Final report

From 8, September of 2025 to 17, December of 2025

CHEVALIER Luc

ZWINGER Manuel

Construction Lab Safety Boost - building solutions for a safer construction lab

Construction laboratory (Technobothnia)
Puuvillakuja 3,
65200 Vaasa

Coach of the project: **Mikael Renlund**

Acknowledgements

For being able to be here in Finland and to have the opportunity the be in the EPS Program, we would like to thank all the people who made this possible. It is a great experience and a pleasure to be here. We earned so many impressions and it is just recommendable to do a EPS semester to everyone who is interested.

We would like to thank Mikael Renlund, our Coach. With all his advice, help and constructive criticism we were capable to proceed. With his support we could improve ourselves and our work.

Also, our special thanks go to Mikael Ehrs. for its management of the EPS program within Novia University of Applied Sciences and therefore make it possible for students like us.

We are as well grateful to our students in the EPS Program for the helpful discussions and their assistance to organize numerous aspects of the project. Some of them became real friend with whom we shared many moments, whether professional or not.

Further, we are thankful for the help of our teachers. We learned a lot about the support work that is necessary around the actual one.

Finally, we would like to say thank you to our families, friends, and all those who supported us privately. Especially with their moral encouragement and financial help.

All these people made our Erasmus experience in Finland, the land of a thousand lakes, very enjoyable.

NOVIA UNIVERSITY OF APPLIED SCIENCES

TECHNOBOTHNIA

Table of contents

1 Foreword

As part of an exchange semester at Novia University of Applied Sciences in Vaasa (Finland), we, Luc Chevalier and Manuel Zwinger, are participating in a project entitled “Construction Lab Safety Boost - building solutions for a safer construction lab” carried out within the framework of the course European Project Semester (EPS). This project takes place in the Construction Laboratory of Technobothnia, a shared facility dedicated to education and research in civil engineering.

1.1 European Project Semester (EPS)

The first European Project Semester (EPS) project took part in 1995 and was organized by Dr. Arvid Anderson in Denmark. More than 20 years later, the EPS is provided by 19 universities all over Europe. It was mainly organized for engineering students to practice their skills for their future work in companies and in multinational teams. Every student who has finished at least two years of study is encouraged to apply for the EPS. During the EPS, the students will be divided in multinational teams, which leads automatically to English as the spoken and written language. The focus lays on teamwork. Besides that, the EPS covers many different fields of skills, which can be seen below [Jorgen Hansen, 2017].

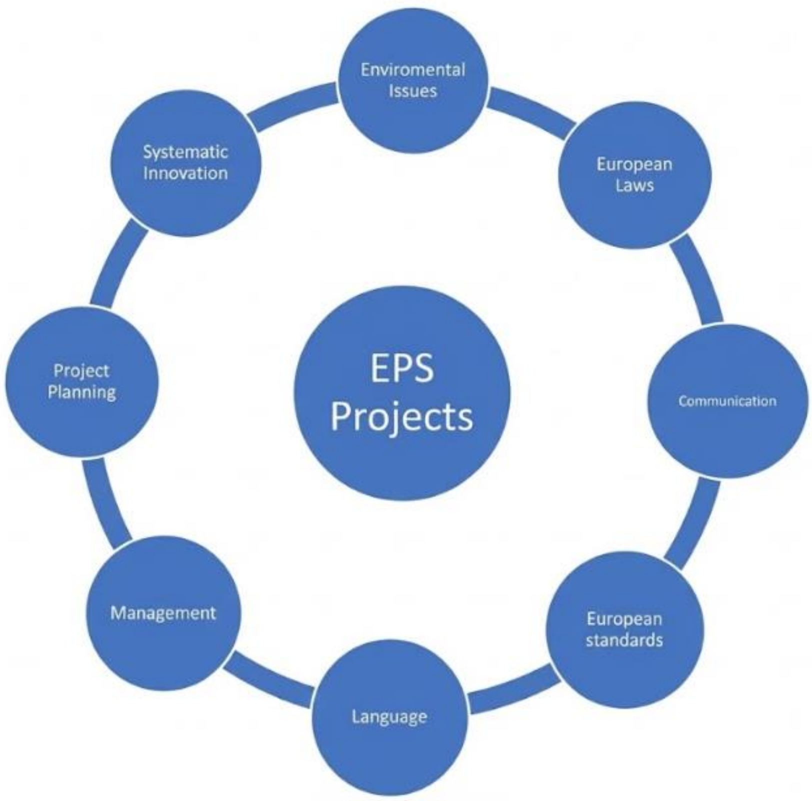


Figure 1: Diagram of the EPS Project

By being part of the EPS, the students have to grow together as a team to solve the various engineering problems. Students improve their English skills and work (mostly) on subjects they have not dealt with before. The support throughout the entire project is huge. Next to the project work, students have courses in the local language to keep also in touch with the real life in the country every day. They are followed by a supervisor (a coach), often a professor of the hosting university, that guarantees their perfect orientation, the achievement of the project and a complete improvement of the competences that are important for the jobs they will perform in the close future.

1.2 The Team

The project team consists of a multi-disciplinary and multi-cultural team. Exceptionally, the group consists of only two people. Both members of the group aspire to become mechanical engineers. Everybody of them will provide his own competences useful for the attainment of the main goal.

Name: Luc Chevalier

Date of birth: 03/02/2004

Country, city: France, Tarbes

University: UTTOP Ecole Nationale d'Ingénieurs de Tarbes

Degree: Mechanical and Industrial Engineering

Contact: luc.chevalier@edu.novia.fi

"I chose the EPS program because I didn't want my Erasmus experience to be like regular lectures, sitting and listening to a professor in front of me. I think EPS is really the right choice for me, especially to improve my English."

Name: Manuel Zwinger

Date of birth: 19.11.2000

Country, city: Germany, Osnabrück

University: Hochschule Osnabrück University of Applied Sciences

Degree: Mechanical Engineering (Bachelor of Science)

Contact: manuel.zwinger@edu.novia.fi

"My motivation for joining the EPS program was to improve my ability to work effectively in teams and enhance my collaboration skills for future engineering projects. I was also inspired by the opportunity to visit a Scandinavian country like Finland during the winter, experiencing both its culture and unique environment. Finally, I wanted to engage in intercultural exchange, learning from diverse perspectives and broadening my understanding through international cooperation."

As mentioned previously, each project is "monitored" by a coach. For this project, the coach is Mikael Renlund, head engineer of the construction laboratory within the Technobothnia group (group of different laboratories). He is also, in a way, the customer of this project because he created the project and the contributions made by this project will directly impact him since he is the main user of this laboratory. Therefore, he is not simply an intermediary, he has the final say on decision-making.

2 Presentations of the Construction Lab (Man/Luc)

2.1 Presentation of Technobothnia

At the Palosaari campus in Vaasa, Technobothnia is Finland's newest and most flexible laboratory complex for engineering education and applied research. It combines in a single building two dozen laboratories in a wide range of technical fields, from mechanics and energy to electronics, automation, and construction engineering.

The center is jointly owned by three institutions of higher education:

- Novia University of Applied Sciences
- Vaasa University of Applied Sciences (VAMK),
- The University of Vaasa

In collaboration, they have the aim to merge expertise, facilities, and resources into a multidisciplinary environment to create real industrial conditions. The philosophy of Technobothnia is to give students and researchers access to state-of-the-art equipment and to experiential learning, as well as enhancing co-operation with home country based and foreign companies.

Technobothnia plays a two-fold role in this context: it functions as both an experimental learning space and a research and development facility. Engineering students gain practical experience through conducting experiments, materials testing, and building prototypes, and businesses can benefit from applied research as well as through the testing services after experimentation, materials testing, and building prototypes. This integration feeds into the Vaasa innovation cluster, which is a region renowned for its industry and energy cluster.

Figure 2: Main Entrance of Technobothnia

2.2 Introduction to the Construction Laboratory

Of the many facilities located in Technobothnia, the Construction Lab is the location to go for research and testing of building material, structures, and civil engineering systems. It is a teaching and experimental environment in which students can explore how material behaves under different conditions and how construction systems behave when subjected to varying stresses.

The mission of the Construction Lab is to close the gap between theory and practice. Students in the civil, environmental, and survey engineering programs use the facilities regularly to perform experiments that reinforce their theoretical knowledge. They are taught to carry out standard tests, analyze results, and implement them in design and construction operations.

Figure 3: Picture 1 of the construction laboratory

In addition to playing a supporting role in education, the Construction Lab is also an active partner of the local and regional construction and infrastructure industries. Construction companies and infrastructure businesses often collaborate with the laboratory to do material testing, product verification, or specific research studies. This bridges the gap between student education and professional practice further, providing real-world relevance to the students' training as well as to the local economy.

2.3 Laboratory Activities and Specializations

The Construction Laboratory facilities and equipment are primarily dedicated to education in construction engineering but also employed in research work and in other related programs such as environmental technology and geotechnical engineering.

Most of the activities of the laboratory can be distinguished into three groups. The first one: educational experiments, students' laboratory experiments to apply theoretical concepts to fields such as materials science, structural analysis, and building physics. The second one is analysis and testing: mechanical and environmental testing of materials and components for industrial or educational use. And the last one is development and innovation: small-scale developments, such as design and prototyping of building or safety systems (for example, the Safety Screen 2.0 developed in this project).

The laboratory holds a large range of measuring and testing instruments, and so accurate and trustworthy analysis becomes feasible. Some of the most significant equipment includes:

- Compression and tension test rigs for the testing of building materials.
- Building physics measuring equipment, used in heat, moisture, and acoustic performance studies.
- A fire furnace, which enables controlled fire testing of elements in buildings.
- Geotechnical gear, including soil compaction, permeability, and bearing capacity testing gear.
- Concrete preparation and testing gear, used in mixing, curing, and testing the strength of concrete specimens.
- Various small-scale gear and measuring equipment are used in different teaching modules.

Each of these resources contributes to making the laboratory an integrated learning environment, in which students can see and interact with real materials and phenomena rather than relying only on theoretical models.

2.4 The Construction Laboratory in more Detail

Due to the diversity of experiments and tests conducted, the Construction Engineering Laboratory is not confined to a single room but distributed across different adjacent rooms. Each section serves a specific field and is equipped with its own apparatus individually designed to suit its field of research. Together, these rooms form a cohesive and efficient whole that enables education, research, and project work.

The laboratory can be broadly divided into three main sections:

- The Concrete Laboratory,
- The Geotechnical Engineering Area
- The Fire Technology Section

All of these go to make the Construction Lab generally very versatile and allow different areas of construction engineering to be studied in a lab-based setting.

2.4.1 Concrete Laboratory

The Concrete Laboratory is the largest and most actively used area of the Construction Lab. It comprises a number of rooms, one central hall (F6P21, every number of room are in this format) and five ancillary rooms (F6P41, F6P33,F6P31, L-A room, changing room and others too, but they are service or cleaning room). This arrangement allows for multiple operations to be carried out simultaneously, from preparation of materials to mechanical testing of hardened concrete specimens.

Figure 4: One of the map of the Construction Laboratory

2.4.1.1 Concrete Laboratory Room (F6P21)

Concrete Laboratory is the name of the central main hall. There are the heavy-duty machines such as compression and tension testing machines, which are used to test the mechanical properties of concrete cubes or cylinders. You can also find tools for working with wood such as a circular saw, measuring tools such as a scale and storage for sand, rubble, etc… This room contains a restricted-access area with machinery that should only be used by qualified personnel. This area is where compression tests, for example, are performed.

Figure 5: Picture 2 of Construction Laboratory

2.4.1.2 Storage Room (F6P41)

Room F6P41 is specially dedicated to the storage and maintenance of machines that can be used by hand (drills, grinders, etc.). Inside you can find a small milling machine, screws, clamps, pencils, tape, a tool for rethreading and all the necessary equipment related to the world of construction. This is an important room for the proper functioning of the laboratory, and its access is limited. Indeed, for security and theft reasons, only a very limited number of people have access to this room.

Figure 6: Picture of the Storage Room

2.4.1.3 Concrete Mixing Room (F6P33)

Room F6P33 is a multi-task room. It houses a concrete cutting machine, a concrete mixer, a vibrating table, Personal Protective Equipment (PPE) cabinet (ear protection, safety glasses, gloves and dust mask) and more. It is a very useful room when students are making and mixing concrete. Along with the main room, it is one of the most used rooms in the lab.

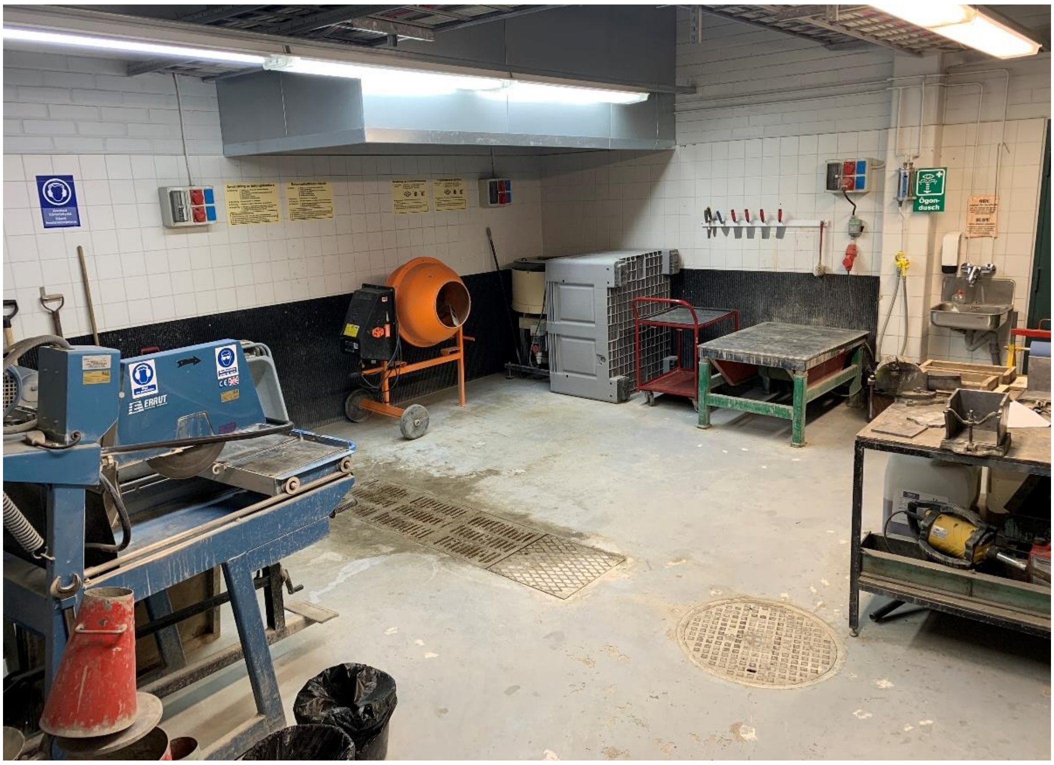


Figure 7: Picture of the Concrete Mixing Room

2.4.1.4 Changing Rooms

The laboratory also houses two changing rooms. These are used by students and staff before accessing the work areas. Safety shoes and overalls are available for students. They include benches, toilets and showers, allowing for comfortable change and preparation. This space helps maintain cleanliness and safety in the laboratory. Safety is a very important point, which we will return to later in this report.

Figure 8: Picture of Changing Room (men)

2.4.1.5 Sieving Room (F6P31)

F6P31 is a room that initially allows for the storage of chemicals in large cabinets. To perform different tests, ovens of different sizes can be found with different temperature ranges. And finally, a shaker machine allows to determine the particle size and distribution, to classify soils and identify their behavior.

Figure 9: Picture of the Sieving Room

2.4.1.6 The Los Angeles Room

The L-A room is named like this because of one of the machines they own: the Los Angeles abrasion testing machine. It is used in laboratory tests with students, but under laboratory personnel supervision. Other machines and equipment can also be found in this room.

Figure 10: Picture in the Los Angeles Room

All these rooms transform the Concrete Laboratory into an interdisciplinary facility for studying building materials, from raw materials and mix design to testing and analysis. The space is used not only to perform standardized tests and not only concrete testing but also with other materials such as steel, aluminum, composite materials, etc. In fact, the material limits are the specifications of the machines.

2.4.2 Geotechnical Engineering Area

Figure 11: Picture of Geotechnical Area

The Geotechnical Engineering Field focuses on the study of soil behavior, stability, and foundation design. This field provides students with hands-on experience on how ground conditions influence structure design and safety.

The geotechnical laboratory is equipped with specialized machines and testing devices used for standard geotechnical laboratory investigations. All equipment is located in a dedicated room, the geotechnical room (F4P54).

The laboratory enables students to connect theory with practice through tests such as permeability and capillary rise tests on aggregates, shear tests on clay (fall cone, vane shear, direct shear, and triaxial tests), Proctor compaction tests, and particle size analyses using sieving and hydrometer methods. Additional tests include water and organic content determination and Los Angeles abrasion tests. The facility is also used for student projects and research related to soil behavior and foundation materials.

2.4.3 Fire Technology Section

The Section of Fire Technology is committed to the study of building materials under fire conditions. In it is a man high fire furnace, that can reach temperatures of a thousand degrees. The furnace allows controlled burning tests to evaluate the performance of building materials and elements under high temperature conditions. Tests are required in order to have a grasp of fire safety in building construction and to ensure that materials comply with European and Finnish fire protection standards. The fire technology section is in a room which is a little bit separated of the rest of the lab.

Figure 12: Picture of the Fire Technology Section

Apart from its educational role, the Fire Technology Section is also available for cooperation with local companies, where they can use it for product testing or verification of performance. Furthermore, all the equipment in the construction laboratory can be made available to companies. Indeed, these companies can request a partnership with the laboratory engineer and thus work together to gain access to specific, non-common machines. For the students, this opens a possibility to participate in applied projects that have an obvious effect on enhancing building safety.

3 Presentation of the project

3.1 Introduction

The construction laboratory was transferred to Technobothnia after the 1995 renovation, but many of the machines currently in use are significantly older. Laboratory safety has gradually been affected by long-term resource constraints and changes in staffing levels. Although the Technobothnia laboratory is jointly operated and funded by three universities, the construction laboratory has its own operational management structure, as owned by Novia. Shared cost-saving measures across the organization have resulted in limited capacity for continuous updates of procedures. Consequently, several procedures have not been revised in line with current practices, and the overall safety level no longer fully aligns with modern expectations.

Today, the situation represents a clear need for improvement: some machines are somewhat outdated or not properly maintained, documentation is incomplete, and safety practices do not fully align with current regulations or best practices: the construction laboratory need a general “safety boost”. This why the exact name of the project is “Construction Lab Safety Boost - building solutions for a safer construction lab”.

So, a new momentum is emerging. This movement also stems from the lab's new engineer, Mikael RENLUND. He understands and values the importance of safety aspects. The time has come for a comprehensive and ambitious safety upgrade, the one that will modernize the laboratory and bring its safety management back to the level it deserves.

3.2 Project objectives

After the project teams were formed, the first "official" meeting with the members of the new project team was held on September 8, 2025. During this meeting, the project objectives were defined. What does Mikael want? How? Why? Does it comply with the law? Following a thorough and lengthy tour (necessary for a clear understanding of the project objectives) of all the rooms in the construction laboratory, the work areas were established. Simultaneously, the project objectives were defined.

These objectives are divided into two main categories:

- Primary (major) objectives: These are the ones on which we must focus as a priority.
- Secondary objectives: These are the ones the team should consider only if sufficient time and money are available.

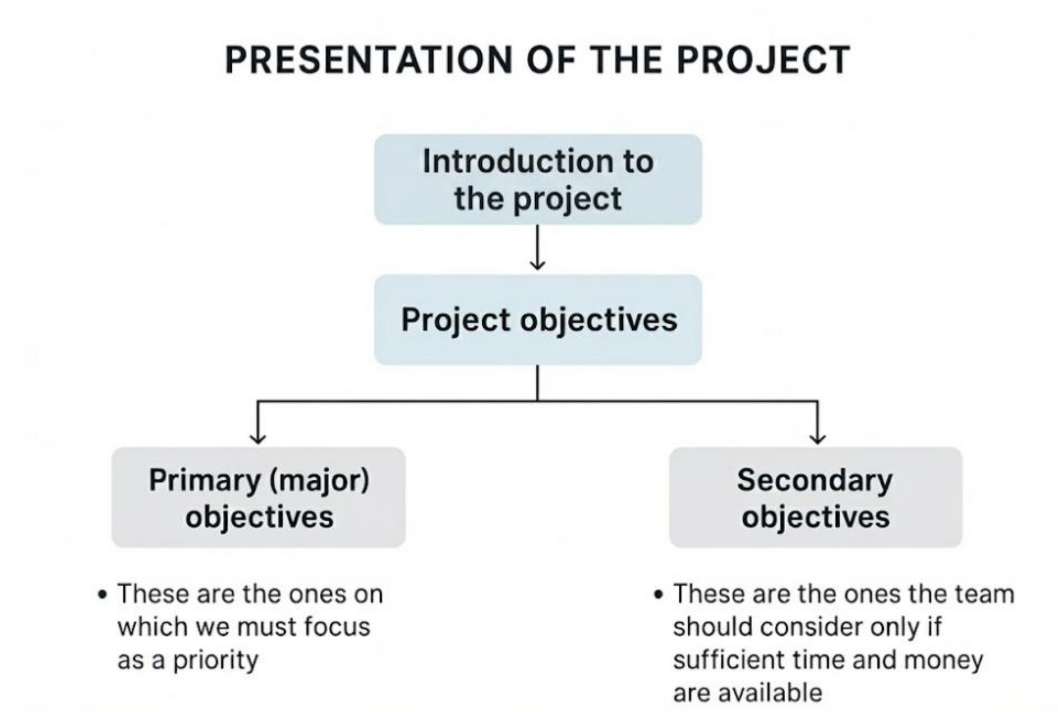


Figure 13: Presentation Diagram

3.2.1 Primary objectives

The primary objectives represent the core tasks of the project. They define the essential goals that must be completed to ensure the success of the Construction Lab Safety Boost. These objectives were identified as mandatory and directly aligned with legal requirements and the expectations of the laboratory engineer.

