considering the types of items and quantity. Should the dimension of the goods exceed the allowable size of the standard pallet; nonstandard pallet must be made for the item. Additional support must be provided for the packaged goods to avoid hazards during transportation (figure 18).

6.3.2 Packaged goods above 1000 kg

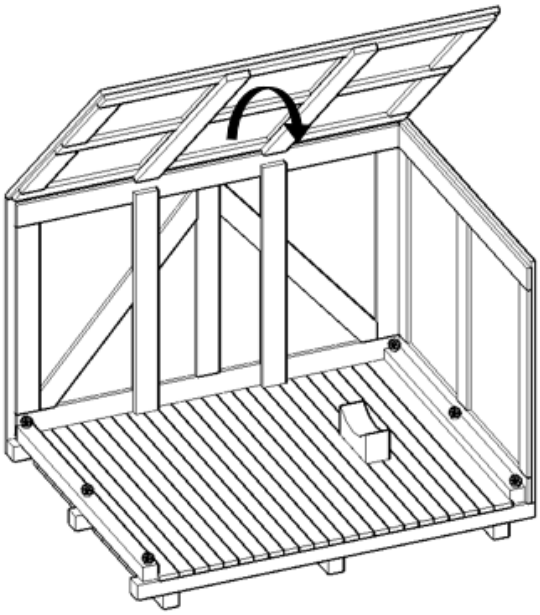


Figure 19 Seaworthy case construction

Packaged goods must be secured into the crate, which its dimension to be adjusted according to the content and weight of the packaged goods. Should have the net mass of the item is above 1000 kg, the construction of the crates must be provided additional support (figure 18 and 19). The item itself provide a hooking lag (figure 20) on two sides, therefore, the item must be secured with web lasing, and additionally if the packaged goods can be fastened to the bottom case, goods must be fastened with bolts and/or log bolts to the longitudinal runners. Additional support must be provided for the goods if requires.

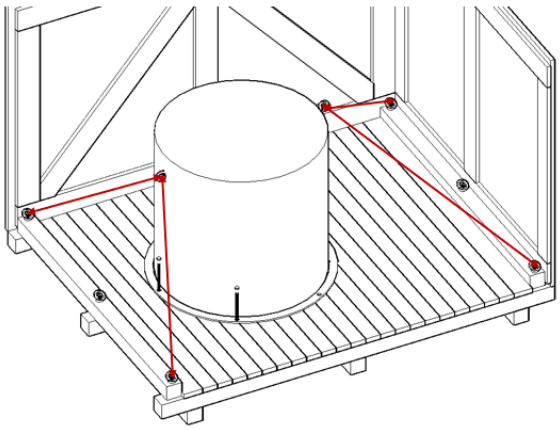


Figure 20 Example of how the packaged goods must be secured on the bottom

6.3.3 Lashing equipment

Web lashing must be used to secure the packaged goods and it must be fastened on bottom case where the eye nuts installed. In order to achieve the maximum tension force, suitable ratchet tensioner, woven textile webbing must be used, and the end fitting must be either single or double wire claw hook (figure 21), however, web lashing must comply with requirement according to EN 12195-2. Lashing capacity must be calculated according to the weight of the goods, but most importantly, the calculation formula must be achieved according to EN 12195-1. In the calculation process the acceleration coefficients (figure 5) and friction factor (figure 6) must be taken into consideration. (SFS-EN 12195-2:2000)