These objectives (or work areas) are:

- Getting familiar with the lab
- Analysis of laws and standards related to workplace safety
- Risk assessment
- Improvement plan
- Protective screen
- Laboratory map

3.2.2 Secondary objectives

The secondary objectives include additional tasks that may further improve the safety and usability of the laboratory. These objectives will be addressed depending on the time, resources, and budget available after completing the primary objectives (as previously mentioned).

These secondary objectives (or work areas) are:

- Signage
- Short machine instructions
- Chemical products
- Organizational system
- Machine instructions

This second list is by no means exhaustive, as numerous objectives were added or modified as the project progressed, particularly during the review of laws and standards (see the chapter "Laws and Standards Analysis"). These secondary objectives could be the subject of work by a future European Project Semester, for example (see further down in the *4.3 Laws and standards analyze* chapter).

3.3 Deliverables

The project is divided into two main parts:

- The first part consists of research, analysis, and the creation of reference documents. This is the theoretical phase of the project, during which the foundations for all practical actions were established.
- The second part focuses on practical implementation, including fabrication, material purchases, and the concrete application of the measures defined during the theoretical phase.

All project deliverables were produced, reviewed with the coach's comments, and then submitted in their revised and final versions. Many of these deliverables are not only essential for this project but will also serve as valuable resources for future teams working on the Construction Laboratory.

During the first part of the project, several theoretical deliverables were required. For instance, after analyzing the laws and standards, a summary document titled *"Room-level safety requirements - Laws and Standards analyze report"* was created. This document is crucial because it defines the recommended actions that the laboratory needs for safety improvement in accordance with relevant legal and technical requirements. It also forms the basis on which all practical improvements were planned.

Theoretical deliverables produced include:

- Room-level safety requirements based on the analysis of laws and standards
- Machine-level risk assessments
- Purchase lists and material specifications

Practical deliverables include:

- Laboratory map
- Safety screen
- The poster “wearing safety shoes is mandatory in this facility“

In addition to the technical deliverables, the EPS Program also requires several academic outputs. The team produced a Mid-Term Report and a Mid-Term Presentation (presented on 20 October 2025), which allowed the supervisors and all the EPS Program people (for example, the others person of the others group, Mikael Ehrs, responsible the EPS program in NOVIA and others people who are interested). to assess the progress of the project at its halfway point. At the end of the program, the team will deliver a Final Report and a Final Presentation (scheduled for 17 December 2025), summarizing all the work completed and the results of the project.

Figure 14: Picture of Mikael Ehrs

3.4 Project limitations

As with any engineering project, this work has been executed under given conditions that accordingly influenced the planning, workload distribution, and the pace of progress. During the whole project, there were two main limitations identified.

3.4.1 Team size: a two-person Project

The project was carried out by a team of only two students. This ensured efficient communication and a consistent vision throughout the work but also greatly limited the total available manpower compared to larger teams.

Figure 15: Picture of the Team

Tasks that normally might be divided up among several people on a team, such as the research of laws and standards, the writing of room-level requirements, machine-level risk assessments, documentation tasks, and deliverables development, were completed by only two individuals. This often entailed careful time management, prioritization of tasks, and sometimes adjusting the scope of the work to what was realistically achievable within the EPS timeframe.

This is one of the reasons why not all the tasks initially planned by the coach could not be completed, although the main work was delivered.

3.4.2 Budget Constraints

For the project, a limit of 1000 euros was set by the coach. In reality, this limit did not pose any constraint in developing the project, as all the materials, tools, and components necessary were well within this range. The most significant costs for the practical part of this project, especially the protection screen, were limited and will be further elaborated upon in the relevant chapter.

However, even though the budget was sufficient, it still had an impact on decision-making: every practical solution had to remain simple, at low cost, and well justified. More advanced or expensive options were not considered, not because of necessity but because they would have been incompatible with the philosophy and constraints of an EPS student project.

3.5 Why choose this Project

This project will provide an opportunity for hands-on experience in the safety engineering area, combining real lab work with the study of laws, standards, and risk analysis. It enables the student to work on concrete safety issues firsthand, furthering improvements that make the laboratory even safer for all. The outcomes of this project will be long-standing and will continue benefiting future students for years to come. Beyond this, the project is also an excellent way of building up important problem-solving, collaboration, and practical design competencies valuable in any type of engineering career. Its versatility between theory and practical implementation makes it a particularly enriching and meaningful learning experience.

4 Development of the Work carried out

4.1 Introduction

The work performed during this EPS is detailed in this part of the report. Sub-chapters represent the main areas of work for the project, which can be called "phases". It covers preliminary investigations, the analytical phases, and practical implementations that formed the practical deliverables at the end. Each section outlines the adopted approach, methods used, and results obtained to give a general overview of the development process that shaped the Construction Lab Safety Boost project.

4.2 Preliminary work: getting familiar with the Laboratory

4.2.1 Participation in Courses held in the Laboratory

Observations of several classes conducted inside the facility were carried out to understand the operation of the Construction Laboratory and its machines under normal conditions. These observations made it possible to see how students position themselves around machines, how they move during demonstrations, and how teaching activities are organized in practice. This early immersion proved to be enlightening with regards to the daily use of the laboratory, including regular behaviors and ways of circulation that could pose certain safety hazards with regard to crowding, visibility, or proximity to hazardous equipment. This observation step is important to understand how the construction laboratory work in global.

Figure 16: Picture 3 of the Construction Laboratory

4.2.2 Online research on laboratory machines

Since a lot of machines used in the laboratory were rather old, the associated documentation was missing or unavailable. Therefore, a parallel work of online research was conducted, based on photos and visual observations of the machines, in order to identify the equipment and gather technical information from online sources. Of course, nowadays, AI is very present in people's lives. An AI like Perplexity (there is also ChatGPT or Google Gemini if it's asked), which directly cites its internet sources in its responses, is very useful because it's easily verifiable. This AI tool is even more practical when searching on older, less common machines, such as the Amsler compression testing machine, which is a German old non-common machine.

Figure 18: Logo of Perplexity

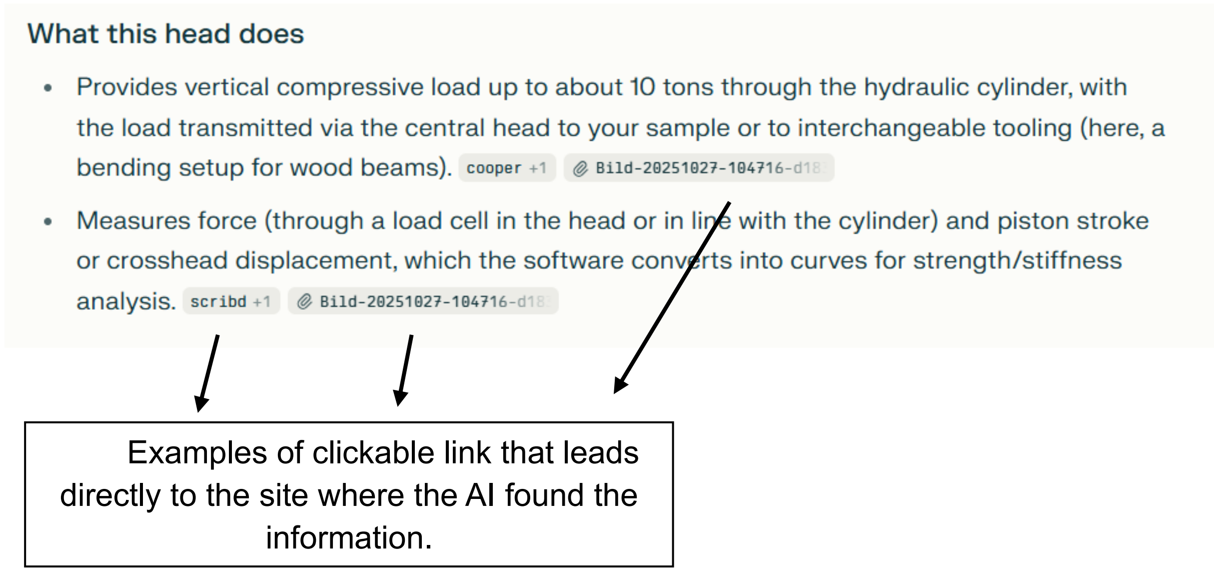


Figure 17: Example of the Output of Perplexity

4.2.3 Interviews with staff (Mikael Renlund)

Weekly meetings were carried out with Mikael Renlund (of course the subject of the meetings wasn't only this), the laboratory engineer, in order to get more detailed information regarding the history, equipment, and known safety issues of the laboratory. For instance, in an exchange, Mickael R. provides the specifications of the Fiskars traction and compression testing machine.

Because several of the machines were unfamiliar, with incomplete documentation, explanations from Mikael regarding their function, operating principles, and associated hazards were frequent. These clarifications were necessary to understand each machine before conducting the analytical phases of the project. Questions regarding the laboratory have also been conducted by tool such as Microsoft teams which is very practical to share documents or to stay in contact.

4.3 Laws and Standards Analyzation

4.3.1 Introduction

Before any practical improvement could be made in the Construction Laboratory, it was crucial to establish exactly what legal and normative requirements apply to this environment. Because many of the machines are old and their documentation is either missing or incomplete, and several of the safety procedures haven't been updated for many years, the first step needed for this project had to be a detailed study of the laws and standards related to workplace safety.

This analysis formed the basis for the entire project. Thus, it was ensured that everything done during the EPS-from signage to risk assessment and protective equipment, right to the design of the safety screen-was in full compliance with the applicable regulations. In order to keep the analysis clear and effective, it was solely based on six key documents: three Finnish laws and three international standards. The documents were chosen because they directly address the core elements of the project, which include workplace environment requirements, machine safety, and risk assessment methodology.

Figure 20: Logo of the Finnish Government

Figure 19: Logo of the ISO

4.3.2 Documents used (three Law and three Standards)

Finish laws

The project took place in Finland and the construction laboratory is also in Finland so the finish is applicable to this place. The following three laws were recommended by the coach. Having lived in this country for almost 40 years now, he is better able to advise on the selection of official documents, such as the following:

1. **Government Decree on the Safe Use and Inspection of Work Equipment** (403/2008; amendments up to 1095/2029 included)

The general duty of the employer to ensure safe working conditions is defined by this Act. It includes duties on hazard prevention, risk assessment, training, and supervision of workers, workplace organization, prevention of accidents, and the general duty to ensure a safe working environment.

2. **Government Decree on the Safety of Machinery** (400/2008; amendments up to 1095/2029 included)

This decree sets out the requirements for the safe use, maintenance, and periodic inspection of work equipment. It includes rules on suitability of equipment, maintenance records, inspection intervals, operator competence, and procedures that make sure work equipment remains safe during its whole lifecycle. This decree addresses the safety requirements for machinery used in the workplace.

3. **Occupational Safety and Health Act** (738/2002; amendments up to 222/2023 included)

This is applied even to the older machines found in the laboratory. It covers protection devices, emergency stops, electrical safety, stability, documentation, guarding, noise, ergonomics, and general requirements for the reduction of mechanical risks.

4.3.2.1 International Organization of Standardization (ISO standards)

ISO standards are globally recognized guidelines that ensure safety, quality, and efficiency. They harmonize technical requirements, guaranteeing that products and services meet the same high standards worldwide. These are THE standardization benchmarks worldwide, and if they are not respected, it must be strongly justified. Just as with laws, the coach advised us to study three standards that are related, directly or indirectly, to the safety of a work area.

4. **Safety of machinery: General principles for design, risk assessment and risk reduction** (ISO 12100:2010)

ISO 12100 is the international reference for machinery safety and defines a structured method to manage risks. In this project, it guided the identification of hazards, the assessment of their severity and likelihood, and the implementation of measures to reduce risks to acceptable levels. It provided the basis for all machine-level risk assessments, ensuring consistency with international standards (topic covered in the following section *4.4 Risk assessment).*

5. **Safety distances to prevent hazard zones being reached** (ISO 13857:2019)

EN ISO 13857 sets minimum safety distances to prevent access to hazardous areas and protect body parts such as hands, arms, and legs. It has to be used to define guard dimensions, barrier spacing, and exclusion zones around machines, ensuring ergonomic safety and minimizing the risk of injuries.

6. **Guards: Requirements for the design and construction of fixed and movable guards** (ISO 14120:2015)

EN ISO 14120 specifies requirements for designing and building guards, including strength, materials, openings, mounting, and overall protection performance. It was particularly relevant for the protective screen designed in this project, ensuring effective protection against mechanical hazards while meeting safety standards.

4.3.3 A Three-Level Safety Structure in the Form of a Funnel

Before presenting the issues identified in the laboratory and the solutions implemented to mitigate them, it is important to explain how the safety documentation for the Construction Laboratory was developed. When the EPS group arrived in September, a document containing the general safety instructions had already been made by the laboratory engineer.

This initial document establishes the mandatory safety rules and internal regulations required to use the Technobothnia construction laboratory, operated by Novia University. It provides a detailed assessment of the main hazards (physical, chemical, fire-related). It also defines strict conduct requirements, including the mandatory use of personal protective equipment (safety shoes, goggles) and the obligation to work under the supervision of a responsible person for any activity. Finally, every user must sign these instructions to confirm that they have read and understood the risks and procedures before accessing the facilities. Overall, this document serves as a general and introductory safety guide for all laboratory users.

Following Mikael's recommendations, the EPS group produced two additional documents to continue and deepen the laboratory's safety analysis. The first expands upon the initial safety guidelines by identifying the risks and corresponding preventive measures at the level of each individual room. This document is titled *Room-Level Safety Requirements – Laws and Standards Analysis Report*. The second document conducts the same type of analysis but at a more detailed scale, focusing on each machine within the laboratory. This report is titled *Machine-Level Risk Assessment Report*.

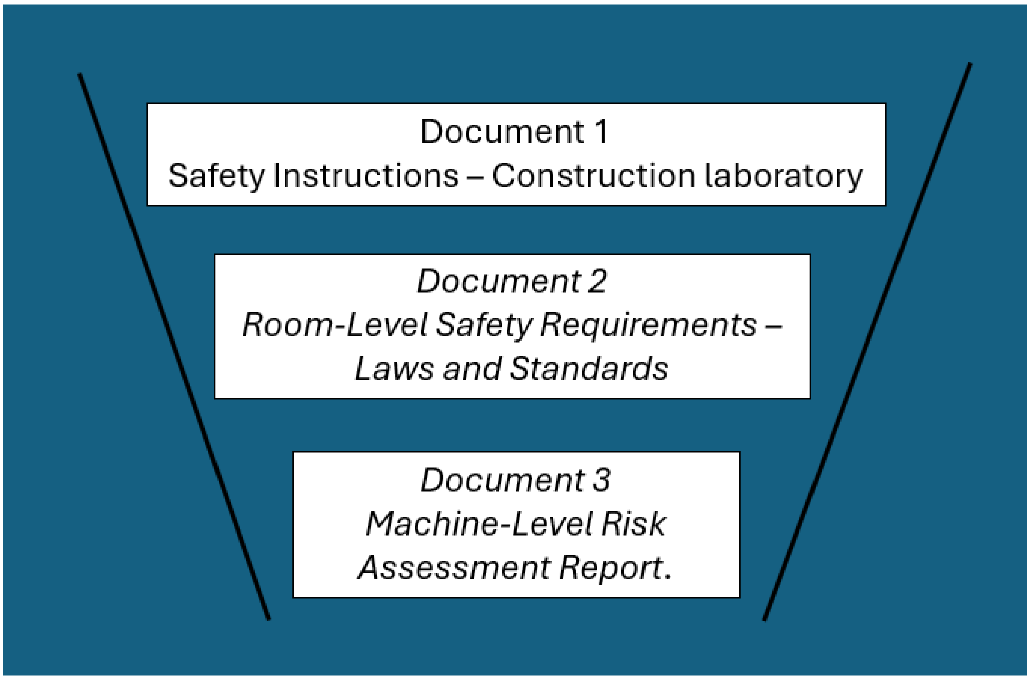


Figure 21: Visualization Funnel Shape of the Document Structure

The hierarchy between these three documents is intentional and follows a funnel-shaped structure. The analysis begins with the laboratory as a whole, then narrows down to each room, and finally focuses on the specific risks associated with each machine. This hierarchical approach ensures a clear, logical, and structured understanding of the safety requirements in the laboratory, making the overall safety framework both comprehensive and coherent.

The remainder of this chapter will focus on the creation of the second document, which was created following an initial analysis of the laws and standards.

4.3.4 Room-Level Safety Requirements (Second Level of the Funnel)

Once the existing general safety instructions were reviewed and the legal foundations clarified through the six documents presented in the previous section, the next logical step was to analyze safety at the room level. This intermediate scale is essential because Finnish law requires that risk prevention measures must be adapted to the specific characteristics of each workplace, not only to general principles.

> Employers have a duty to take care of the safety and health of their employees while at work by taking the necessary measures. For this purpose, employers shall consider the circumstances related to the work, working conditions and other aspects of the working environment as well as the employees' personal abilities.

Figure 22: Extract from the Section 8 laws 738/2002

As previously mentioned, the Construction Laboratory is composed of several rooms with very different functions, equipment, environmental conditions, and hazard types. For example, the concrete mixing room presents risks related to dust, noise, and rotating machinery, the fire technology area contains high-temperature equipment, vibrations, and compacting machinery and the central hall hosts high-force testing machines and restricted-access zones. Because of this diversity, a universal general instruction sheet is not sufficient to guarantee the safety of all users.

The goal of the *Room-Level Safety Requirements – Laws and Standards Analysis Report* was therefore to translate the legal obligations into precise and room-specific measures. To do this, each room was inspected individually, and hazards were identified based on the laws and standards previously analyzed. The following figure present the elements that were systematically examined:

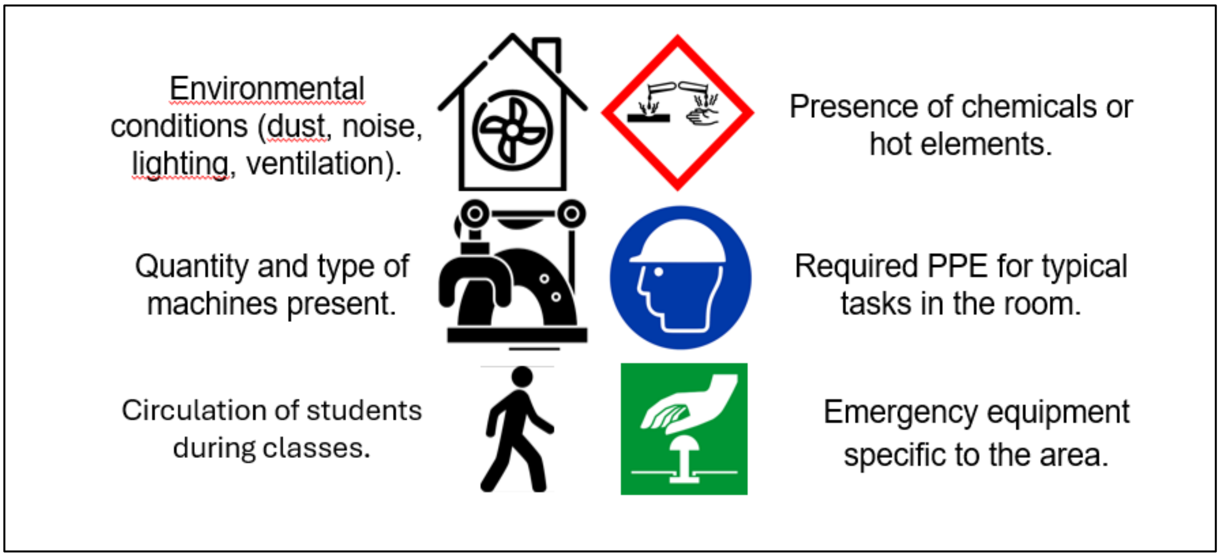


Figure 23: Elements that were systematically examined for each room

Based on these observations, the group developed targeted requirements for each space. Examples include mandatory dust masks in F6P33 during using the concrete mixer, install taping in the Los Angeles machine room, and special attention to heat-related hazards in the fire technology section.

4.3.4.1 Example

Let's take the sieving room as an example. This room has a unique feature: it also houses the laboratory's chemical storage. A specific issue related to this feature has therefore been identified in the room. Identified specific issue:

Specific issues

- Chemical cabinet is no longer compliant (ventilation, material, labeling issues)

Figure 24: Extract from the chapter 3.3 of the room-level risk requirement document (P12)

After identifying the issues, laws and standards provide requirements based on the identified risk. Risk requirement identified for the specific issue:

Specific risk requirements

- **Replace the Chemical Cabinet**
  A modern, ventilated cabinet with correct hazard labeling must be installed.
  Legal basis: OSH Act §38; Decree 403/2008 §7 (markings & safety devices).

Figure 25: Extract from the chapter 3.3 of the room-level risk requirement document (P13)

The document create is called *Room-Level Safety Requirements – Laws and Standards Analysis Report*: The entire document is broken down as follows: an introduction, a summary of the laws, a summary of the standards, an enumeration of the issues and then an enumeration of the risk requirements.

4.3.5 Conclusion

A full document called *Room-Level Safety Requirements, laws and standards analysis* report is the result of this work. It interprets the six reference documents into concrete safety measures applicable to each room of the Construction Laboratory. It intends to perform a clear and structured interpretation of legal and normative obligations, making them usable in daily laboratory operation. Thanks to such an approach, the safety requirements pass explicitly to the level where real activities take place: the rooms. The results/conclusion of this analyze of standards and laws are available in annex 1.