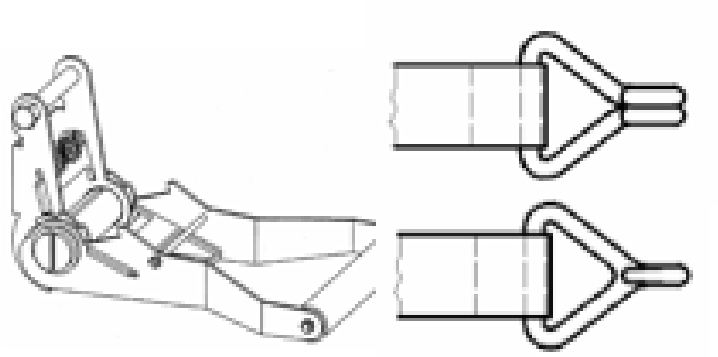


Figure 21 Web lashing and hooks

6.3.4 Calculation securing forces

According to EN 12195-1 the calculation methods are applied for securing cargoes on the load carrier, but in this case the packaged goods must be secured on the pallet/bottom case. Therefore, the same calculation methods must be applied to secure the packaged good efficiently. This calculation formula concerns only on direct lashing, which means the web lashing has direct connection on the bottom of the case as well as on the packaged goods. (SFS-EN 15195-1:2010.) Packaged goods must be secured in longitudinal direction both on forward and backward using two lashing on each side. To do so, every lashing capacity F_R must be calculated as the lashing points of packaged goods are in different length.

For diagonal lashing (SFS-EN 15195-1:2010, 22)

$$F_R = m * g \frac{(C_{xy} - \mu * f_\mu * C_z)}{2(cos\alpha * cos\beta_{xy} + \mu * f_\mu * sin\alpha)} \quad (1)$$

F_R	Restraining force of a lashing device
f_μ	Conversion factor
m	Mass of the load
g	Gravitational acceleration
L	Lashing length
C_x	Longitudinal acceleration coefficient
C_y	Transverse acceleration coefficient
C_z	Vertical acceleration coefficient
μ	Friction factor
α	Vertical lashing angle
β_x	Longitudinal lashing angle
β_y	Transverse lashing angle
LC	Lashing capacity of lashing device (1kN = 100 daN)

The other calculation methods are calculating web lashing. Therefore, the web lashing length and angles must be calculated according to the Pythagorean Theorem as it illustrates on next. (Adopted from Hermann)

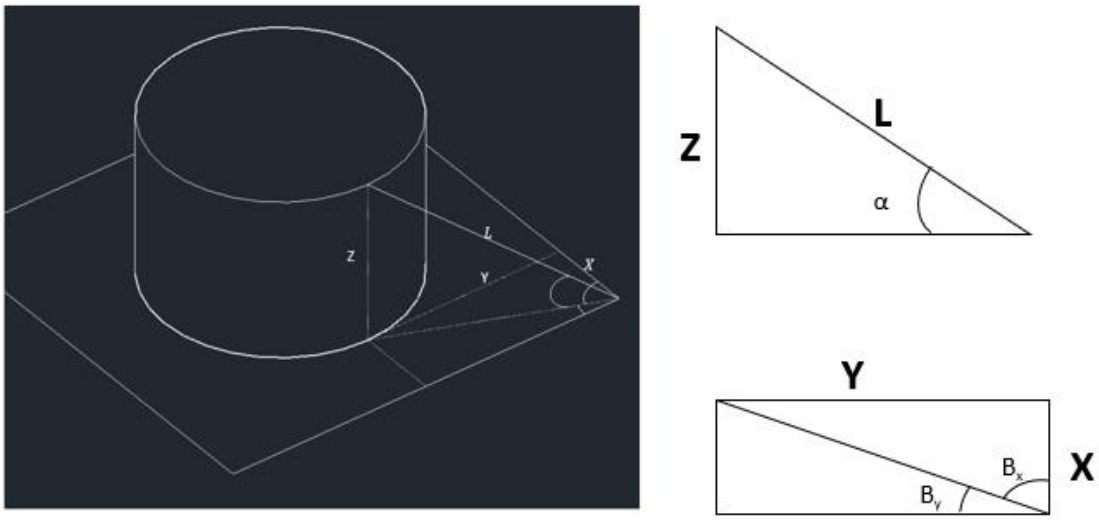


Figure 22 Principle of how to calculate lashing length and angles

$$L^2 = X^2 + Y^2 + Z^2 \quad (2)$$

$$L = \sqrt{X^2 + Y^2 + Z^2} \quad (3)$$

6.3.5 Calculation of bending stress

The bending stress is calculated according to worst case scenario. Item of net weight 1551,1 kg supported with two longitudinal runners and two transverse runners. Forces acting on each longitudinal runner is 1551,1 kg/2 = 775,55 kg and the distance (*L*) between transverse runners is 1,5 m. The following calculation methods are used and illustrated in appendix 3 as a free body diagram.