It is at this stage that the analysis naturally goes to the next step. The standards examined more in details, especially ISO 12100 emphasize that beyond room-level commitments, a comprehensive risk analysis is also necessary at each machine level in accordance with the Finnish *Occupational Safety and Health* Act (738/2002, Section 10). This type of machine-level analysis would go into details about mechanical, electrical, thermal, and operational risk and on each machine that is considered dangerous and/or use in classes with the students.

4.4 Risk assessment

This step focuses on identifying specific mechanical, electrical, thermal, and operational hazards directly linked to machine operation. It is also essential because several machines in the Construction Laboratory are old and lack updated documentation, making a structured evaluation necessary to maintain safe usage during teaching activities.

This is the aim of the third document (see figure 21 in funnel shape) which bears the name of *Machine-Level Risk Assessment Report* (in the

4.4.1 Methodology

To ensure the safety of the laboratory equipment, the group followed the structured approach defined by the SFS-EN ISO 12100 standard. This method takes place in two successive phases: risk assessment, followed by risk reduction if necessary (it's the same process as for the room-level risk requirements in the previous chapter). First, the EPS team carried out a risk assessment. This involves identifying potential hazards on the machine (such as moving parts or hot surfaces) and then estimating the severity and probability of possible damage. This analysis allows to decide whether the current risk is acceptable or if it must be reduced. To help the group in this identification task, the standard lists a very wide range of hazards

When the risk is judged too high (*See the chapter 4.4.4 Risk matrix)* for how the risk level was assessed), we apply the risk reduction strategy required by the standard (*clause 6.1, SFS-EN ISO 12100, P22*), called the "three-step method." These steps must be followed in a specific order:

- Step 1 (Inherently Safe Design): Modify the machine's design itself to eliminate the danger (for example, reduce power or speed).
- Step 2 (Safeguarding): If the danger cannot be eliminated by design, protective devices (guards, barriers) or safety components (sensors, emergency stops) must be installed.
- Step 3 (Information): Finally, for the remaining risks, users must be informed via warnings, pictograms, and training procedures.

All this process is described in writing, but also more visually through the workflow in annex 2 which is an extract of the standard also.

In the context of this laboratory, the machines are already designed, manufactured, and installed. It is therefore impossible for us to intervene on Step 1 (internal design) without modifying the machine's function or canceling its manufacturer's warranty. Consequently, our safety work focuses directly on Step 2, by adding external protective measures where necessary, and on Step 3, by improving signage and safety instructions for operators. The standards also provide us with indications on how to avoid or counter this or that risk.

4.4.2 Machines

A preliminary step in conducting a risk assessment at machine level is to identify the machines themselves on which the assessment is being carried out. In this way, fourteen major machines were identified (some are duplicate). Small handheld machines (such as drills, angle grinders, etc.) are excluded from this list because the risk is considered low and they are covered as part of the general premises safety assessment. The purpose of this document this to demonstrate the detailed risk assessment for each identified machine. So which are these machines? Here is the list with the exact name of the machines but for more details, annex 3 is few pages with each machine and a little utility explanation text:

- Fiskars traction and compression testing machine
- Amsler compression testing machine
- Errut concrete cutter
- Esko concrete mixer
- Weissberger vibration table
- Scanteknick MR-3 Shaker
- Nabertherm Type L9/C6 Furnace
- Genlab MINO/50/SS Oven
- Bosch Professional GCM table saw
- L.A. abrasion testing machine
- SARLIN Furnaces Type 1250H 666-90

4.4.3 Identified Hazards

The objective is to list all potential risks associated with the use of the machine, not only for the people operating it but also for those nearby (it is very important to consider these individuals, as there may be up to 25 students around the machine at any given time). To ensure that no hazards are overlooked, the standard, as mentioned previously, provides a large number of the main hazards that can be encountered on virtually all machines (see annex 4 which is an extract from the ISO 12100 standard). These hazards are classified by category (for example: mechanical hazards, electrical hazards, thermal hazards, etc.).

In addition, the standard also provides recommendations for actions to counter/limit these hazards. These can include protective screens, installing pictograms, installing an emergency stop button, etc.

4.4.4 Risk Matrix

The hazards have now been identified, and the standard requires them to be classified by level. This will subsequently be called the risk level (R). In this way, a hierarchy is imposed in the way risks are treated, since risks will be of varying levels.

The method used to determine the risk level (**R**), combining severity (**S**) and probability of occurrence (**P**) is not defined in the standard but relies on a qualitative risk assessment (discussion between the two members of the EPS group). It is described by the following formula:

$$\boldsymbol{R} = \boldsymbol{S} \times \boldsymbol{P}$$

The result can be used with the following figure:

Severity (S)	
1	Minor
2	Serious
3	Severe

X

Probability of occurrence (P)	
1	Rare
2	Possible
3	Frequent

=

R	Interpretation
1 to 2	Low
3 to 4	Medium
6 to 9	High

Figure 26 : Method for the risk analyze

This method (of risk estimation), while not defined by the standard, is nevertheless used by some companies and is very common. Our source is the following website: https://www.vectorsolutions.com/resources/blogs/levels-of-a-risk-matrix/.

4.4.5 Risk Assessment Document

The risk assessment for each machine is presented in tables (one per machine) with seven columns (see figure 27 below). These tables list the names of the identified hazards along with their respective categories. Next comes an example of a situation in which the risk could occur, followed by the means to mitigate the risk. The second set of columns corresponds to the risk matrix part and therefore includes severity, probability, and risk level.

Hazard category	Hazard	Description of hazardous situation	Severity (S)	Probability (P)	Risk level (R)	Risk reduction measures (with normative references)

Figure 27 :Names of the column of the tables of the Risk Assessment

This structured format not only ensures consistency with ISO 12100 but also makes the document very practical to use. The goal was that, the laboratory engineer can use this document as a basis for planning future safety improvements or deciding which machines require updated instructions or additional guarding and same for the document mentioned in the last chapter (*4.3 Laws and standards analyze*).

Above and beyond the practical utility of this, the machine-level risk Assessment report also played a direct role in guiding the next steps of the project. Several machines showed a recurring risk pattern: possible projection of fragments during compression or cutting operations, combined with the presence of students standing close during demonstrations (see on figure 28 an extract of the risk assessment of the Fiskar traction and compression testing). According to both ISO 13857 (safety distances) and ISO 14120 (guarding requirements), such risks must be controlled through physical protective measures whenever elimination through design is not possible.

Mechanical	Ejection hazard	Specimen or fragments may eject when it breaks under tensile load or compression.	Severe (3)	Possible (2)	High (6)	Transparent fixed guard or impact shield (ISO 14120, ISO 14119). Pictogram "Warning – flying objects" (ISO 7010 – W021). PPE: safety goggles (EN 166). Define safety distance (ISO 12100 §6.3.2).

Figure 28 : Example of a Row in the Risk Assessment

This observation had been guessed by the coach and naturally led to the design and implementation of the safety screen, a modular protective barrier intended to shield students and operators from flying debris during testing operations. The risk assessment tables clearly pointed out which machines this measure was highly needed for-specifically, the Fiskars traction and compression testing machine-and therefore served as the technical justification for developing this solution.

The risk assessment tables for each machine are visible in annex 5 and allow you to see the measures to be put in place in the laboratory to have a healthy and safe environment.

4.5 Protection Screen

4.5.1 Objective

The protection screen is designed with practical usability and safety in mind. Its primary objectives are:

- **Ease of handling:** The screen must be light enough to be carried and positioned by a single person, ensuring flexibility and quick deployment in different work environments.
- **Material choice:** Constructed primarily from wood, the design balances sturdiness with cost-effectiveness, while also allowing straightforward fabrication and repair.
- **Structural strength:** The screen must be sufficiently robust to withstand typical mechanical stresses, providing reliable protection without compromising portability.
- **Visibility:** A large integrated window ensures clear observation of processes, enabling operators to monitor equipment and experiments without exposure to risk.
- **Versatility of use:** The screen is mainly intended for application with the Fiskars press but also in the fire laboratory and at other occasions, making it a multi-purpose safety device that supports both mechanical testing and laboratory experiments.

Together, these objectives ensure that the protection screen offers a practical, durable, and cost-efficient solution, while maintaining operator safety and usability across different testing environments.

4.5.2 Research for the Protection Screen

4.5.2.1 Introduction

The design and implementation of protection screens represent a critical aspect of occupational safety in the construction laboratory. These barriers are intended to safeguard personnel and equipment from hazardous impacts, ranging from high-velocity concrete particles to larger flying samples generated during testing or processing. Establishing appropriate standards for protection screens is therefore essential, ensuring that safety measures are not only consistent but also scientifically validated.

A central challenge in this field lies in quantifying the forces exerted by different types of projectiles. Concrete particles, due to their density and irregular shape, can create significant localized stresses upon impact, while larger samples pose risks of broader structural damage. Understanding these forces provides the foundation for determining the minimum thickness and material properties required for effective screens.

Industry practices further highlight the role of specialized companies in defining protective specifications. By combining empirical testing with international standards, these organizations establish guidelines that balance safety, cost-efficiency, and usability. This research article explores the interplay between standards, impact forces, and industrial decision-making, with the aim of clarifying how protection screen thickness is determined and how these measures contribute to comprehensive risk reduction strategies.

4.5.2.2 Standards

Additional guidance for protection screen design and verification can be found in **ISO 14120:2015 (SFS-EN ISO 14120)**, which specifies the *general requirements for the design and construction of guards* as well as the *permitted methods of verification*. This standard provides a framework for ensuring that protective structures meet consistent safety criteria across industries as mentioned before in chapter 4.3 Laws and Standards Analyz. The official e-paper version is available through the ISO online browsing platform.

These are some of the important segments of ISO 14120:

Clause / Subclause	**Title / Purpose**	**What it Requires (Paraphrase)**
5.4 — Materials, rigidity and impact requirements	Ensuring guards are strong enough, rigid, suitable materials	Guards shall resist foreseeable static and dynamic forces (pressure, impacts). Materials for viewing panels must be suitable to resist mass & velocity of ejected objects.
5.4.2 — Impact and ejection resistance	Specific requirement to design guards so they can withstand/contain impacts / ejection	The guard shall, "as far as practicable," be designed to withstand and contain reasonably foreseeable impacts and ejections. Viewing panels need special material / mounting treatment.
5.4.4 — Secure fixing	How guards are attached / fixed so they stay in place under loads	Guard or parts shall be secured by fixings (bolts, clamps, welds, adhesive etc.) of adequate strength, spacing & number so that under any foreseeable loading or impact they remain in place.
6 — Selection of types of guards	Choosing guard type (fixed, movable etc.) based on hazard, frequency etc.	Guards are to be selected based on risk assessment; if frequent access required, movable guards; if not, fixed guards; also guard types according to size/number of hazards etc.
7 — Verification of the safety requirements for guards	How to verify that guard meets requirements	Subclauses: general; impact strength; safety distances; containment; noise; guard operating forces. You must verify via test, calculation, or other acceptable method.
8 — Information for use	What instructions/documentation must accompany the guard	Information to users: correct installation, removal, inspection, maintenance; hazards associated with guard; how to use guard safely; limits of guard, etc.

4.5.2.3 Research for Forces created by Concrete Particles

The following research is based on following sources:

Topic	Reference
Concrete strength ranges (15–150 MPa)	Engineering Toolbox; Eurocode 2 strength classes
Stress–strain & strain at failure ($\varepsilon \approx 0.002–0.003$)	ACI 318; Eurocode 2
Fracture energy / energy partition (1–5 % to kinetic)	Carpinteri A. *Scaling of energy dissipation in crushing and fragmentation*; Ouchterlony F. *Swebrec function*
Fragment velocity ranges (10–118 m/s under dynamic loading)	Fan Y. et al., 2023 – UHPC fragment velocity study
Impact contact time (5 ms)	Sun, B., *Hertz elastic dynamics of two colliding elastic spheres* (2020)

4.5.2.3.1 Assumptions for Fragment Motion

- Specimen height = 0.20 m
- Compressive strain to failure ≈ 0.002–0.003 → displacement = 0.4–0.6 mm
- Work ≈ Force × Displacement → tens to hundreds of joules stored elastic energy
- Only 1–5 % of that work becomes kinetic energy of fragments (based on brittle fracture energy studies)
- Representative fragment mass = 10 g (0.01 kg)
- Impact contact time = 5ms

4.5.2.3.2 Path of Calculation

- assumed piston area: $A = \pi \cdot r^2$
- applied force by the press: $F = \sigma \cdot A$
- displacement of specimen: $\delta = L \cdot \varepsilon$
- applied work by the press: $W = F \cdot \delta$
- possible kinetic Energy: $E_{kin} = \frac{1}{2} \cdot m \cdot v^2$ (assumption of 1–5 % of work)
- Converting equation to speed: $v = \sqrt{\frac{2 \cdot E_{kin}}{m}}$
- Impact Force: $F_{impact} = m \cdot \frac{v}{\Delta t}$

4.5.2.3.3 Constants used

Symbol	Meaning	Value
d	piston diameter	0.20 m
r	radius	0.10 m
$A = \pi \cdot r^2$	piston area	0.03 m² (exact 0.03142 m²)
L	specimen height	0.20 m
ε	compressive strain	0.002–0.003
$\delta = L \cdot \varepsilon$	displacement	0.0004–0.0006 m
m	fragment mass	0.01 kg
Δt	impact contact time	0.005 s

With some research and estimations about the applied forces of a hydraulic press, the probable speed and weight of a concrete part, this table could be created. It shows some estimations of the impact force on to the protection screen.

Concrete Type	Strength (MPa)	Pressure (bar)	Total Force (N)	Force (tonne-force)	Estimated E_kin to Fragments (J)	Fragment Velocity (m/s)	Impact Force*
Low-strength concrete	15	150	471 000	48 t	2–5 J	20–32 m/s	40–80 N
Normal structural concrete	25	250	785.000	80 t	3–8 J	25–40 m/s	50–100 N
High-quality structural conrete	35	350	1.099.000	112 t	5–10 J	30–45 m/s	60–120 N
High-strength concrete	60	600	1.885.000	192 t	10–25 J	45–70 m/s	90–200 N
UHPC	150	1500	4.712.000	480 t	30–60 J	75–110 m/s	150–300 N

*Impact force ≈ (momentum change over 5 ms contact) → $F \approx m \cdot v/\Delta t$. For m = 0.01 kg and Δt = 0.005 s, $F = 2 \cdot v$ approximately (so 20 m/s → 40 N, 100 m/s → 200 N).

4.5.2.4 Conclusion for Forces created by concrete particles

Normally a hydraulic press can reach a maximal pressure of 350 bar. Therefore, the calculation of the High-quality structural concrete might be the most reasonable. With this in mind, a 10g fragment can reach a maximal force of 120N. Higher forces could occur because of heavier fragments, but it is unclear if this is the case. More information are needed.

4.5.2.5 Specific information needed for better calculation

- Press piston diameter
- Height of specimen
- Type of concrete that are tested
- Fragment examples?

4.5.2.6 Final Verdict for Forces created by concrete particles

The calculations carried out did not meet the intended objectives. Due to miscommunication and a misunderstanding of the initial requirements, parameters were selected that did not reflect the original request. Consequently, the resulting values cannot be applied to the analysis of the protective screen and should not be used for decision-making.

4.5.2.7 Investigation of the Forces generated by flying Samples

4.5.2.7.1 Physical Formulas

The press force is: $F = m \cdot a = 10.000 \text{ kg } \cdot 9.81 \text{m/s}^2 = 98{,}100 \text{ N}$.

Elastic energy stored (approximation using a spring/work assumption):

$$E = \frac{1}{2} F \Delta x$$

where Δx is the distance (m) the system compresses/deforms before sudden release.

If that energy converts to kinetic energy of a whole sample (mass m):

$$E = \frac{1}{2} m v^2 \Rightarrow v = \sqrt{\frac{2E}{m}}$$

If the sample then stops over distance d(shield or body stopping distance), the average impact force would be:

$$F_{\text{impact}} = \frac{E}{d}$$

Average deceleration is calculated with this formula:

$$a = F_{\text{impact}}/m$$

and stopping time (approx) with this:

$$t_{\text{stop}} = v/a$$

4.5.2.7.2 Assumptions used

- All stored elastic energy released converts to the sample's translational kinetic energy (this is an upper bound — in reality some energy goes into deformation, heat, etc.).
- Press max force $F = 98{,}100$ N (metric tons → N).
- Compression (deformation) before sudden release: tested values Δx =0.0001 m (0.1 mm), 0.001 m (1 mm), 0.002 m (2 mm). (These numbers could be replaced with measured values for higher accuracy.)
- Sample masses considered: 0.1 kg, 1 kg, 5 kg, 10 kg.
- Stopping distances considered: d = 5 mm — very short, e.g., hard impact / small embed, and d = 20 mm — softer stopping, thicker screen / some deformation.

4.5.2.7.3 Scenarios

A) $\Delta x = 0.1$ mm→ $E = 4.905$ J

mass (kg)	v (m/s)	F_impact (N) d=5 mm	t_stop (ms) d=5 mm	F_impact (N) d=20 mm	t_stop (ms) d=20 mm
0.1	9.90	981.0	1.01 ms	245.3	4.04 ms
1.0	3.13	981.0	3.19 ms	245.3	12.8 ms
5.0	1.40	981.0	14.3 ms	245.3	57.1 ms
10.0	0.991	981.0	31.0 ms	245.3	124 ms

B) $\Delta x = 1.0$ mm→ $E = 49.05$ J

mass (kg)	v (m/s)	F_impact (N) d=5 mm	t_stop (ms) d=5 mm	F_impact (N) d=20 mm	t_stop (ms) d=20 mm
0.1	31.6	9,810	0.322 ms	2,452.5	1.289 ms
1.0	9.90	9,810	1.01 ms	2,452.5	4.04 ms
5.0	4.47	9,810	4.56 ms	2,452.5	18.3 ms
10.0	3.13	9,810	9.90 ms	2,452.5	39.6 ms

C) $\Delta x = 2.0$ mm→ $E = 98.10$ J

mass (kg)	v (m/s)	F_impact (N) d=5 mm	t_stop (ms) d=5 mm	F_impact (N) d=20 mm	t_stop (ms) d=20 mm
0.1	44.3	19,620	0.226 ms	4,905	0.903 ms
1.0	13.99	19,620	0.712 ms	4,905	2.86 ms
5.0	6.26	19,620	2.50 ms	4,905	10.2 ms
10.0	4.43	19,620	5.03 ms	4,905	20.0 ms

4.5.2.7.4 Conclusion of the Forces generated by flying Samples

There are too many uncertainties for the calculation to be considered reliable. The issue of the safety screen tipping over is inherently dynamic, whereas the determined force values only reflect a static perspective. Applying these static results would lead to oversized or impractical foot dimensions that do not reasonably represent the actual conditions.

4.5.2.8 Using Polycarbonate (PC) as screen

Because the energy absorption capacity of polycarbonate depends on factors such as projectile geometry, impact velocity, and whether the material is laminated, two conversion approaches are applied.

- **PC thickness (mm) at 5 J/mm**: a conservative estimate, assuming relatively low energy absorption per millimeter.
- **PC thickness (mm) at 20 J/mm**: an optimistic estimate, reflecting laminated or higher-performing systems.

The required thickness is calculated using the relation:

$$\text{thickness}_{mm} \approx \frac{E(\text{J})}{\text{J/mm}}$$

With these assumptions, the before calculated Energy and a safety factor of 2, we can create following table:

Δx (mm)	E (J)	thickness if 5 J/mm (mm)	thickness if 20 J/mm (mm)	With safety factor ×2 for thickness of 20 J/mm
0.1	4.905	0.98 mm	0.25 mm	0.5 mm
1.0	49.05	9.81 mm	2.45 mm	4.9 mm
2.0	98.10	19.62 mm	4.91 mm	9.82 mm

4.5.2.9 Using PMMA (Plexiglas) as Screen

The protective properties of PMMA (Polymethylmethacrylate) are characterized by its impact strength. For cast PMMA tested at 23 °C, the typical *Notched Izod impact strength* is approximately 74 J/m. This value provides a benchmark for evaluating the material's resistance to sudden mechanical stresses and is widely referenced in material property databases such as the **AZoM Material Property Database** (AZoM, PMMA).

4.5.2.9.1 What does Notched Izod mean?

The Izod impact strength is the energy absorbed per unit width of the specimen that fails under a pendulum impact.

So:

$$\text{Energy per unit width} = 74 \, \frac{\text{J}}{\text{m of width}}$$

That means a PMMA specimen 1 m wide (through-thickness, per mm thickness) absorbs 74 J before fracturing at the notch.

For a more intuitive scale:

- Per millimetre of specimen width, $74\text{J/m} = 74 \times 10^{-3}$ J/mm $= 0.074\text{J/mm}$.

That's the energy per millimetre of specimen width before fracture (under notched Izod conditions).

4.5.2.9.2 Convert this to a usable "J per mm thickness" for a panel

The notched Izod test involves a beam of ~3 mm thickness and ~10 mm width. The result, 74 J/m, represents total absorbed energy per mm thickness per 1 m of width.

To approximate energy per area:

$$\text{Energy per area} = \frac{74\ \text{J/m}}{t}$$

with $t \approx 3\text{mm} = 0.003\text{m}$,
so $74/0.003 \approx 24{,}667$J/m² ≈ 24.7 J per mm² × 10^{-3} = 0.0247 J/mm².

That means roughly 0.025 J of energy absorbed per mm² of PMMA cross-section before cracking.

4.5.2.9.3 Use this to estimate required thickness (for a 1 m² area struck by sample)

To absorb a total energy E, the required *through-thickness area energy* product is:

$$E = (\text{Energy per area}) \times A$$

We can invert to get the required area (if one thickness of 3 mm cracks at 24.7 kJ/m²):

$$A_{\text{required}} = \frac{E}{24{,}667}$$

If the impact area is small, the local thickness must scale up inversely.

However, for practical shielding design it's easier to express this as energy absorbed per mm thickness for a 1 m² plate:

$$E_{\text{abs, per mm}} = 24.7\text{kJ/m}^2 \text{ per 3 mm} = 8.2\text{kJ/m}^2 \text{ per mm thickness}$$

Convert that to per mm of thickness per m² area:

$$8.2\text{kJ/m}^2\text{/mm thickness} = 8.2\text{J/mm}^2\text{/m}^2 = 8.2\text{J/mm of thickness over 1 m}^2\text{ area}$$

To get the total energy a 1 m², t-mm-thick sheet can absorb before fracture:

$$E_{\text{sheet}} = 8.2\text{kJ/m}^2\text{/mm} \times t(\text{mm}) \times A(\text{m}^2)$$

4.5.2.9.4 Apply of the energies

Let's assume the impact area is a circular contact of diameter 50 mm (0.05 m). That's $A = \pi r^2 = \pi(0.025)^2 \approx 0.00196$m².

To compute the required thickness t to absorb each energy before fracturing this formula is used:

$$t = \frac{E}{(8.2 \times 10^3 \text{J/m}^2\text{/mm}) \times A}$$

With this and the fact that for a real shielding design you apply a safety factor, often ×3 – ×5, we can create following table:

Δx (mm)	**E (J)**	**Nominal PMMA thickness from Izod (50 mm impact area)**	**With safety factor ×3**
0.1	4.9	0.3 mm	≈ 1 mm
1.0	49	3.0 mm	≈ 9 mm
2.0	98	6.1 mm	≈ 18 mm

4.5.2.9.5 Conclusion

The biggest uncertainty in this calculation is how much elastic energy is stored before release (i.e., the actual Δx). The compression/displacement should be measured on the setup for the specimen that is used – that directly scales energy linearly: doubling Δx doubles E.

Also, the stopping distance drastically changes peak force. Increasing stopping distance (thicker shield, energy-absorbing backing) lowers peak force roughly as $1/d$.

The calculated numbers are upper bound (we assumed *all* stored energy converts to the sample's kinetic energy). In real events, some energy is dissipated elsewhere, so actual speeds may be lower — but still hazardous.

For the PMMA, the thicknesses represent the approximate value at which PMMA would *begin to fracture* under a single impact of that stored energy, not necessarily stop or contain the projectile. Also, Izod values are measured under specific geometry (notched, pendulum) and strain rate; real high-velocity or mass impacts tend to deliver energy in a smaller area and cause catastrophic cracking well before full energy absorption.

In practice, the material differences between PC and PMMA mean that PC behaves very differently from PMMA when it is struck by a fast-moving object such as a flying test sample. Polycarbonate is a ductile material, which allows it to bend and deform under impact instead of shattering. When the material flexes, it absorbs a large portion of the kinetic energy and converts it into heat and plastic deformation. This deformation spreads the load over a longer time and distance, reducing the peak impact force. Even if it becomes cracked or deeply indented, a polycarbonate shield generally remains intact and continues to provide protection.

PMMA, on the other hand, is much more brittle under high-strain rate impact; it tends to crack or shatter rather than deform plastically. Therefore, in a real shielding design you'd apply a safety factor, often ×3 – ×5. It resists small loads well and maintains its shape until a critical stress is reached. Once that limit is exceeded, it fails suddenly by cracking rather than deforming. This brittle fracture releases the stored energy almost instantly and often causes the panel to shatter or break into large pieces. As a result, PMMA cannot absorb much impact energy and offers little protection against high-speed projectiles, even though it is clear and has good surface hardness.

The impact geometry (mass, velocity, shape of the sample) significantly affects how energy is transmitted into the shield. These calculations treat it as a point of mass impacting and stopping via uniform energy absorption; real conditions may vary.

4.5.2.10 How do companies choose the thickness of a protection screen?

4.5.2.10.1 Legal and regulatory framework

The **EU Machinery Regulation (EU) 2023/1230**, which will replace Directive 2006/42/EC as of January 2027, introduces updated requirements for the design and safety of machinery. According to Annex III, section 1.3.2, machinery must be constructed in such a way that operators are protected against the risk of ejected parts during operation. In this context, protective walls are classified as guarding devices under the regulation.

To demonstrate compliance, manufacturers must apply harmonized EN standards that cover the design, testing, and documentation of protective measures. These standards provide the technical framework to ensure that protective walls and other guarding devices meet the required safety performance and can be validated through recognized verification procedures.

4.5.2.10.2 Key technical standards

The design and verification of protective screens are governed by several harmonized EN ISO standards.

EN ISO 14120 – General requirements for guards
This is the primary standard for machine guards and protective enclosures. It specifies that guards must provide protection against ejected or detached parts, demonstrate mechanical strength through testing or calculation, and be mounted with appropriate safety distances. A key requirement is that the guard must withstand the kinetic energies of parts that could become projectiles during operation.

EN ISO 23125 – Machine tools (turning machines)
Although originally developed for lathes, this standard is widely applied as a reference for protection against ejected parts in hydraulic or mechanical test rigs. The concept involves defining a test projectile (commonly a steel cylinder or cube) and firing it at the protective screen with a specified energy level. The screen must not be perforated or shattered, and no fragments may pass through to the operator side.

The standard distinguishes between categories of protection:

- *Category A*: ≤ 20 J (small parts)
- *Category B*: 20-200 J (medium-size parts)
- *Category C*: > 200 J (large or heavy parts)

Hydraulic press testing typically involves energies in the range of 100–1000 J, which corresponds to Category B–C protection levels.

EN ISO 14119 – Interlocking devices
This standard applies when guards are equipped with doors or panels that include interlocking systems. Such devices must ensure that access to hazardous zones is prevented while the press or machinery is under load, thereby integrating functional safety with mechanical protection.

4.5.2.10.3 Material choice and performance (polycarbonate)

Polycarbonate (PC) is generally regarded as the standard material for protective screens due to its combination of mechanical and practical properties. It offers exceptionally high impact resistance (Izod > 800 J/m), remains transparent for visibility, is ductile rather than brittle (avoiding shattering under stress), and is both lightweight and easy to mount.

Laboratory data provide indicative values for its resistance to impact energies:

- A 6 mm PC sheet can withstand impacts up to approximately 120 J without perforation.
- A 10 mm sheet resists energies in the range of 250–300 J.
- Sheets of 12–15 mm thickness can withstand 500 J or more, depending on the mounting configuration.

It is important to note that the actual energy resistance of PC panels depends strongly on both the panel size and the stiffness of the supporting frame. Proper mounting is therefore essential to achieve reliable protection performance.

4.5.2.10.4 Test methods to verify protection

Manufacturers typically verify the performance of protective screens through a series of standardized procedures.

Projectile energy absorption test
A steel body of known mass (typically 1–5 kg) is launched or dropped to reproduce the expected kinetic energy, calculated as $½ m v^2$. The protective screen must not be penetrated, and only limited deformation is permitted.

Static load test (EN ISO 14120, Annex C)
A defined surface pressure, for example 1600 N, is applied to confirm the strength of the fixation and mounting system.

Documentation
A formal test report is prepared, recording the projectile mass, velocity, energy, observed deformation, and any cracking. This documentation provides traceability and evidence of compliance with relevant standards.

4.5.2.10.5 Typical design guidance

Use case	Kinetic energy (J)	Recommended PC thickness	Reference
Small specimens (< 0.5 kg, low velocity)	< 50 J	6 mm	EN ISO 14120
Medium specimens (1–2 kg, 10–20 m/s)	100–400 J	10–12 mm	EN ISO 14120 + 23125
Large fragments (> 5 kg, > 20 m/s)	> 1000 J	15–20 mm + steel frame	EN ISO 23125 / Machinery Regulation

Additional requirements:

- No gaps or unprotected joints.
- Panels easily replaceable after impact damage.

4.5.2.11 Final Verdict for the Protection Screen Research

The calculations performed could not be used for reliable decision-making, as the resulting numbers were not reasonable and were based on assumptions rather than validated parameters. Following a detailed discussion with the coach, it was agreed that a thickness of 8 mm is sufficient. This conclusion is supported by direct observation of an 8 mm example, which appeared sturdy enough to meet the intended protective function.

In addition to meeting the practical requirements, the 8 mm option is also more cost-effective. Opting for 10 mm thickness would significantly increase material costs and could exceed the available budget, without providing a proportionate improvement in safety performance. Therefore, the 8 mm thickness represents a balanced solution that ensures adequate protection while maintaining economic feasibility.

It should also be noted that the tests typically performed by companies are not feasible in this context. Standardized projectile and load tests require specialized equipment and controlled conditions that are not available for this project. As a result, practical observation and reasoned judgment were prioritized over formal test procedures in determining the appropriate thickness.

4.5.3 Design Phase

The design phase began with both team members independently creating initial sketches of the protection screen. These early drafts provided the foundation for discussion and comparison, ultimately leading to the decision to pursue a modular screen concept. The modular approach was chosen to ensure flexibility, ease of handling, and adaptability to different testing environments.

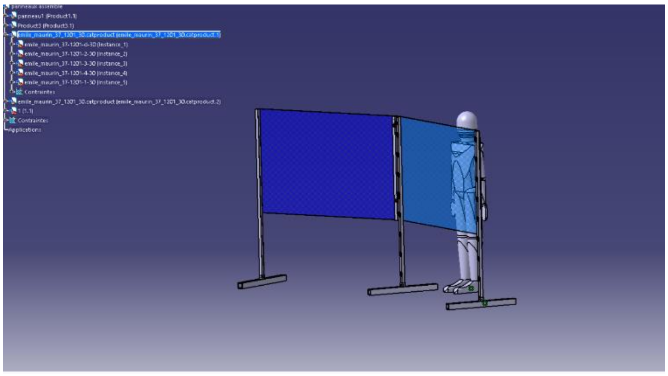


Figure 29 : Protection Screen Sketch Version 1

Once the concept was agreed upon, the sketch underwent multiple rounds of revision. The design was repeatedly adjusted and refined in response to feedback, particularly from the coach, who emphasized both practicality and safety. During this process, some miscommunication occurred, which led to further revisions of the sketch to ensure that all requirements were correctly understood and implemented.

4.5.3.1 Added and Changed Objectives in the Design Phase

During the design phase, several objectives were revised and new ones were introduced to better align the protection screen with practical requirements and available resources.

- **Material adjustments:** The column and frame were redesigned to be made from wood instead of hollow metal tubes. This change improved cost efficiency, simplified handling, and made use of readily available materials.
- **Extended coverage:** The protective screen was adapted to provide shielding from both sides of the Fiskars press, ensuring comprehensive operator safety.
- **Window construction:** The window frame was planned to be built from plywood slats cut from an existing plywood plate in the storage area, maximizing resource use and reducing material costs.

- **Mounting flexibility:** A moveable mounting point was added to the lower beam of the Fiskars press, allowing the screen to be positioned and adjusted as needed.
- **Tool-free assembly:** All components were designed to be mountable by hand and without tools, ensuring quick setup and easy relocation.
- **Minimal welding:** The design emphasized using the least amount of welding possible, reducing complexity and dependency on specialized equipment as requested by the coach.
- **Reuse of available beams:** The columns were specified to be constructed from a beam already available in the storage area, further supporting cost-effective and resource-efficient design.

These changes reflect the iterative nature of the design process, where objectives evolved to balance safety, practicality, and budget constraints. The revised goals ensured that the protection screen would be sturdy, adaptable, and feasible to construct with the materials and tools at hand.

This iterative approach required numerous meetings and considerable time investment before the sketch reached a stage where the coach was satisfied with the outcome. Despite the progress, some measurements remained incomplete at the end of the design phase. These details were intentionally deferred to the prototyping phase, where practical testing and adjustments could provide more accurate input.

4.5.3.2 Final Design

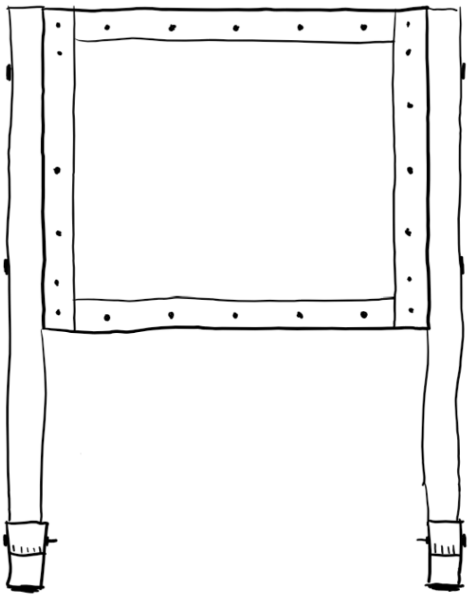


Figure 30 : Protection Screen Version 2

Further details on the final design can be found in ANNEX 6 : Sketch of Protection Screen 2.0.

The protection screen was conceived as a modular system to ensure flexibility, ease of transport, and straightforward assembly. The main protective element is a polycarbonate (PC) plate, chosen for its high impact resistance and transparency, which is securely attached to a wooden frame.

The frame itself is constructed from overlapping plywood struts, providing both strength and stability while making efficient use of available materials. This layered approach enhances rigidity without adding excessive weight, ensuring the screen remains sturdy yet manageable.

To further support modularity, the columns are designed to be detachable from the frame, allowing the screen to be disassembled into smaller components for easier handling and storage. In addition, the metal feet are detachable from the columns, enabling an even better storage capability.

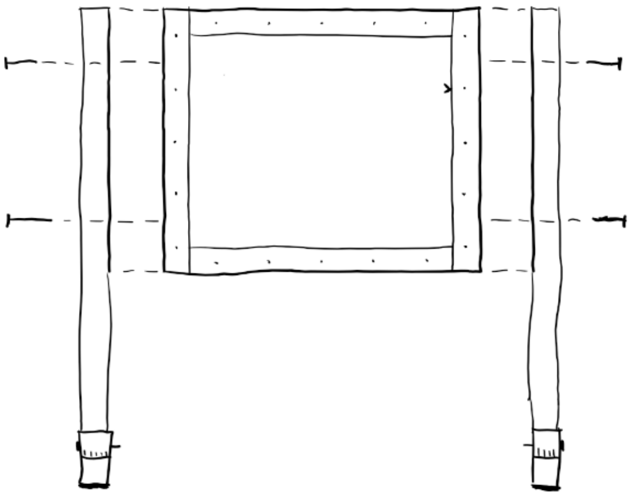


Figure 31: Protection Screen with Detachable Columns

To make the protection screen both practical and long-lasting, several design details were incorporated. The wooden frame is equipped with threaded wood inserts, allowing components to be mounted securely while also enabling repeated assembly and disassembly without damaging the structure. To further reinforce the frame, metal pipes were inserted into the mounting holes, preventing wear at critical points and thereby extending the overall service life of the screen.

Figure 32: Threaded Wood

In addition, the feet of the screen were lined with textile tape, ensuring that the screen can be repositioned without leaving scratches on the floor.

The protection screen is designed to integrate seamlessly with the Fiskars press through a dedicated mounting plate. The frame can be securely attached to this plate, ensuring stable positioning during operation while allowing straightforward installation and removal when needed.

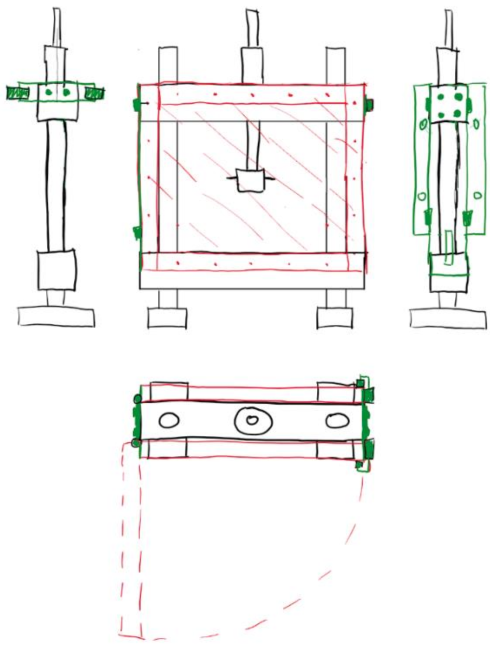


Figure 34: Protection Screens installed on the Fiskars Press

For operator convenience, the Fiskars press is equipped with vertical toggle clamps. This mechanism enables the screen to be opened quickly and easily, providing fast access without compromising safety. The clamp ensures reliable closure during use, while still allowing effortless release when the machine must be reached.

Figure 33: Vertical Toggle Clamp

To ensure secure and practical installation of the protection screen on the Fiskars press, an adapter plate is used in combination with the existing mounting plate. This adapter plate allows the lower part of the mounting plate to be fixed reliably, providing a stable connection between the press and the protection screen frame.

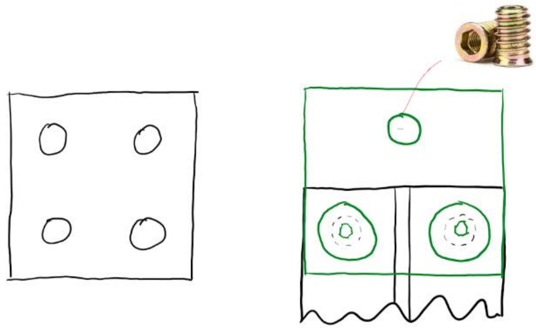


Figure 35: Sketch Distance Plate(left) and Adapter Plate(right)

In addition, a distance plate must be installed at the upper part of the mounting plate. The purpose of this plate is to create the necessary spacing that ensures proper alignment and overall mountability of the screen. By compensating for dimensional differences, the distance plate guarantees that the frame can be attached without distortion and remains functional during operation.

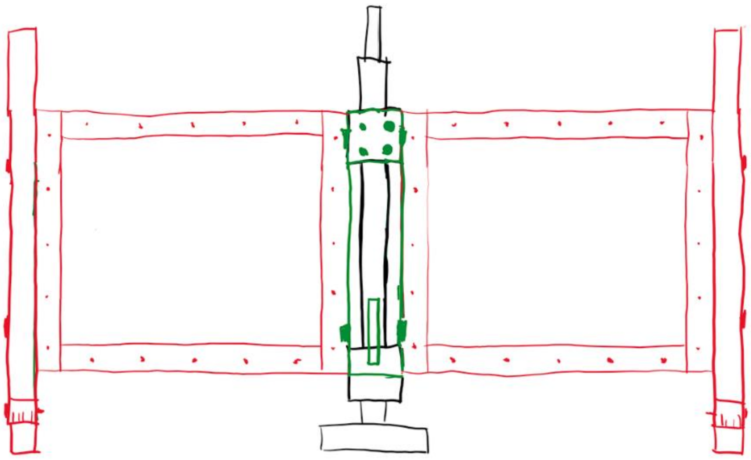


Figure 36: Sketch Protection Screens opened up and

During the design discussions, further improvements were identified to enhance both usability and safety of the protection screen. One desired feature is the ability to keep the protection in place while the Fiskars press is being opened, ensuring that operators remain shielded throughout the entire operating cycle.

To support flexible mounting, the columns are designed with long holes so they can be securely attached to the frame. These elongated slots also provide adjustability, allowing the screen to compensate for variations such as an uneven floor surface. This ensures that the screen remains stable and properly aligned regardless of the installation environment.

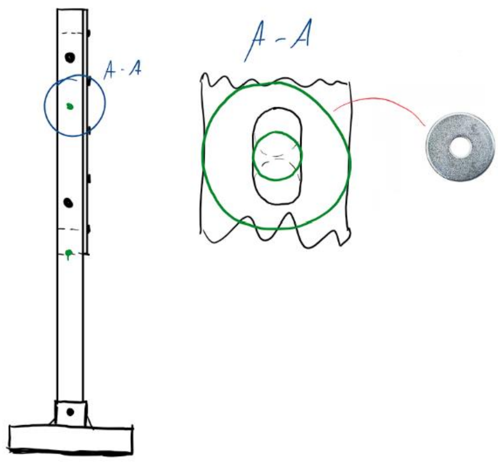


Figure 37: Protections Screen Sketch Side View

4.5.3.3 Communication Error and Resulting Misunderstanding

During the project, a communication error occurred that led to a significant misunderstanding. It was initially assumed that the design required two separate protection screens. In reality, the intention was to construct two window frames attached to each other as part of a single, integrated screen system.

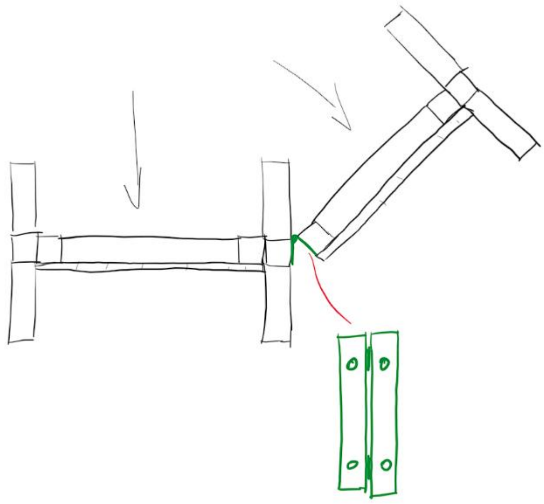


Figure 38: Hinge attachment for Protection Screen Sketch

This misinterpretation caused additional design work and revisions, as the team had to clarify the actual objective and adapt the concept accordingly. A solution was developed and documented, ensuring that the corrected design reflected the intended configuration. However, due to time constraints within the project schedule, there was no opportunity to implement the revised solution during the manufacturing phase.