Support reaction bending moment (Valtanen 2013, 316.)

$$M_{max} = \frac{FL}{4} \quad (4)$$

Section modulus (Valtanen 2013, 304.)

Rectangle

$$W_z = \frac{bh^2}{6} \quad (5)$$

Square

$$W_x = \frac{a^3}{6} \quad (6)$$

Tensile stress (Valtanen 2013)

$$\sigma = \frac{M}{W_x} \quad (7)$$

M_{max}	Bending moment of support reaction
W_x	Section modulus
a	Cross-section of supporting beam
σ	Tensile stress

6.4 Labelling and shipping

Goods must be marked and used the graphical symbols according to ISO 780:2015. In order to ensure proper, safe and efficient handling of packaged goods, graphic symbols must be considered. Marking must provide enough visibility for mechanical handling, storing and transporting. Standardized graphical symbols used for packaged shown in appendix 4. Example of how cases must be marked shown in figure 22.

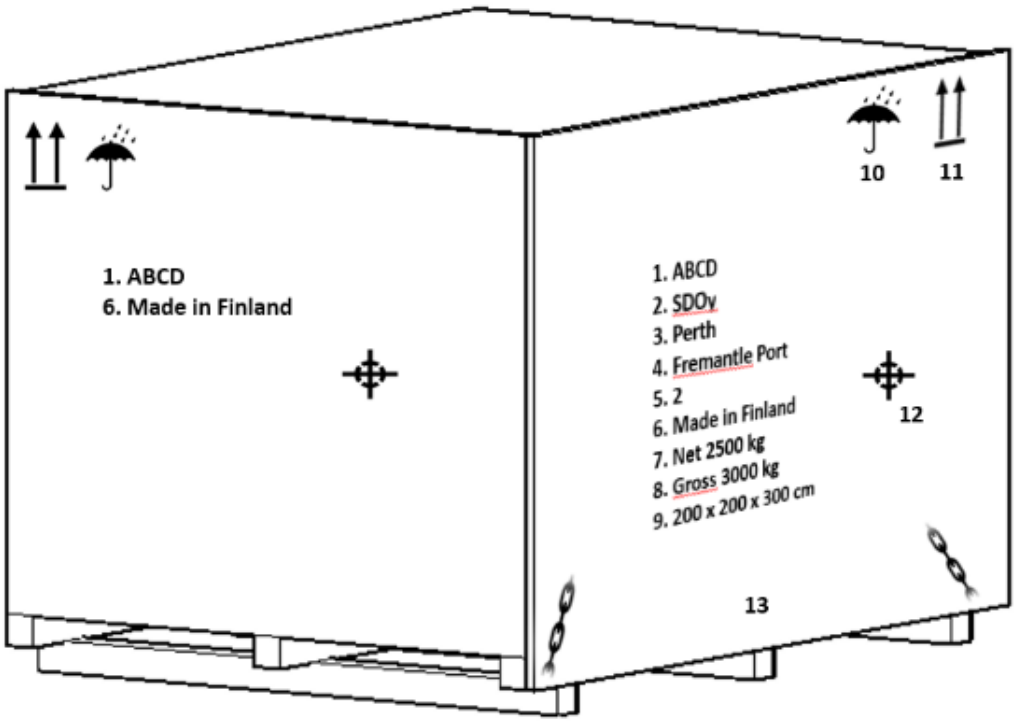


Figure 23 Example of marking

Table 19 Key to figure 22 (Adopted from HPE Packaging guidelines)

Lettering		Marking symbols
1. registration mark	6. country of origin	10. Protection from humidity
2. identification number	7. net weight	11. this side up
3. place of destination	8. gross weight	12. center of gravity
4. port of destination	9. dimensions	13. apply lifting gear hear
5. total number of packages		

Table 20 Standardized symbols (Adopted from HPE Packaging guidelines)