The design was adapted so that the frames could be connected directly to each other. This connection was achieved by using plates with hinges as attachments, allowing the frames to be joined securely while still enabling movement and flexibility. With this approach, the frames could be adjusted as needed, ensuring both usability and safety.

4.5.4 Planning Phase

The construction process began with a dedicated planning phase, during which the key steps for building the protection screen were carefully prepared. A central task was the planning of plywood board cutting, ensuring that the available material could be used efficiently and that each component would fit the intended design.

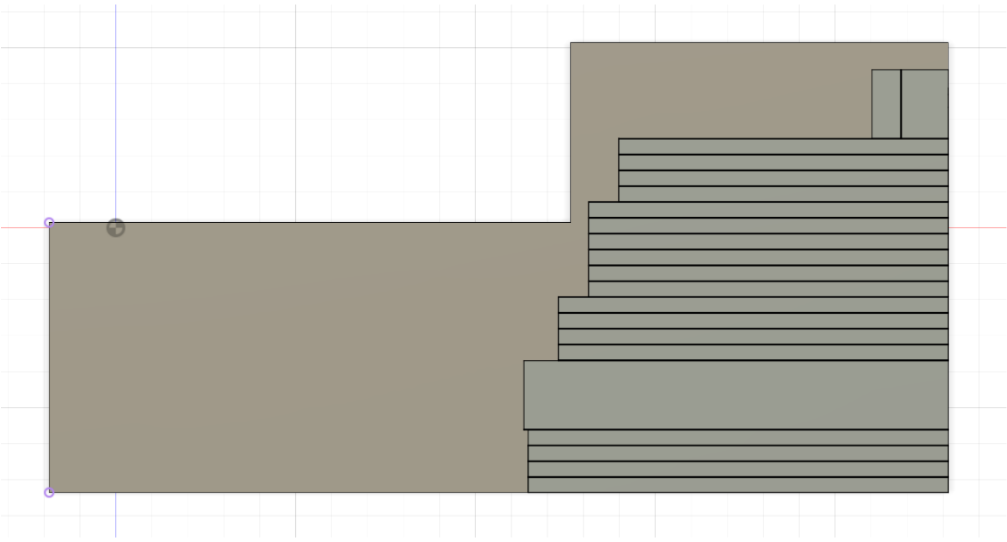


Figure 39: Plywood Cutting Plan

The cutting plan was created using the CAD software "Autodesk Fusion". This digital approach allowed precise visualization of the plywood board layout and ensured that material usage was optimized. By working in CAD, adjustments could be made quickly. Also, in developing the cutting plan, the thickness of the saw blade was carefully considered. Allowances were included for the kerf to avoid dimensional inaccuracies and ensure that each part would fit on the plywood board.

Further on, to achieve accurate dimensions, measurements for the individual parts and screws were taken directly at the Fiskars press. This ensured that the screen would align correctly with the machine and meet the practical requirements of its intended use.

In parallel, a ANNEX 7 : Part List was initiated, documenting all necessary components and materials. This list served as the foundation for organizing the construction process, helping to track resources and guide subsequent steps in prototyping and assembly. More information about the part list will follow in chapter Project Management

4.5.5 Prototyping and Manufacturing Phase

4.5.5.1 Prototyping Phase

The prototyping phase marked the transition into manufacturing, where the protection screen design was realized in practice. The screen was developed as a one-off construction, tailored specifically to the requirements of the Fiskars press.

During that, multiple versions of several components were produced to allow for testing and refinement. For example, two frames and three columns were manufactured, ensuring that variations could be compared directly during assembly.

This approach made it possible to identify weaknesses and improve the design in real time. By having more than one of each part available, adjustments could be implemented immediately, and the most effective solutions were carried forward. As a result, the parts were optimized during manufacturing, leading to a more robust and practical final construction.

Figure 40: Prototyping the column-feet ratio

Also, during the prototyping phase, several important construction decisions were finalized to improve the stability and usability of the protection screen. One key step was determining the ratio between the columns and the feet, ensuring that the screen would stand securely and maintain proper balance during operation.

In addition, the number of screws used to build the window frame was adjusted directly during manufacturing. This change allowed the frame to be assembled more efficiently while still providing sufficient strength and rigidity. By refining these details in practice, the team was able to optimize the design and adapt it to real workshop conditions.

4.5.5.2 Manufacturing Phase

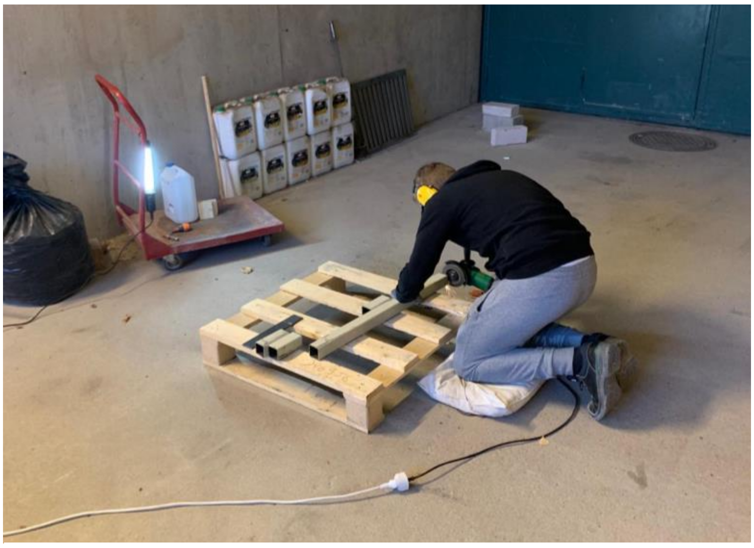


Figure 41: Manuel Z. cutting hollow steel sections

At the start of the manufacturing phase, a significant amount of preparatory cutting was carried out to produce the necessary components for the protection screen. This step ensured that all raw materials were available in the correct dimensions before assembly began.

The following parts were cut and prepared:

- Hollow tube pipes, serving as structural elements in the design.

- Columns, which form the vertical supports of the screen.

- Plywood slats, cut from larger boards to construct the frame and window sections.

- A flat steel bar, intended for mounting the vertical toggle clamps on the Fiskars press.

- Threaded rod segments, used for building wing screws.

During the manufacturing phase, the cutting of the columns and plywood components was carried out directly by the coach. These tasks involved handling heavy materials and operating equipment that posed a higher level of risk. For safety reasons, it was determined that such operations were too dangerous for students to perform. By assigning this work to the coach, the project ensured that all critical

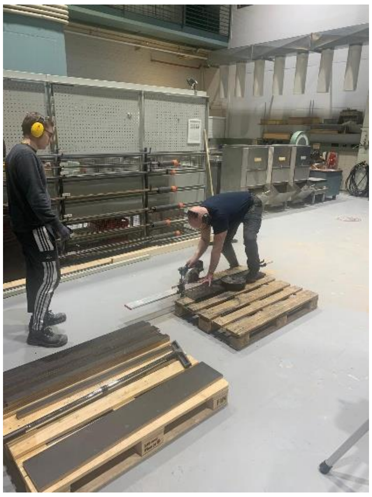


Figure 42: Mikael R. cutting plywood

parts were prepared accurately while maintaining a safe environment for the student team.

During the manufacturing phase, several critical tasks were carried out under close supervision to ensure both safety and accuracy. The welding of the feet was performed by students, but always under the direct supervision of the coach, given the risks associated with welding equipment. Following this, the drilling of all holes was completed. Since the use of the drill press also required careful handling, this step was likewise conducted under supervision.

Figure 43: Manuel Z. is welding the metal feet

A design and planning error became evident at this stage: the initial layout did not account for sufficient play between the holes. As a result, many holes had to be redone, which caused delays but also provided valuable lessons in precision planning. To support proper alignment, an assembly aid for the frame was created, ensuring that the frame could be assembled correctly and consistently.

Figure 44: Assembly Aid and Frame on that

When the frame was assembled, vertical toggle clamps were installed at the Fiskars press to secure the protection screen in place. The PC plates were cut, but due to limited experience with the jigsaw, they had to be recut to achieve the required accuracy. At the same time, the columns and feet were adjusted to each other, ensuring stability and proper fit.

Once all parts are prepared, they will be mounted together, forming the complete protection screen structure. During this stage, the position of the hinges at the mounting plate will be determined through prototyping, ensuring that the connection is both functional and secure.

4.5.6 Results and Limitations

The manufacturing of the protection screen ultimately led to a functional prototype, but several design errors and limitations became apparent during the process. Among the most significant issues were the purchase of screws that were too short, which complicated assembly, and the lack of play between parts, making adjustments and fitting more difficult than anticipated.

These problems could have been avoided by creating a complete CAD model of the protection screen prior to manufacturing. A digital model would have allowed precise verification of dimensions, tolerances, and assembly requirements, reducing the risk of such errors. However, due to time constraints, the CAD modeling step was not carried out in the final phase of the project. The limitations encountered serve as valuable lessons for future projects, emphasizing the need for careful preparation to ensure accuracy and efficiency in manufacturing.

Due to time constraints, the protection screen could not be fully completed within the initial project schedule. While significant progress was made in design, prototyping, and partial assembly, the final construction and adjustments remain outstanding.

The completion of the protection screen has therefore been postponed, with the remaining work scheduled to be finalized by the 17th of December. This extension ensures that the screen can be finished properly without compromising quality or safety standards.

4.5.7 Measures against these Limitations

Although the protection screen provides a significant improvement in safety, it is important to note that it cannot guarantee 100% protection. To address this limitation, a template for a template for the Safety Description Sheet of the Fiskars press was created. This document outlines the intended use, safety precautions, and operational boundaries of the screen.

In addition, pictograms will need to be added in the construction laboratory to visually reinforce safe handling practices and ensure clear communication for all users. The completion of this task, along with further refinements of safety description sheets for other machines, will be carried out by the next EPS project group, ensuring continuity and improvement of the safety measures.

The Safety Description Sheet is included in the project documentation and can be found in ANNEX 8 : Safety Description Sheet for Fiskars for reference.

4.6 Laboratory Map

The elaboration of a full, updated map about the Construction Laboratory was another important part of the project. This idea came from Mikael at the beginning of the semester. The existing signs about orientation were incomplete (not fit with the expectations of Mikael R.) or just outdated.

The purpose of this new laboratory map is, therefore, twofold. First, it enhances the overall navigability of the laboratory, enabling users to more easily identify where each room is and how different parts of the facility are related to one another. Second, and more importantly, it enhances safety: the map clearly indicates essential safety features, including the locations of emergency exits, first aid equipment, eyewash stations, PPE storage, etc.

4.6.1 Specifications

The specifications come from Mikael R. because he ordered the laboratory map. Following discussions with him and the group, the points requested and which must appear on the map are:

- Changing room
- Emergency exits
- Emergency stops button
- First aid kit
- Eye-washer
- Fire extinguishers
- PPE cabinet
- Chemical cabinet

Also Mikael ordered a map just for the concrete laboratory for now. The fire technology section and the geotechnical section are not taken into account. From that point on, the group used two software to achieve the final result.

4.6.2 Software used

For the creation of the map, two software were used: PhotoFiltre7 and Inkscape.

4.6.2.1 PhotoFiltre7

This software is used for editing images, especially for simple graphical manipulations, such as color modification, retouching, and image preparation. In this project, PhotoFiltre 7 software has been used to change the background color in a very simple way. The result of this manipulation has enabled a clearer and more neutral visual platform to be created, which enhances the readability of the visual base before undertaking the drawing process.

Figure 45: Logo of PhotoFiltre 7

4.6.2.2 Inkscape

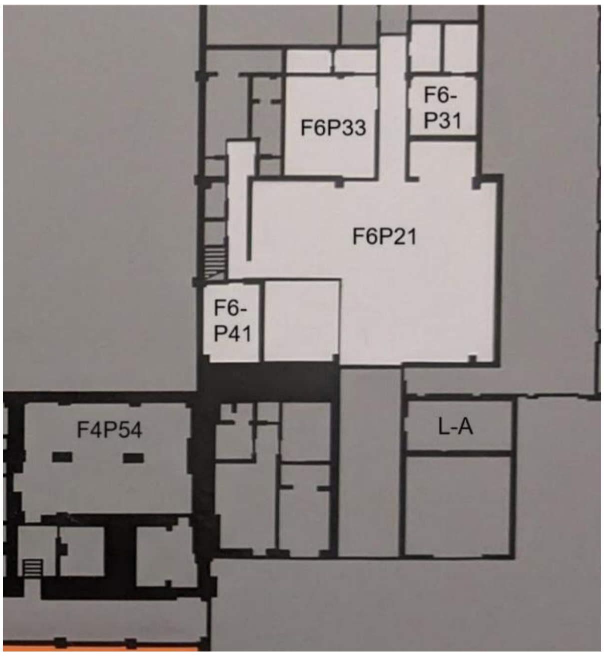
Figure 46: Logo of Inkscape

Inkscape is a vector graphic tool that is typically used for making drawings, diagrams, and scaling illustrations. For the purposes of the laboratory map illustration, Inkscape software was employed to trace the original design by drawing the walls, doors, and boundaries of the rooms with straight, accurate lines that take into consideration the scale of the original design.

4.6.3 Results

4.6.3.1 The Background

One of the most important aspects of creating a map like this is maintaining the correct room scale. It makes sense to have a map that accurately reflects the size of the (numerous) rooms so that users can easily find their way around. To ensure the correct scale for the rooms and walls, the EPS group started with a photo of an existing map. Indeed, for ease of use, it's preferable to begin with a model that has the correct room dimensions rather than starting from scratch. Within the lab, several overview maps of the different laboratories are available. These maps are used to indicate the location of these laboratories, but they don't show the points Mikael wants.



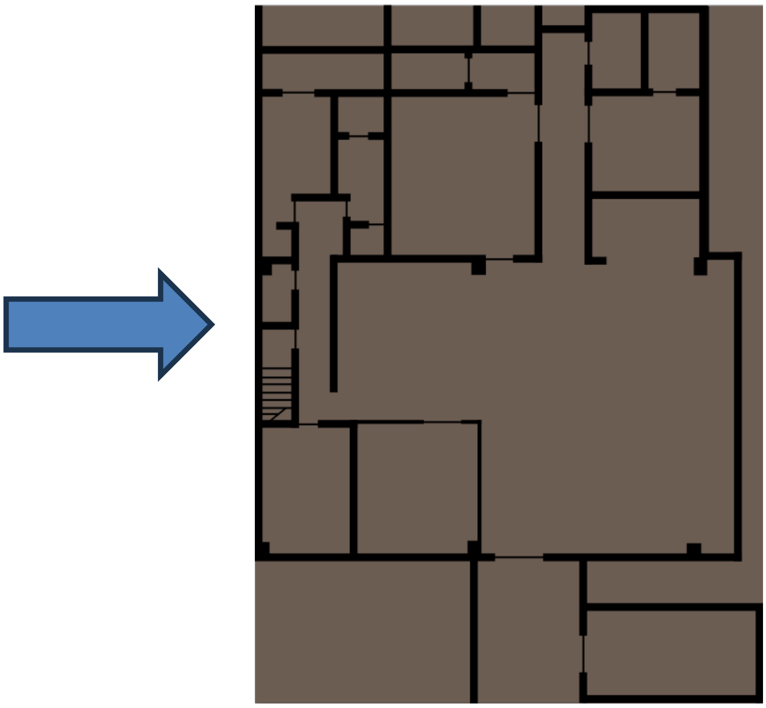


Figure 47: Process of the Map

Thus, starting from a photo of an existing map (see figure 47) and tracing the walls with Inkscape tools, the result is as follows: As a result, the map is cleaner, notably with straight lines (taking a photo of a map alters the perspective and therefore adds curvature to straight lines), while still respecting the openings and sizes of the rooms. Furthermore, the map has been cropped because part of the original map is not part of the concrete laboratory (for example the room F4P54 is part of the geotechnical area but not from the concrete laboratory).

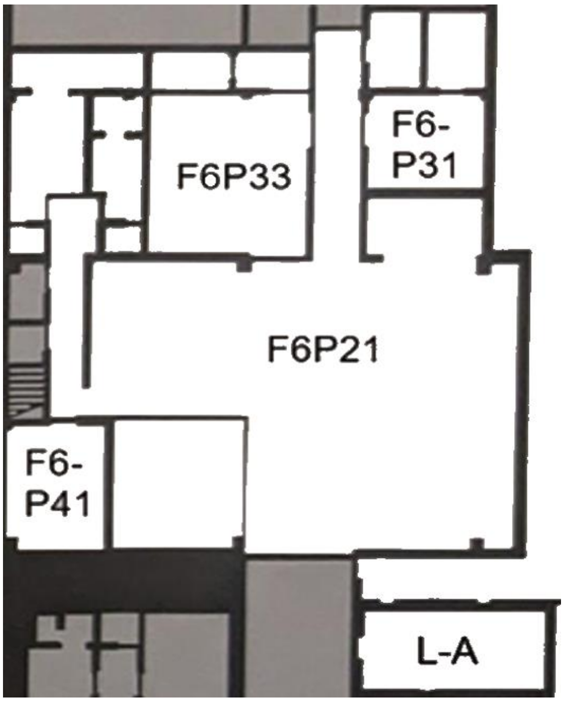


Figure 48: First sketch of the Map

Here is an example (figure 48) of a map where the lines have not been corrected and are therefore slightly curved or not parallel. They are not very clear either, due to the fact that it comes from a photo that has been modified and zoomed in several times.

4.6.3.2 The Colors

Once the layout and scale were nailed down, the next step was to incorporate colors. The laboratory engineer made this request explicitly, since coloring greatly enhances readability and will assist users in instantaneously attaining information about the utilization of different areas within the laboratory.

After several discussions with the coach, a compromise was found on visual clarity, usability, and aesthetic neutrality. The final map is therefore structured around three main color families: grey, blue, and beige which is slightly inspired by the existing maps in the laboratory so as not to completely lose the person who will read the map

- Grey tones are used for areas of circulation or just the space out of the concrete laboratory elements. This neutral color provides a clear background by contrasting with the other colors
- Beige color corresponds to rooms and areas with high utilization by students during practicals, such as the main concrete laboratory hall and the concrete mixing room. This color highlights spaces where most activities take place and are thus expected to have higher concentrations of people.
- Blue is used for areas that are less occupied by students or are essentially used as storage, preparation, or resting space.

Figure 49: Chosen Colors

The following figures show few examples of color versions of the maps throughout the various meetings and discussions. Reaching a compromise took a long time, but the result pleases the "customer", Mikael R and the EPS team

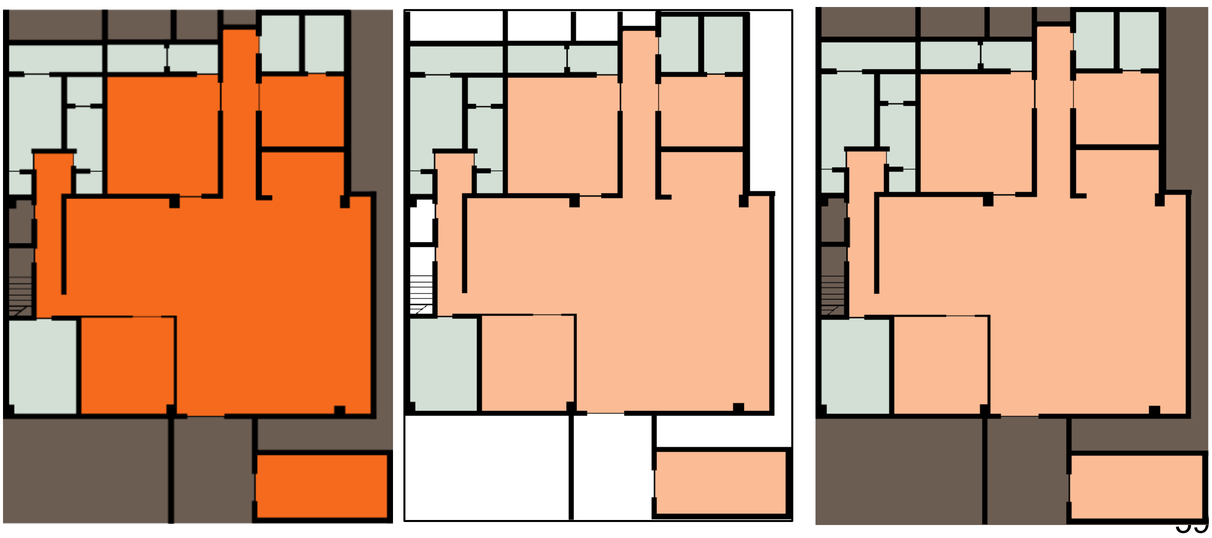


Figure 50: Evolvement of the Map

4.6.3.3 Pictograms and information

Once the color has been chosen, the next step is to implement the elements the coach wants to appear on the map, as outlined in section 4.6.1 Specifications. These elements will appear as standardized pictograms and will then be described in a key alongside the map. These elements are standardized by the standard Graphical symbols. Safety colors and safety signs. Registered safety signs (ISO 7010:2019).

This standard aims to define standardized safety signs (colors, shapes, and graphic symbols) for accident prevention, firefighting, health hazard information, and emergency evacuation. Its main objective is to ensure universal and rapid understanding of safety messages, regardless of language, through the use of symbols rather than words.

For example, the emergency exit pictogram Is referenced in this standard. Every pictogram referenced had a reference number, an image, a name and a function (see on the figure 51 below).

	**Reference No.** **ISO 7010-E002**
	Referent **Emergency exit (right hand)**
	Function To indicate an escape route to a place of safety
	Image content Human figure moving (to the right) through door-way

Figure 51: Pictogram of Emergence ExitFigure 52: Pictogram of Emergence Exit

There is also more additional information like if the pictogram must be accompanied by a supplementary text like instructions or manuals to increase the comprehension (see on Annex 9 the full table of the fire extinguisher).

There are also some pictograms that Mikael wanted and there are not standardized. For example, for the chemical cabinet or the PPE (Personal Protective Equipment) cabinet there is no symbol referenced. That is why the EPS group had to find a symbol that best represented these elements by associating it with a meaningful color: blue is used for PPE pictograms and yellow is often associated with chemicals and cupboards containing these products. Also, for the changing room, a symbol clear and understandable symbol needed to be found.

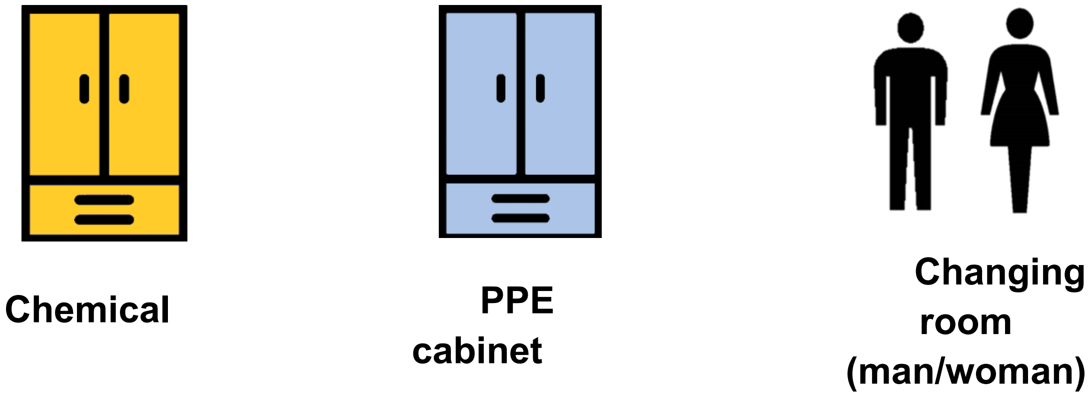


Figure 53: Map Symbols that are not standardized

Finally, using pictograms like the ones mentioned earlier without explaining what they mean doesn't make sense. That's why a legend has been added to the map; it clarifies all the symbols used and also describes the exact names of the rooms, not just their numbers on the map. Of course, laying out the legend required numerous discussions with the coach to ensure the legend elements were in the right place with the correct pictogram and rooms names to avoid any possible errors.

4.6.3.3.1 Implementation

The final version of the map is a deliverable and is included in Annex 10 at the end of this document. The concrete laboratory map will also be added to the document entitled *Safety instruction – Construction laboratory*, which, as a reminder, must be read by anyone entering the laboratory or by any students attending classes there.

Finally, the map was printed and then displayed on a wall in a strategic location, almost at the entrance to the central hall. (see Figure 53).

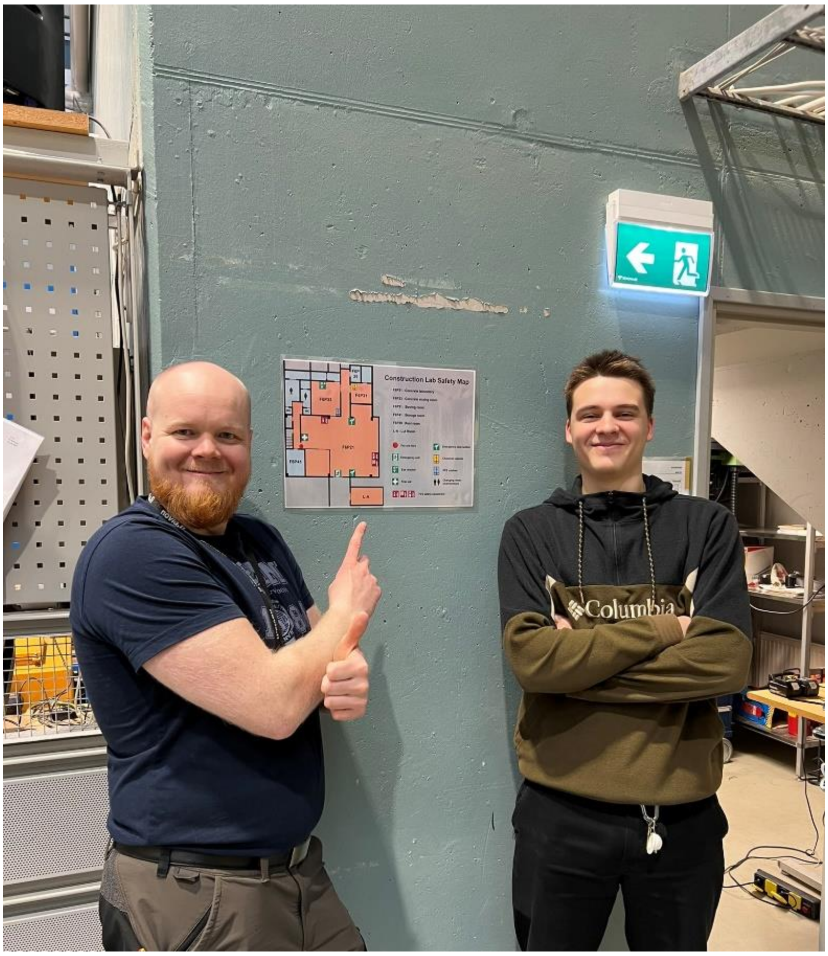


Figure 54 : Photo of Luc and Mikael during the installation of the map

4.7 Project Management

4.7.1 Work Breakdown Structures (WBS)

In the WBS, the entire project is split down into three different sections and after that in further subsections, to reach the construction of a detailed WBS that will give insight into the needed time and resources. This WBS will be used to make the main task manageable. On annex 11 the complete WBS can be found with the different layers.

First, the three main parts that will be mentioned are: the Initial Research, the Necessary Tasks, and the Optional Tasks this type of project requires. By the initial research point of view, defining the Standards and Laws & Regulations are the main goals followed by a risk assessment phase that includes researching machines, creating a backbone file, and creating all necessary documentation.

The necessary tasks section concerns the study and the implementation of the midterm and final deliverables (reports and presentations), supported by the creation of maps for the construction and fire labs. The necessary tasks part also provides the construction of a protection screen part.

The final main section is the optional tasks. This section describes all the tasks that the different project members have to fulfill to improve safety. Among them are, adding floor markings and signs for an emergency button, writing new instructions for machines, managing chemicals, in fact the task that are recommended by the creation of the two main documents in this project cited in the preceding paragraphs.

4.7.2 Schedule (Gantt chart)

A precisely structured schedule was developed to ensure the smooth progression of the project. This schedule was created using Microsoft Excel and served as a key project management tool throughout the project lifecycle.

The Gantt chart allowed the project to be divided into clearly defined phases, including preliminary analysis, design activities, implementation, testing, and final validation. Each task was assigned a specific duration and organized in a logical sequence, taking into account task dependencies and project constraints.

This planning approach made it possible to monitor progress effectively, identify critical milestones, and anticipate potential delays. Regular updates of the schedule ensured alignment between planned and actual progress, contributing to efficient coordination and timely completion of the project objectives.

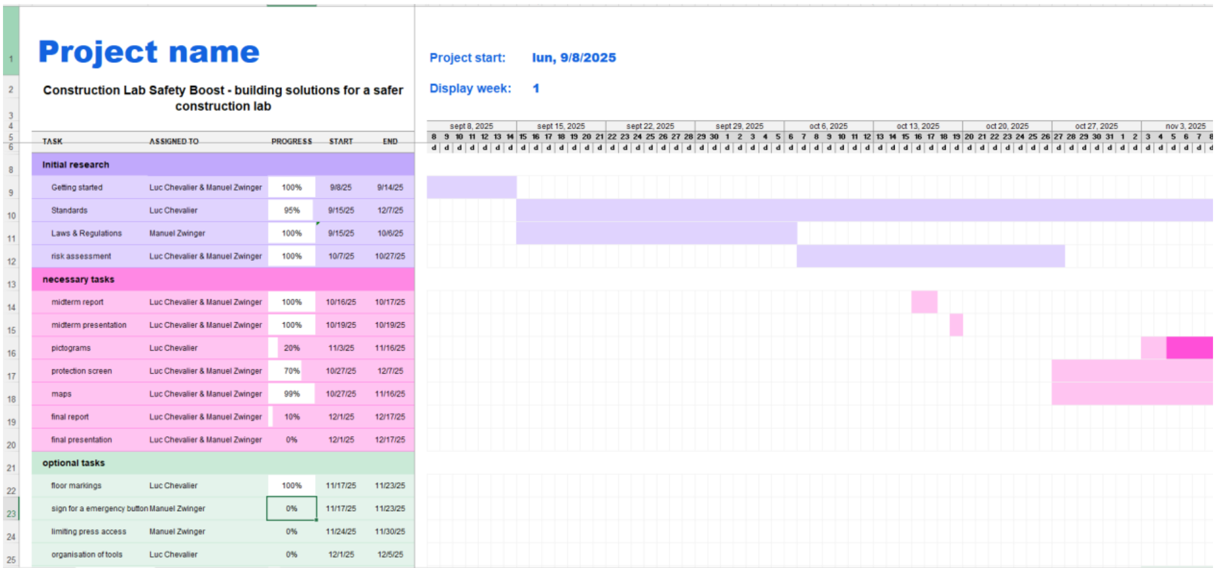


Figure 57: Gantt Chart Part 1

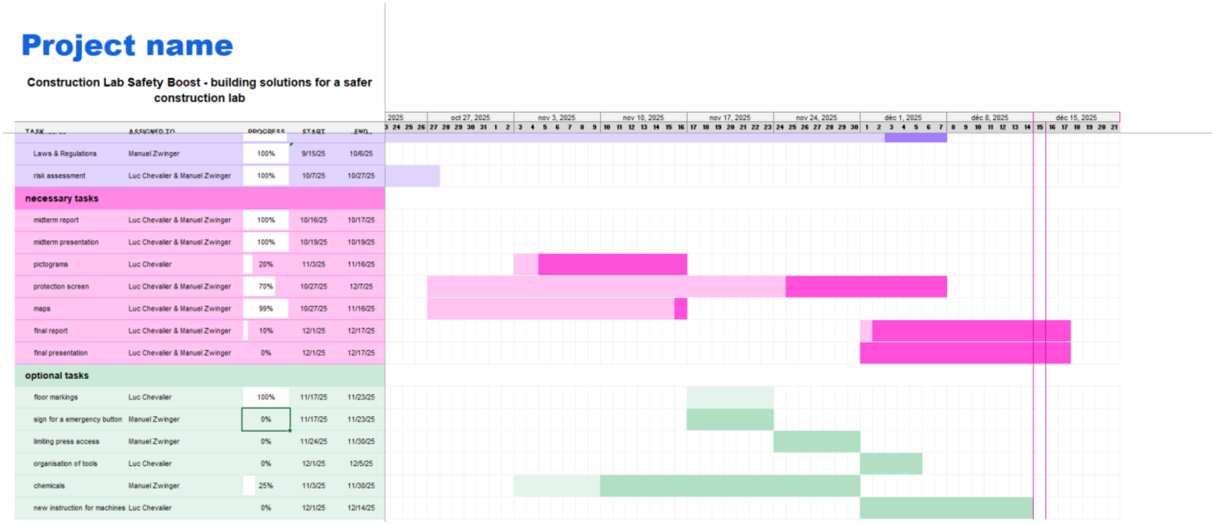


Figure 56: Gantt Chart Part 2

4.7.3 Human resources plan

In addition to the Gantt chart, a RACI chart was created to ensure clear role distribution and effective project management. It was initially intended to assign specific tasks to each team member; however, some of the planned responsibilities could not be strictly followed due to changes that occurred during the project. These adjustments did not have a significant impact on the overall progress, as collaboration and shared responsibilities remained the key factors ensuring the successful completion of the project.

5 Conclusion

The project *Construction Lab Safety Boost – building solutions for a safer construction lab* achieved results that went beyond initial expectations. The deliveries of the risk assessment and the protection screen exceeded the expectations of the coach, demonstrating both technical rigor and practical applicability. In parallel, the analysis of laws and standards, the improvement plan, and the laboratory map fully met the expectations of the coach, providing a solid foundation for future safety management in the Construction Laboratory.

Taken together, these outcomes show that the project succeeded in combining theoretical analysis with practical implementation. The risk assessment documents and safety structures provide long-term value, while the protection screen represents a tangible step toward safer laboratory operations.

5.1 Lessons Learned

- **Communication clarity is essential**: Misunderstandings about the number of screens and frames highlighted the need for precise documentation and stakeholder alignment.
- **Planning tolerances matter**: Errors such as insufficient play between holes and screws of incorrect length underline the importance of CAD modeling and digital verification before manufacturing.
- **Safety supervision is non-negotiable**: Welding and drilling tasks required coach oversight, reinforcing the principle that student involvement must be balanced with professional supervision.
- **Iterative prototyping adds value**: Producing multiple versions of parts allowed optimization during manufacturing and improved the final design.
- **Time management is critical**: The screen could not be fully completed within the EPS timeframe, showing the importance of realistic scheduling and prioritization.

Overall, the project provided not only technical deliverables but also valuable insights into collaborative engineering practice, safety culture, and iterative design. It sets a strong precedent for future EPS groups to continue improving laboratory safety.

5.2 Conclusion of the Work done

The primary objectives defined at the start of the project were mostly successfully addressed:

- **Getting familiar with the laboratory**: Through observations, participation in courses, and interviews with staff, the team gained a clear understanding of daily operations and safety challenges.
- **Analysis of laws and standards**: A structured review of three laws and three standards was conducted, resulting in a funnel-based safety framework and room-level requirements.
- **Risk assessment**: Hazards were identified, documented in a risk matrix, and compiled into a comprehensive risk assessment document for multiple machines.
- **Improvement plan**: Practical measures were proposed to enhance safety, aligning with both legal requirements and coach expectations.
- **Protective screen**: A prototype was designed and manufactured, with iterative adjustments during prototyping. Although not fully completed due to time constraints, the screen demonstrated feasibility and provided a foundation for future safety.
- **Laboratory map**: A digital map of the laboratory was created, offering a clear overview of spaces, equipment, and safety zones.

5.2.1 Conclusion of Segments

Each segment contributed to the overall success of the project:

- The laws and standards analysis provided the theoretical backbone.
- The risk assessment offered actionable insights into machine safety.
- The protection screen embodied the practical implementation of safety measures.
- The laboratory map improved orientation and safety awareness.

Together, these achievements demonstrate that the primary objectives were fulfilled and that the project delivered both immediate improvements and long-term resources for the Construction Laboratory.

5.3 What could have improved the Project

Despite the fact that the project met its primary goals, there are a number of things that could have been improved in order to avoid hitches in the process. Throughout the semester, communication problems were experienced by the group, which, in most cases, arose from varying perceptions of tasks, as well as lack of complete transfer of information. This slowed the project's progress at certain points and led to easily avoidable mistakes.

On the other hand, a better management of timings can avoid alike effects of rushed conclusions. Certain stages within the project would take longer than anticipated, especially dealing with the analytical components and the creation of the document that follows this step. A more balanced plan would allow for anticipating periods of high and low workloads, thus better balancing the project as a whole and ensuring smoother, more consistent progress.

5.4 View into the Future

The work completed during this EPS project provides a solid foundation for future teams to continue improving safety in the Construction Laboratory. In particular, the risk assessment, the Safety Description Sheet for the Fiskars press, and the improvement plan represent essential deliverables that will guide upcoming EPS groups in their work. These documents ensure that hazards are clearly identified, safety measures are documented, and practical steps for improvement are already outlined.

Beyond these deliverables, several additional aspects can be highlighted as opportunities for future development:

- **Completion of the Protection Screen**: The prototype was not fully finished due to time constraints. Finalizing its construction and testing will be a priority later. Further improvements will be carried out to the lab engineers of the construction lab.
- **Integration of CAD Modeling**: A complete CAD model of the protection screen and other safety devices would help avoid design errors and streamline manufacturing.
- **Implementation of Pictograms and Signage**: Visual safety communication in the laboratory should be expanded, using standardized pictograms and clear signage to reinforce safe practices.
- **Expansion of Safety Description Sheets**: The template created for the Fiskars press can be extended to other machines, ensuring consistent documentation across the laboratory.

- **Refinement of the Laboratory Map**: The digital map can be updated with safety zones, restricted areas, and emergency exits to further enhance usability. Also, the map could be used in other parts of the construction laboratory.
- **Knowledge Transfer**: Lessons learned from this project, such as the importance of communication, tolerances, and supervised student work, should be documented and shared to prevent repetition of past errors.
- **Continuous Risk Monitoring**: Future teams can update the risk assessment regularly, reflecting changes in equipment, procedures, or laboratory use.

By building on these foundations, the next EPS group will not only complete unfinished tasks but also expand the scope of safety improvements. This continuity ensures that the Construction Laboratory evolves into a safer, more efficient, and better-documented environment for both students and staff.

6 ANNEXE 1: Conclusion/results of the analysis of standards and laws

Extract from the document called: *Room-Level Safety Requirements, laws and standards analysis.*

3. Conclusions and Recommended Actions

3.1 Introduction

Analysis of the applicable Finnish laws, government decrees, and international machinery standards confirms that safety requirements are to be met by the Construction Laboratory at two complementary levels:

- Room-level responsibilities include making sure that every room offers a safe place for the intended activities.
- Machine-level responsibilities involve the assessment and equipping of individual machines regarding their specific hazards.

The legal framework, which is the Occupational Safety and Health Act, as well as Government Decree 403/2008 and Government Decree 400/2008, lays clear responsibility on the employer to identify hazards, evaluate risks, give appropriate instructions, use safe equipment, ensure that there are protective devices available, and control exposure to dangerous agents: dust, noise, chemicals, or mechanical hazards.

ISO international standards 12100, 13857 and 14120 provide technical principles for the reduction of risks, safety distances, guarding solutions, and safe design. Individually and together, these sources create a consistent and mandatory framework for the Construction Laboratory to attain a level of safety that is both compliant and efficient

3.2 General issues and safety requirements applicable to all rooms with machinery

General issues

The comparison between the legal requirements and the current state of the laboratory indicates that several deficiencies are recurrent across multiple rooms. The most common issues include:

- Missing, outdated, or non-visible operating instructions
- Emergency stop devices absent, inaccessible, or not clearly marked
- Missing ISO 7010-compliant safety pictograms
- Hazard zones unmarked or insufficiently marked
- Lack of visible PPE indications
- Dust accumulation, especially cement-based dust
- Noise levels requiring proper warning signage and hearing protection
- Some rooms are lacking access control despite the presence of hazardous equipment

These deficiencies represent non-conformities with both Finnish legislation and the machinery safety standards.

General safety requirements

- **Updated and Visible Operating Instructions**
  Install updated English instructions directly on or next to each machine.
  (Legal basis: OSH Act §14–15; Decree 400/2008 — Annex I.7)

- **Accessible and Clearly Marked Emergency Stops**
  Ensure that Emergency Stops are present, visible and unobstructed for each machine.
  (Legal basis: Decree 403/2008 §10; ISO 13850)

- **Installation of ISO 7010 Safety Pictograms**
  Add standardized signage for warnings, mandatory PPE and restricted areas.
  (Legal basis: Decree 403/2008 §7; Decree 400/2008 Annex I.7.1)

- **Safety Marking of Hazard Zones**
  Apply black-and-yellow marking tape and define safety perimeters around hazardous machines.
  (Legal basis: ISO 13857; ISO 12100)

- **Clear PPE Requirements and Availability**
  Place PPE signage at room entrances and machines.
  (Legal basis: OSH Act §15)

- **Housekeeping and Dust Management**
  Improve organization and cleaning procedures to reduce tripping hazards and dust exposure (not for the fire section).
  (Legal basis: OSH Act §8 and §38–39)

- **Noise Management**
  Install hearing protection signage (for most of the room).
  (Legal basis: OSH Act §39)

3.3 Specific issues to each room

Now the document will focus more on the specific issues related to the room. For example, a room containing chemicals will have specific issues with risk requirements only related to that room.

Concrete Laboratory (F6P21)

The Main Room (F6P21) is the central and most active area of the Construction Laboratory. It contains major testing machines and general material-processing equipment. The room experiences high student circulation and frequent simultaneous machine use. The main machines are the traction and compression testing Fiskars press, the compression testing Amsler press, the Eskot concrete mixer, and the Bosch Professional GCM table saw.

Specific issues

- **No room-specific issues were identified**. All observed problems (missing instructions, outdated signage, unclear PPE reminders, incomplete hazard markings, etc.) are already fully covered by the *General issues and safety requirements applicable to all rooms with machinery* section 3.2

Specific risk requirements

- **No additional actions** beyond those already mentioned in the general requirements in *General issues and safety requirements applicable to all rooms with machinery (*section 3.2)

-

Concrete mixing room (F6P33)

Room F6P33 is a multi-task room. The main machines are the Eskot concrete mixer, the Weissberger vibration tables and a Errut concrete cutter.

Specific issues

- **No room-specific issues were identified**. All observed problems (missing instructions, outdated signage, unclear PPE reminders, incomplete hazard markings, etc.) are already fully covered by the *General issues and safety requirements applicable to all rooms with machinery* section 3.2

Specific risk requirements

- **No additional actions** beyond the general requirements covered by the *General issues and safety requirements applicable to all rooms with machinery* section 3.2

Changing room

The laboratory also houses a changing room. This is used by students and staff before accessing the work areas. Safety shoes and overalls are available for students. It includes lockers, benches, toilets and showers, allowing for comfortable change and preparation.

Specific issues

- No technical safety issues were identified. There might be only a lack of visible PPE reminders.

Specific risk requirements

- **Install PPE Reminder Signage**
  Simple posters will remind students to wear safety shoes, goggles, gloves, etc., before entering the Concrete Laboratory.

Storage room

Room F6P41 is specially dedicated to the storage and maintenance of machines like hand and power tools (drills, grinders, etc.).