Symbols	Explanation		
	Must be handled with care		Keep the cargo dry
	Must be handled on top		Center of gravity
	For lifting cargoes		Use no hooks

7 Expremintal results

The lab equipment used in this test shown in table below

Table 21 Laboratory equipment

Equipment	Picture	Equipment	Picture
Upright drill		Force measure-ment	
S-Type load cell		Hydraulic test machine	
Straps		U-shape welded components for log bolt	

Table 22 Tested components and materials

Materials	Strength classes	Dimension (mm)/diameter
End beam	Unclarified	100 x 100
Longitudinal skids	Unclarified	100 x 100
Bottom board	Unclarified	32 x 100
Bolts	8.8	M20 x 210
Washers	8.8	M20
Eye nuts	8.8	M20
Screw bolt	8.8	M12 x 80

7.1 Board to wooden beam

In the first experimental, the board and runner screwed together with log bolt (M12*80). It is realized during the preparation of the test that it is not possible to measure the tension force if the log bolt screwed to the wooden board and runner as there is no contact between head screw and the rest of the testing equipment, therefore, Stainless steel components had been welded together as a U-shape with a 12 mm diameter hole in the center, and 12 mm diameter holes on the both sides. The board, beam and U-shape components screwed together. Components attached with straps, and the tensile force applied on the U-shape component. The main purpose of this test was measuring the maximum tensile force that the log bolt would pull off the wooden material, which means the packaged good that fastened with one log bolt on the bottom has the capacity to hold the item for average force of 17,73 kN.

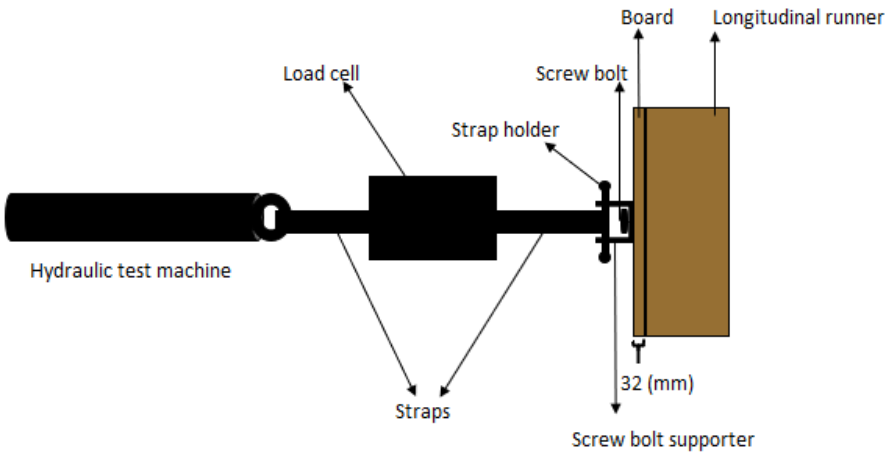


Figure 24 fastening tension force test (side view)

Table 23 First test results

Test	Tension force (kN)
1	16,34
2	18,48
3	18,38

7.2 Beam to beam on length wise

In the second experimental, two wooden beams had screwed together with bolt (M20 x 220 in mm) and eye nut (M20). The main target of this investigation is to find out the maximum applied force to the wooden beams, bolt and eye nut could hold the packaged good which tensioned with web lashing.

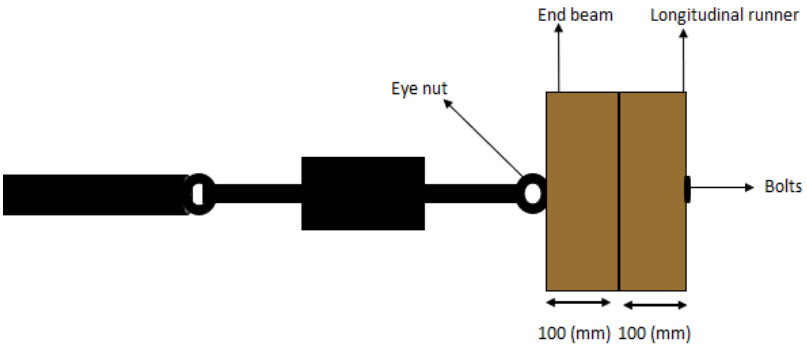


Figure 25 Fastened with bolt and eye nut tension force test (side view)

Table 24 Second test results

Test	Tension force (kN)
1	14,30
2	15,19
3	12,94

7.3 Beam to beam on side wise

In the third experimental, it is used the same method as 7.3 but forces applied from side.