Specific issues

- **No room-specific issues were identified.** All observed problems (missing instructions, outdated signage, unclear PPE reminders, incomplete hazard markings, etc.) are already fully covered by the *General issues and safety requirements applicable to all rooms with machinery* section 3.2

Specific risk requirements

- **No additional actions** beyond the general requirements covered by the *General issues and safety requirements applicable to all rooms with machinery* section 3.2

Sieving room (F6P31)

F6P31 is a room that initially allows for the storage of chemicals in large cabinets. The main machines are a Scanteknik MR-3 Shaker, a Nabertherm Type L9/C6 Furnace, and a Genlab MINO/50/SS Oven. This is also the place of the chemical product storage.

Specific issues

- Chemical cabinet is no longer compliant (ventilation, material, labeling issues)
- Thermal hazard concentration (ovens + furnace in the same small room)

Specific risk requirements

- **Replace the Chemical Cabinet**
  A modern, ventilated cabinet with correct hazard labeling must be installed.
  Legal basis: OSH Act §38; Decree 403/2008 §7 (markings & safety devices).
- **Improve Thermal Hazard Communication**
  Install thermal hazard pictograms on the furnace and ovens.
  Legal basis: ISO 14120; ISO 7010 W017.

Los Angeles room

The L-A room is named like this because of one of the machines they own: the Los Angeles abrasion testing. The main machines inside are the L-A abrasion machine, the Scanteknik MR-3 Shaker and a Humboldt laboratory jaw crusher but not used.

Specific issues

- **No room-specific issues were identified**. All observed problems (missing instructions, outdated signage, unclear PPE reminders, incomplete hazard markings, etc.) are already fully covered by the *General issues and safety requirements applicable to all rooms with machinery* section 3.2

Specific risk requirements

- **No additional actions** beyond the general requirements covered by the *General issues and safety requirements applicable to all rooms with machinery* section 3.2

Geotechnical room

The Geotechnical Engineering Field focuses on the study of soil behavior, stability, and foundation design. This field provides students with hands-on experience on how ground conditions influence structural design and safety.

Specific issues

- **No room-specific issues were identified**. All observed problems (missing instructions, outdated signage, unclear PPE reminders, incomplete hazard markings, etc.) are already fully covered by the *General issues and safety requirements applicable to all rooms with machinery* section 3.2

Specific risk requirements

- **No additional actions** beyond the general requirements covered by the *General issues and safety requirements applicable to all rooms with machinery* section 3.2

Fire technology section (F6142)

The Section of Fire Technology is committed to the study of building materials under fire conditions. The main machines are a SARLIN Furnaces Type 1250H 666-90 and a Nabertherm Type L9/C6 Furnace

Specific issues

- Very high thermal hazards

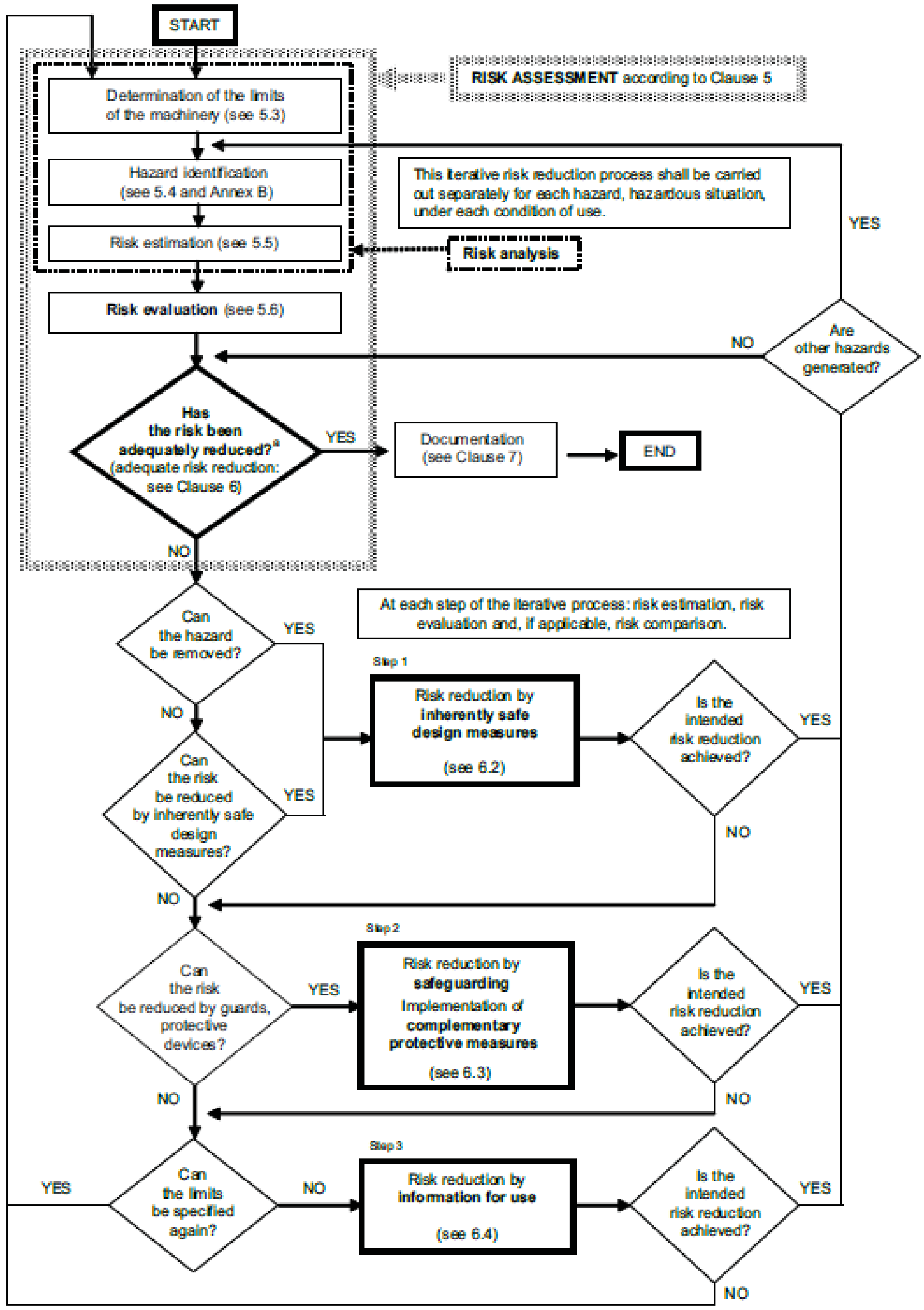
Specific risk requirements

- **Install Thermal Hazard Signage (ISO 7010 W017)**
  For both furnaces and any surrounding heat surfaces.
  Legal basis: ISO 14120; Decree 400/2008 — Annex I.5.

7 ANNEX 2: Extract of the standard ISO 12100 (figure 1, P10)

SFS

ISO 12100:2010(E)



a The first time the question is asked, it is answered by the result of the initial risk assessment.

Figure 1 — Schematic representation of risk reduction process including iterative three-step method

8 ANNEX 3: Inventory of assessed machines

Fiskars traction and compression testing machine

Device for subjecting materials (concrete, steel, etc.) to an increasing load until rupture for measuring the mechanical resistance of the material tested

Amsler compression testing machine

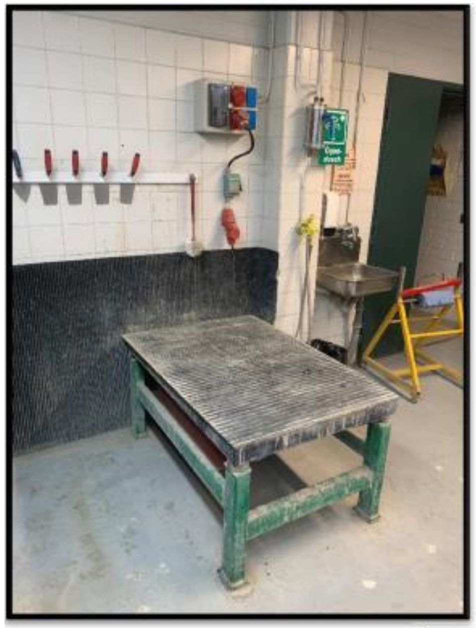
Vertical hydraulic compression testing machines to measure the mechanical resistance of the material tested

Errut concrete cutter

Machine used for cutting concrete blocks, slabs or reinforced elements. Equipped with a large blade, it is designed to make precise cuts in those materials

Esko concrete mixer

Rotating drum machines used to mix cement, sand, gravel and water to produce concrete and it ensure uniform and efficient mixing of concrete components.



Weissberger vibration table

Vertical hydraulic compression testing machines to measure the mechanical resistance of the material tested

Scanteknick MR-3 Shaker

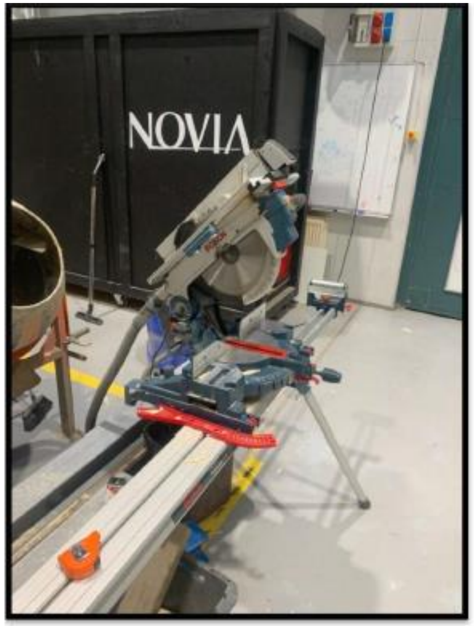
Compact shaking device with a circular or orbital motion platform with a vertical rods system and adjustable clamps for holding molds securely in place. Used to siew particle sizes in the sand/rock specimen, to determine particle size and distribution and to classify soils

Nabertherm Type L9/C6 Furnace

Electric heating cabinet used for drying, curing or heat-treating samples (max 1100°C). Used to harden materials, or perform controlled heat treatments on laboratory or industrial samples.

Genlab MINO/50/SS Oven

Electric heating cabinet used for drying, curing or heat-treating samples (from 30°C to 250°C). Same used as the Nabertherm furnace.



Bosch Professional GCM table saw

Stationary cutting machine equipped with a circular blade and mounted on fixed base. Uses to cut wood and plastic

L.A. abrasion testing machine

Rotating steel drum used to test how resistant aggregates are to abrasion and impact. It contains solid steel spheres that come to strike the specimen. It evaluates the durability and toughness of concrete, aggregates for roads and pavements. It ensures materials meet quality standards and can withstand mechanical

SARLIN Furnaces Type 1250H 666-90

Furnace that can go at 1250°C. The goal is to build fire simulation and test fire scenarios on different materials. (for example, 1050°C for 2 hours)

Nabertherm Type L9/C6 Furnace

Electric heating cabinet used for drying, curing, or heat-treating samples (max 1100°C). This furnace is a laboratory and industrial heating furnace designed for heat treatment, material testing,

9 ANNEX 4: Extract of the standard ISO 12100 (Annex B, P54)

Table B.1

No	Type or group	Examples of hazards		Subclause of this International Standard
		Origin[a]	Potential consequences[b]	
1	Mechanical hazards	— acceleration, deceleration; — angular parts; — approach of a moving element to a fixed part; — cutting parts; — elastic elements; — falling objects; — gravity; — height from the ground; — high pressure; — instability; — kinetic energy; — machinery mobility; — moving elements; — rotating elements; — rough, slippery surface; — sharp edges; — stored energy; — vacuum.	— being run over; — being thrown; — crushing; — cutting or severing; — drawing-in or trapping; — entanglement; — friction or abrasion; — impact; — injection; — shearing; — slipping, tripping and falling; — stabbing or puncture; — suffocation.	6.2.2.1 6.2.2.2 6.2.3 a) 6.2.3 b) 6.2.6 6.2.10 6.3.1 6.3.2 6.3.3 6.3.5.2 6.3.5.4 6.3.5.5 6.3.5.6 6.4.1 6.4.3 6.4.4 6.4.5
2	Electrical hazards	— arc; — electromagnetic phenomena; — electrostatic phenomena; — live parts; — not enough distance to live parts under high voltage; — overload; — parts which have become live under fault conditions; — short-circuit; — thermal radiation.	— burn; — chemical effects; — effects on medical implants; — electrocution; — falling, being thrown; — fire; — projection of molten particles; — shock.	6.2.9 6.3.2 6.3.3.2 6.3.5.4 6.4.4 6.4.5
3	Thermal hazards	— explosion; — flame; — objects or materials with a high or low temperature; — radiation from heat sources.	— burn; — dehydration; — discomfort; — frostbite; — injuries by the radiation of heat sources; — scald.	6.2.4 b) 6.2.8 c) 6.3.2.7 6.3.3.2.1 6.3.4.5

10 ANNEX 5: Risk assessment for each machine

Fiskar's machine						
Hazard category	**Hazard**	**Description of hazardous situation**	**Severity (S)**	**Probability (P)**	**Risk level (R)**	**Risk reduction measures (with normative references)**
Mechanical	Crushing hazard	Crushing of fingers or hands between moving crosshead and fixed frame during test operation.	Serious (2)	Possible (2)	Medium (4)	Guarding per ISO 14120 to prevent access to moving parts. Pictogram “Warning – Crushing hazard” (ISO 7010 – W024). Emergency stop per ISO 13850. Operating instructions: keep hands clear during operation (ISO 12100 §6.4).
Mechanical	Shearing hazard	Shearing points between moving clamps and test specimen when closing grips.	Serious (2)	Possible (2)	Medium (4)	Protective cover (ISO 14120) or fixed distance guard. Two-hand control during specimen loading (ISO 13851). Warning pictogram (ISO 7010 – W011). Training and job sheet instructions.
Mechanical	Ejection hazard	Specimen or fragments may eject when it breaks under tensile load or compression.	Severe (3)	Possible (2)	High (6)	Transparent fixed guard or impact shield (ISO 14120, ISO 14119). Pictogram “Warning – flying objects” (ISO 7010 – W021). PPE: safety goggles (EN 166). Define safety distance (ISO 12100 §6.3.2).

Amsler's machine

Hazard Category	Hazard	Description of Hazardous Situation	Severity (S)	Probability (P)	Risk Level (R)	Risk Reduction Measures (with normative references)
Mechanical	Crushing hazard	Hands or fingers can be trapped between the upper piston and the lower platen during sample placement or compression.	Serious (2)	Possible (2)	Medium (4)	Install fixed guard around compression area (ISO 14120 §5.2). Provide two-hand control or deadman pedal (ISO 13851). Ensure pressure is released before changing samples (ISO 4413 §5.3.3). Require gloves and safety shoes.
Mechanical	Ejection of fragments	Sample or tooling may break and eject fragments during compression.	Serious (2)	Possible (2)	Medium (4)	Provide transparent shield around compression area (ISO 14120 §5.4). Require use of face and eye protection (EN 166). Inspect platens regularly and limit pressure (ISO 4413 §5.2.5).

Concrete cutter Errut

Hazard category	Hazard	Description of hazardous situation	Severity (S)	Probability (P)	Risk level (R)	Risk reduction measures (with normative references)
Mechanical	Cutting / Severing hazard	Operator may come into contact with the rotating diamond blade during cutting or cleaning operations.	Severe (3)	Possible (2)	High (6)	Install a fixed and movable guard covering the blade according to ISO 14120 §5.4. Provide two-hand control or pedal interlock (ISO 13851). Display warning pictograms “Do not touch – rotating blade”. cut-resistant gloves, face shield, safety shoes (ISO 12100 §6.4).
Mechanical	Ejection of parts or fragments	Fragments of concrete or the blade may be ejected at high velocity during cutting.	Serious (2)	Possible (2)	Medium (4)	Use protective cover/shield in accordance with ISO 14120. Apply safe distance (ISO 13857). Require use of face and eye protection (EN 166) and hearing protection (EN 352). Apply pictograms “Wear eye and ear protection”.
Mechanical	Crushing / Shearing hazard	Hands or fingers may be caught between moving table and fixed frame or stops.	Serious (2)	Possible (2)	Medium (4)	Guard or limit travel zones per ISO 13857. Add mechanical stops and warning labels.
Mechanical	Entanglement hazard	Clothing or accessories could be caught by the rotating blade or belt drive.	Serious (2)	Rare (1)	Low (2)	Enclose all drive belts and pulleys (ISO 14120). Require tight-fitting clothing. Apply warning label “Keep hands and clothing away from moving parts”.

Noise	High noise levels	Sound levels during cutting may exceed 85 dB(A).	Minor (1)	Possible (2)	Low (2)	Require hearing protection (EN 352). Post warning “Noise hazard”. Perform periodic noise measurements (ISO 11202).
Material / Substances	Projection of water	Water splashes during cutting concrete	Minor (1)	Possible (2)	Low (2)	Wear waterproof apron.
Mechanical / Control	Unexpected start-up	Machine may start unintentionally when connected to power or foot pedal pressed.	Serious (2)	Rare (1)	Low (2)	Ensure emergency stop (ISO 13850). Use start interlock system (ISO 12100 §6.2.11).

Concrete Mixer Esko

Hazard category	Hazard	Description of hazardous situation	Severity (S)	Probability (P)	Risk level (R)	Risk reduction measures (with normative references)
Mechanical	Entanglement / drawing-in	Operator's hands or clothing may be caught by the rotating drum or paddles during operation or cleaning.	Serious (2)	Possible (2)	Medium (4)	Visible warning pictogram "Do not reach into moving parts" (ISO 7010 – W001). Provide written operating instructions and training (ISO 12100 §6.4). Require close-fitting clothing and prohibit gloves during operation (EPP) . Use emergency stop device (ISO 13850).
Mechanical	Ejection of material	Fragments or stones may be projected during mixing or discharge.	Serious (2)	Possible (2)	Medium (4)	Provide protective screen or barrier (ISO 14120). Use pictogram "Warning: flying objects" (ISO 7010 – W021). Operator must wear safety goggles. Implement restricted access zone (ISO 12100 §6.3.2).
Mechanical	Crushing / shearing	Hands can be trapped between drum and frame, or at tilting hinge and rotating mechanisms.	Serious (2)	Possible (2)	Medium (4)	Apply hazard marking (ISO 7010 – W011). Include clear instruction in job sheet: "Never place hands near hinge or drum base". Regular inspection of hinge mechanism (ISO 14119 §6.3).

Mechanical	Overturning of mixer	Mixer tipping due to uneven floor or overloading during discharge.	Serious (2)	Rare (1)	Low (2)	Require use on level ground (stated in operating instructions per ISO 12100 §6.4). Add pictogram “Warning: risk of tipping” (ISO 7010 – W001 combined). Provide load limit label on frame. Conduct pre-use stability check.
Material / substance	Contact with wet cement	Wet concrete or cement causes skin burns or irritation.	Serious (2)	Possible (2)	Medium (4)	Pictogram “Warning: corrosive” (ISO 7010 – W009). PPE: chemical-resistant gloves (EN ISO 374-1), long sleeves, goggles (EN 166). Include SDS and handling instructions (ISO 12100 §6.4). Provide emergency washing point.
Material / substance	Dust inhalation from cement	Cement dust may cause respiratory irritation when handling dry material.	Serious (2)	Possible (2)	Medium (4)	Use pictogram “Wear respiratory protection” (ISO 7010 – M016). PPE: FFP2/FFP3 mask (EN 149). Prefer wet loading method (ISO 12100 §6.3.2). Provide training and ventilation.
Noise	High sound pressure during operation	Continuous mixing noise can exceed safe exposure limits.	Minor (1)	Possible (2)	Low (2)	Label with pictogram “Hearing protection required” (ISO 7010 – M003). PPE: ear defenders (EN 352). Administrative control: limit exposure time (ISO 12100 §6.3.2). Perform noise measurement and document results (ISO 11200).

Weissberger vibration table

Really small vibration

Hazard category	Hazard	Description of hazardous situation	Severity (S)	Probability (P)	Risk level (R)	Risk reduction measures (with normative references)
Mechanical	Ejection of objects	Fixtures, moulds or loose objects can be thrown off the table.	Serious (2)	Possible (2)	Medium (4)	Wear safety shoes (ISO 12100 §6.4).
Vibration	Hand–arm vibration exposure	Prolonged manual contact with vibrating surfaces or tools transmits harmful vibration to operator's hands/arms.	Minor (1)	Rare (1)	Low (1)	Minimise manual contact time
Noise	High sound pressure levels	Vibratory equipment and loose items hitting table can create impulsive/noisy environment.	Minor (1)	Possible (2)	Low (2)	Measure noise levels (ISO 11202). Provide hearing protection (EN 352) when >85 dB(A). Post pictogram "Hearing protection required" (ISO 7010 – M003).