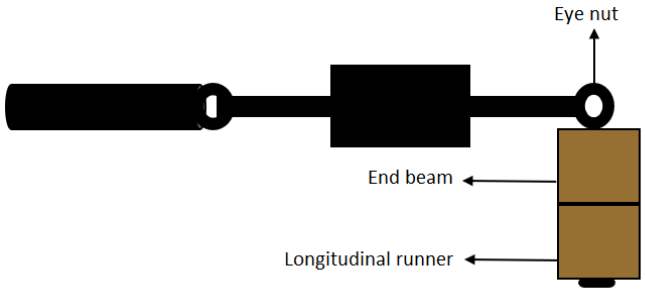


Figure 26 Side force (top view)

Table 25 Third test results

Test	Force applied from the side (kN)
1	10,16
2	13,97
3	14,58

8 Conclusions

The main target of this research was to develop and specify packaging and shipping instructions and to determine the minimum requirements for materials used in packaging for securing the products during storing, handling and transporting. First, it was necessary to understand the requirements and restrictions of designing and implementing the packaging guidelines as given via guidelines from Sammet.

The outcome of this research would help Sammet Dampers Oy to set general packaging principles and methods for the packagers. The proposed results of this research provided instructions on how items must be packaged, sealed and shipped. This assures that the packaging and shipping process must be conducted as required and that it would also improve the co-operation between the company and contract manufacturer. The packaging instructions described in the results are extremely useful for the company to apply for different types of products and most importantly for the packagers, as it applies to most of the products packed and shipped by the contract manufacturer.

The results managed to demonstrate that when determining and specifying packaging instructions for any transportation mode, such as road, rail, air and sea, hazards

during the transportation must be considered. This means that the research results described and explained what sort of packaging materials and securing methods must be used in a heavy-duty packaging and shipping process. Thus, it is essential for the company that same packaging instruction could be used for any new contract manufacturer. Hence, based on packager experience, the packager could easily be adapted to implement different products same packaging methods as required.

In terms of wooden materials used in packaging, the EU standards dictate the requirements and specifications of what sort of wooden materials could be used in construction as well as in the packaging industry. These standards were adapted to the packaging design and implementation.

It appears that the results achieved in this study was based on the results of the laboratory experimental and standards that determine the requirements of the wooden materials used in packaging. The requirement of the packaging materials which are specified in this research can be generalized for different types of products. The packaging instructions that are detailed in this research had already been implemented and used for other products. Generally, the results of this research are reliable and could be used for other products. All the calculation methods that implemented in this research (appendix 1 and 2) were used accordingly and the person in charge had already been checked it.

9 Discussion

The purpose of this study was to define packaging and shipping instruction for the case company based on product types. In addition, it had to specify the minimum requirements and specifications for the materials used in packaging. For the theoretical framework, literature sources and other sources from the internet were utilized in order to create a comprehensive plan that would benefit the research.

The research process was challenging and demanded enormous investigation to master the EU standards related to the packaging industry. However, conducting this research and delivering the results that the company demanded was a delightful expe-

rience. Thus, to a future Logistics Engineer, not every term related to packaging materials was familiar, and hence, it took a while to investigate them. This research provided good perspective to the packaging industry especially to heavy duty packaging, and it was helpful to go through the packaging processes, which would be invaluable in the future career-wise.

The research would have been more reliable, if the results had been gained based on practical use. However, they will be tested sooner rather than later, and it is very interesting to follow the results in terms of packaging functionality. Nevertheless, the results of this study are trustworthy and could be investigated furthermore in the future if requires.

The main challenge was how to limit the subject of the research, particularly woods which is used in packaging. Hours and hours were spent on studying the wood spices, strength classes and mechanical and physical properties. There is no standard requirement for wooden packaging except wooden materials which is used in packaging must comply with requirement of ISMP 15 which explained on this study, but there is EU standard (Eurocode 5) for wood materials which is used in construction industry. Hence, the wooden packaging materials must adopt and calculate according to Eurocode 5.

The theme of this research was challenging, but in the end, I was thrilled with the result I managed to deliver. It was fascinating to learn and go through new things, specially the wooden materials as it was not familiar. All in all, I am pleased with the results, particularly the packaging instructions which can be utilized for different packing purposes. As mention earlier, it would have been great to know more about wood mechanical properties in terms of specifying, calculating and determining the suitable wooden spices. Therefore, the result could be verified furthermore in the future by Eurocode 5.

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Appendices

Appendix 1. Parameters

Table 26 Parameters in the formulas

Symbol	Unit	Term
F_R	N	Restraining force of a lashing device
F_B	N	Blocking force
f_μ	-	Conversion factor
m	kg	Mass of the load
g	m/s^2	Gravitational acceleration
L	m	Lashing length
C_x	-	Longitudinal acceleration coefficient
C_y	-	Transverse acceleration coefficient
C_z	-	Vertical acceleration coefficient
μ	-	Friction factor
α	°	Vertical lashing angle
β_x	°	Longitudinal lashing angle
β_y	°	Transverse lashing angle
H/L		The ratio height H and length L which is a key value in the tables in forward and backward direction
H/B		The ratio height H and width B which is a key value in the tables in transverse direction
LC	kN	Lashing capacity of lashing device (1kN = 100 daN)
M_{max}	Nmm	Bending moment of support reaction
W_x	mm^3	Section modulus
a	mm	Cross-section of supporting beam
σ	N/mm^2	Tensile stress
σ_{c24}	N/mm^2	Strength class according to EN 338
σ_{pine}	N/mm^2	Pine strength class
n		Safety
n_{c24}		Safety to C24

Appendix 2. Lashing capacity calculation

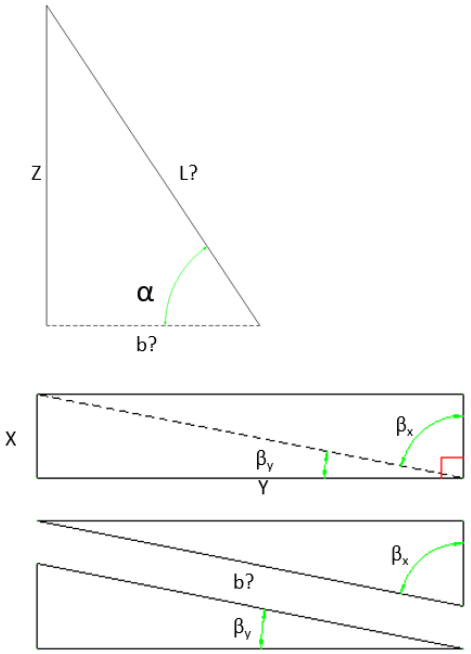

Figure 27 Triangles used in the calcultion

$$L = \sqrt{X^2 + Y^2 + Z^2}$$

X^2	0,2 m
Y^2	1,0 m
Z^2	2 m

$$L \sim 2{,}2 \text{ cm}$$

$$\text{b} = \sqrt{L^2 - Z^2} \sim 1{,}0 \text{ m}$$

For diagonal lashing

$$F_R = m * g \frac{(C_{xy} - \mu * f_\mu * C_z)}{2(cos\alpha * cos\beta_{xy} + \mu * f_\mu * sin\alpha)}$$

Longitudinal direction in road transportation

Forward

$$F_R = m * g \frac{(C_x - \mu * f_\mu * C_z)}{2(cos\alpha * cos\beta_x + \mu * f_\mu * sin\alpha)}$$

m	1551,1 kg
g	9,81 m/s^2
C_{xyz}	According to figure 5
Cosα	b/L = 62,98° = 0,45
$Cos\beta_y$	Y/b = 11,30° = 0,98
$Cos\beta_x$	90° - 11,30° = 78,69° = 0,19
Sinα	Z/L = 62,98° = 0,89
μ	0,3 (according to the figure 6)
f_μ	1,0 (for direct lashing)

$$F_R = \left(1551{,}1 \text{ kg} * 9{,}81 \frac{m}{s^2}\right)\left(\frac{(0{,}8 - 0{,}4 * 1{,}0 * 1{,}0)}{2*(0{,}45*0{,}19+0{,}3*1{,}0*0{,}89)}\right) = 10675{,}15 \text{ N} \sim 1068 \text{ daN}$$

Each lashing capacity must be 1068 daN

Backward

$$F_R = m * g \frac{(C_x - \mu * f_\mu * C_z)}{2(cos\alpha * cos\beta_x + \mu * f_\mu * sin\alpha)}$$

X^2	0,2 m
Y^2	1,0 m
Z^2	1,74 m
L	2,01 m
b	1,01 m
m	1551,1 kg
g	9,81 m/s^2
C_{xyz}	According to the figure 4
Cosα	b/L = 59,62° = 0,50
$Cos\beta_y$	Y/b = 11,30° = 0,98
Cosβx	90°- $Cos\beta_y$ = 78,69° = 0,19
Sinα	Z/L = 59,62° = 0,50
μ	0,3
f_μ	1,0 (for direct lashing)

$$F_R = 4250{,}507 \text{ N} \sim 426 \text{ daN}$$

Each lashing capacity must be 426 daN

Appendix 3. Bending calculation

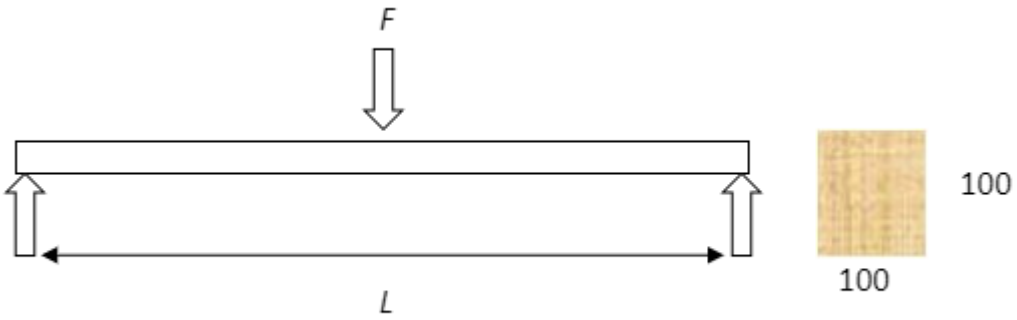

Figure 28 Free body diagram and support beam cross-section

m 1551,1 kg/2 = 775,55 Kg

g 9,81 m/s^2

L 1,5 m

F *m*g* = 7608,15 N

Maximum bending moment

M_{max} $\frac{FL}{4} = \frac{7608{,}15\ N * 1{,}5m}{4} = 2853{,}05\ \text{Nm}$

Section modules

a 100 mm

W_x $\frac{a^3}{6} = \frac{(100mm)^3}{6} \sim 167 * 10^3 mm^3$

Load stress

M $2853{,}05 * 10^3\ \text{Nmm}$

W_x $167 * 10^3 mm^3$

σ $\frac{M}{W_x} = 17{,}35 \frac{N}{mm^2}$

According to EN 338

Bending of C24 is used. C24 = 24 N/mm^2 (including safety factor, because according to Pine bending stress PUUINFO 87 N/mm^2)

$$n_{c24} = \frac{\sigma_{c24}}{\sigma} = \frac{24\ \frac{N}{mm^2}}{17{,}35\frac{N}{mm^2}} = 1{,}38$$

$$n = \frac{\sigma_{pine}}{\sigma} = \frac{87\ \frac{N}{mm^2}}{17{,}35\frac{N}{mm^2}} = 5{,}01$$

According to EN 338, the structure allows 24 N/mm2, so the beam/runner could resist.