Bosch table saw						
This machine is dangerous. It may not be used by any student.						
Hazard category	**Hazard**	**Description of hazardous situation**	**Severity (S)**	**Probability (P)**	**Risk level (R)**	**Risk reduction measures**
Mechanical	Rotating saw blade	Contact with rotating blade can cause severe lacerations or amputations.	Severe (3)	Frequent (3)	High (9)	Blade guard; Motor brake; Pictogram 'Warning – sharp blade' (ISO 7010 – W006); Training required
Mechanical	Workpiece kickback	Improper clamping or blade binding may eject workpiece violently.	Severe (3)	Possible (2)	High (6)	Use clamps; Riving knife/splitter; Training on kickback prevention; PPE: safety goggles (EN 166)
Mechanical	Clothing, gloves, jewelry	Loose clothing or accessories may be caught by rotating blade.	Severe (3)	Possible (2)	High (6)	Require close-fitting clothing; Pictogram 'Do not wear gloves or jewelry' (ISO 7010 – W001)

Mechanical	Sliding arms, fence, adjustments	Fingers may be pinched during adjustment or sliding motion.	Serious (2)	Possible (2)	Medium (4)	Clear instructions; Pictogram 'Pinch hazard' (ISO 7010 – W011); Use handles only
Substance	Dust and chips	Fine wood dust may irritate respiratory system or pose fire risk.	Serious (2)	Possible (2)	Medium (4)	PPE: FFP2 mask (EN 149); Pictogram 'Wear respiratory protection' (ISO 7010 – M016)
Noise	Motor and cutting noise	Operation may exceed 85 dB and cause hearing damage.	Serious (2)	Possible (2)	Medium (4)	Noise measurement; PPE: hearing protection (EN 352); Pictogram 'Hearing protection required' (ISO 7010 – M003)

SARLIN Furnaces Type 1250H 666-90

Hazard category	Hazard	Description of hazardous situation	Severity (S)	Probability (P)	Risk level (R)	Risk reduction measures (with normative references)
Thermal	Hot chamber, door, and workpieces	Contact with hot surfaces or materials may cause severe burns.	Severe (3)	Possible (2)	High (6)	Thermal insulation; Pictogram 'Hot surface' (ISO 7010 – W017); PPE: heat-resistant gloves (EN 407), Use laboratory tongs for loading and unloading of material
Thermal	Radiant heat during loading/unloadin g	Heat escaping when door is opened may cause discomfort or burns.	Serious (2)	Possible (2)	Medium (4)	Training: open door carefully; Limit exposure; Use PPE
Fire	Combustible materials or overheating	Improper loading or malfunction may cause fire.	Severe (3)	Possible (2)	High (6)	Use only approved materials; Overtemperature protection; Fire extinguisher nearby; SOPs
Mechanical	Door locking mechanism	Fingers may be pinched or crushed during door closing or locking.	Serious (2)	Rare (1)	Low (2)	Use handles only; Pictogram 'Crushing hazard' (ISO 7010 – W011); Training
Substance	Off-gassing from materials	Heated materials may release vapors or fumes.	Severe (3)	Possible (2)	High (6)	Exhaust ventilation or fume hood; Pictogram 'Wear respiratory protection' (ISO 7010 – M016); PPE: FFP2/FFP3 mask (EN 149); Provide SDS for materials

L.A. abrasion testing machine

Hazard category	Hazard	Description of hazardous situation	Severity (S)	Probability (P)	Risk level (R)	Risk reduction measures (with normative references)
Mechanical	Steel balls and aggregate	Steel balls may strike hands or cause crushing during loading/unloading.	Severe (3)	Possible (2)	High (6)	Use scoop/tongs; PPE: gloves (EN 388); Training on safe loading; Pictogram 'Crushing hazard' (ISO 7010 – W011)
Mechanical	Moving drum during test	Hands or clothing may be caught in rotating drum if accessed during operation.	Severe (3)	Possible (2)	High (6)	Interlocked lid; Pictogram 'Do not reach into moving parts' (ISO 7010 – W001); Emergency stop (ISO 13850); Protective cage is already installed
Mechanical	Material fragments	Abraded particles may be ejected when opening drum or sieving.	Serious (2)	Possible (2)	Medium (4)	Open drum only after full stop; PPE: safety goggles (EN 166); Dust shield
Substance	Dust from aggregate	Fine dust may irritate respiratory system or pose long-term health risks.	Serious (2)	Possible (2)	Medium (4)	Dust extraction; PPE: FFP2 mask (EN 149); Pictogram 'Wear respiratory protection' (ISO 7010 – M016)
Noise	Drum rotation and impact	Continuous operation may exceed 80 dB and cause fatigue.	Serious (2)	Possible (2)	Medium (4)	Noise measurement; PPE: hearing protection (EN 352); Pictogram 'Hearing protection required' (ISO 7010 – M003)

NOVIA UNIVERSITY OF APPLIED SCIENCES

TECHNOBOTHNIA

Genlab MINO/50/SS Oven

Hazard category	Hazard	Description of hazardous situation	Severity (S)	Probability (P)	Risk level (R)	Risk reduction measures (with normative references)
Thermal	Hot chamber, shelves, door	Contact with hot stainless steel surfaces can cause burns.	Severe (3)	Possible (2)	High (6)	Thermal insulation; Pictogram 'Hot surface' (ISO 7010 – W017); PPE: heat-resistant gloves (EN 407); Use laboratory tongs for loading and unloading of material
Thermal	Radiant heat when door open	Heat escaping when door is opened may cause discomfort or burns.	Serious (2)	Possible (2)	Medium (4)	Training: open door carefully; Limit exposure; Use heat-resistant gloves
Fire	Combustible samples	Flammable materials may ignite at elevated temperatures.	Severe (3)	Possible (2)	High (6)	Restrict to approved materials; Standard Operating Procedure (SOP); Fume extraction; Fire extinguisher nearby
Mechanical	Door closing	Hands may be pinched when closing the oven door.	Serious (2)	Possible (2)	Medium (4)	Door handle design; Pictogram 'Crushing hazard' (ISO 7010 – W011); Instruction: use handle only
Substance	Off-gassing / vapors	Heated samples may release vapors or fumes.	Serious (2)	Possible (2)	Medium (4)	Ventilation or fume hood; PPE: respiratory protection (EN 149); Provide safety data sheet (SDS) for materials

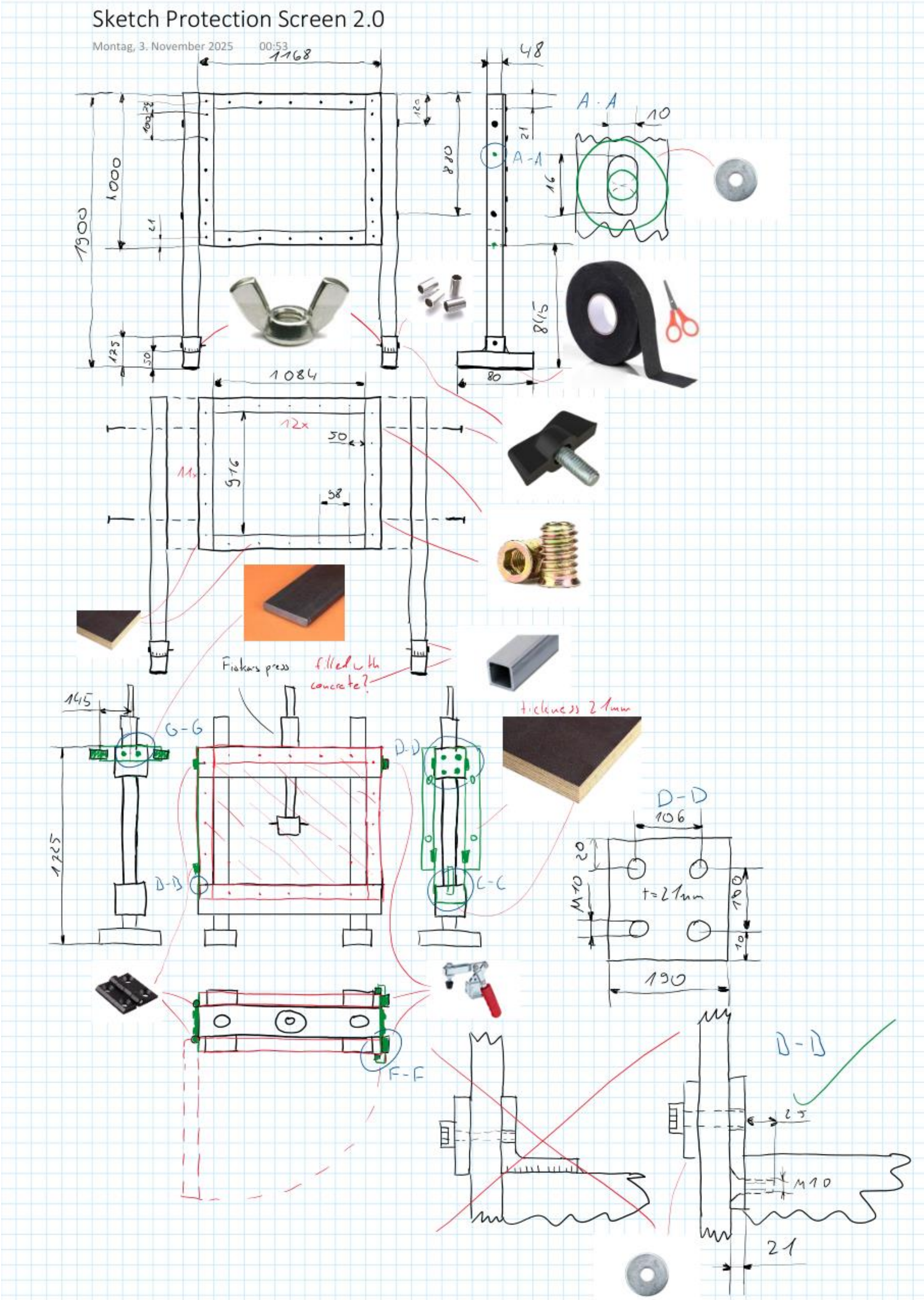
Nabertherm Type L9/C6 Furnace

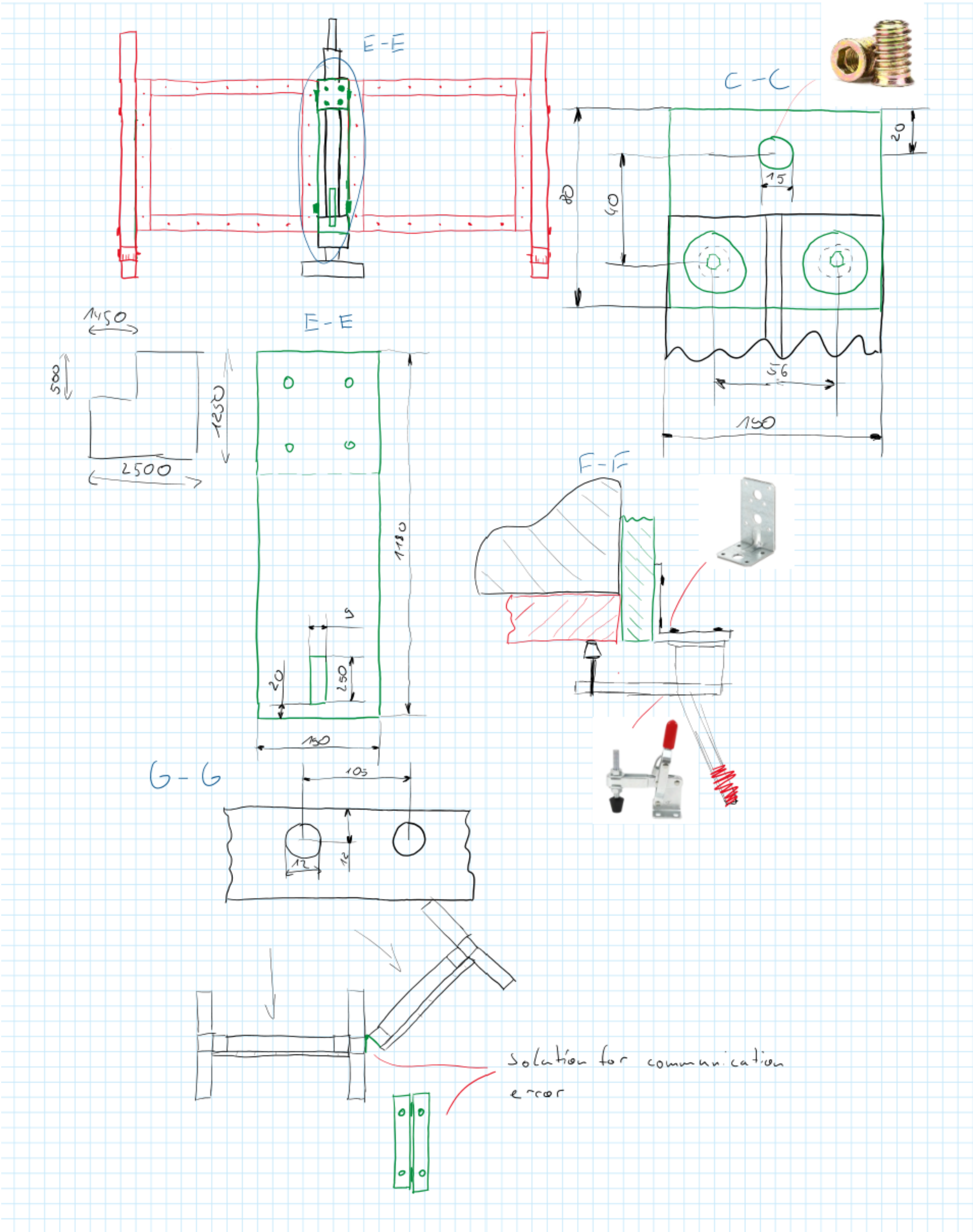
Hazard category	Hazard	Description of hazardous situation	Severity (S)	Probability (P)	Risk level (R)	Risk reduction measures (with normative references)
Thermal	Hot furnace chamber and door	Contact with furnace interior, door, or hot crucibles can cause severe burns.	Severe (3)	Possible (2)	High (6)	Thermal insulation; Pictogram 'Hot surface' (ISO 7010 – W017); PPE: heat-resistant gloves (EN 407); Clear instructions: open door only with PPE; Use laboratory tongs for loading and unloading of material
Thermal	Radiant heat	High radiant heat near open door may cause discomfort or burns.	Serious (2)	Possible (2)	Medium (4)	Use heat shields; Limit exposure time; Training on safe loading/unloading
Fire / Explosion	Combustible samples	Flammable or volatile materials may ignite or explode when heated.	Severe (3)	Possible (2)	High (6)	Restrict use to approved materials; Provide fume extraction; Written Standard Operating Procedure (SOP); Emergency fire extinguisher nearby; Training per ISO 12100 §6.4
Mechanical	Door movement	Hands may be pinched or struck when closing/opening the furnace door.	Serious (2)	Possible (2)	Medium (4)	Door handle with thermal insulation; Pictogram 'Crushing hazard' (ISO 7010 – W011); Instruction: use handle only
Substance	Off-gassing / fumes	Heated samples may release toxic gases or dust.	Severe (3)	Possible (2)	High (6)	Exhaust ventilation or fume hood; Pictogram 'Wear respiratory protection' (ISO 7010 – M016); PPE: FFP2/FFP3 mask (EN 149); Provide SDS for materials

Scanteknik MR-3 Shaker

Hazard category	Hazard	Description of hazardous situation	Severity (S)	Probability (P)	Risk level (R)	Risk reduction measures (with normative references)
Mechanical	Vibrating sieve stack	Hands or clothing may be caught between sieves or frame during operation.	Severe (3)	Possible (2)	High (6)	Protective cover/guard over sieve stack (ISO 14120); Pictogram 'Do not reach into moving parts' (ISO 7010 – W001); Operating instruction: keep hands away; Emergency stop (ISO 13850)
Mechanical	Particles / samples	Fragments or hard particles may be ejected from the sieve due to vibration.	Serious (2)	Possible (2)	Medium (4)	Protective lid or transparent cover; Pictogram 'Warning: flying objects' (ISO 7010 – W021); PPE: safety goggles (EN 166)
Mechanical	Sieve change / clamping	Fingers may be pinched between frame and sieve rim when inserting or removing sieves.	Serious (2)	Possible (2)	Medium (4)	Clear instruction: 'Change sieves only when stopped'; Protective gloves (EN 388); Hazard marking (ISO 7010 – W011)
Noise	Vibration / motor noise	Continuous vibration may generate noise levels >80 dB.	Serious (2)	Possible (2)	Medium (4)	Noise measurement (ISO 11200); Pictogram 'Hearing protection required' (ISO 7010 – M003); PPE: hearing protection (EN 352)
Substance	Dust generation (e.g. cement, minerals)	Fine dust may be inhaled and irritate respiratory system.	Serious (2)	Possible (2)	Medium (4)	Pictogram 'Wear respiratory protection' (ISO 7010 – M016); PPE: FFP2/FFP3 mask (EN 149); Ventilation or dust extraction

11 ANNEX 6 : Sketch of Protection Screen 2.0




E-E
C-C
20
80
40
15
56
150
1450
500
1250
2500
E-E
1180
9
20
250
150
F-F
G-G
105
12
12
Solution for communication error

12 ANNEX 7 : Part List

Part List

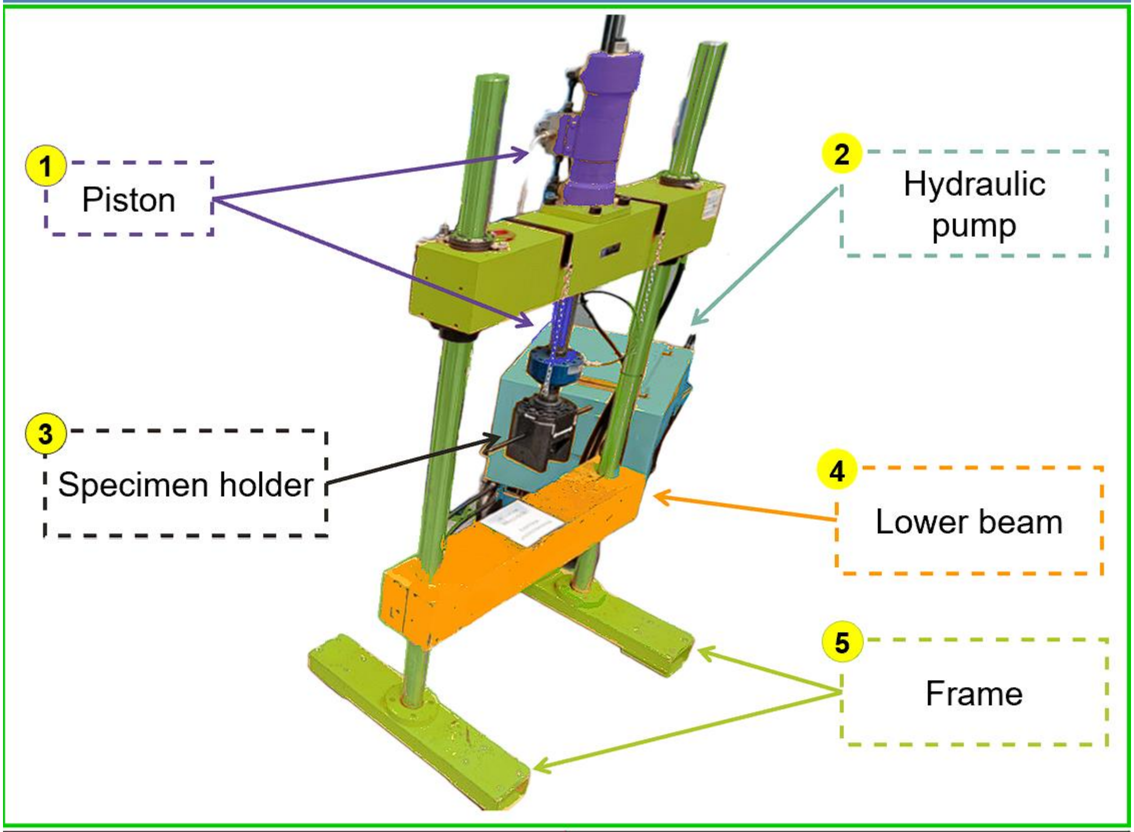
Pos.	Amount	Unit	Naming	Comment	Order Link/Place	Costs
1	7	Pieces	Wing Nut - M8		boltnia bolt	2,72 €
2	215	Leight	threaded rod - M8		storage room	0,78 €
3	2	Pieces	countersunk screws	M10x30	boltnia bolt	0,28 €
4	4	Pieces	machine screws	M10x60	storage room	0,52 €
5	4	Pieces	body disks - M10		storage room	0,17 €
6	17	Pieces	body disks - M8		boltnia bolt	0,60 €
7	8	Pieces	body disks - M4		storage room	0,17 €
8	432	Leight	metal pipe - 12x1		storage room	2,48 €
9	210	Leight	metal pipe - 15x2		storage area	3,24 €
10	1600	Leight	tennis racket grip tape		puuilo	6,99 €
11	2	Pieces	polycarbonate plate	1168x1000	https://cronvall.fi /variant/20568	367,93 €
12	3	Pieces	square hollow steel section - long	50x50x4x800	ikh tahwa	- €
13	3	Pieces	square hollow steel section - short	50x50x4x125	ikh tahwa & storage area	100,00 €
14	3	Pieces	long timber - column	48x48x1850	storage area	20,00 €
15	4	Pieces	plywood long timber - vertical long	21x42x1168	storage area	- €
16	4	Pieces	plywood long timber - vertical short	21x42x1084	storage area	- €
17	6	Pieces	plywood long timber - horizontal long	21x42x1000	storage area	- €
18	4	Pieces	plywood long timber - horizontal short	21x42x916	storage area	- €
19	1	Pieces	plywood plate	21x190x1180	storage area	- €
20	1	Pieces	Distance plate	21x190x130	storage area	- €
21	1	Pieces	Locking plate	21x190x80	storage area	82,50 €
22	100	Pieces	wood screw - flat head		puuilo	4,49 €
23	100	Pieces	wood screw	Leight: max 40mm	puuilo	4,49 €

24	6	Pieces	Machine Screw - M8x120		puuilo	2,52 €
25	7	Pieces	Threaded insert for wood - M8x18		boltnia bolt	6,65 €
26	1	Pieces	flat steel bar 5x50x290		puuilo	16,99 €
27	4	Pieces	screwable hinges		puuilo	19,98 €
28	8	Pieces	Allen screw - M8x20		storage room	1,60 €
29	8	Pieces	Allen screw - M4x10		storage room	1,84 €
30	8	Pieces	lock nuts - M8		storage room	2,00 €
31	2	Pieces	heavy-duty angle connector		puuilo	3,98 €
32	2	Pieces	Vertical toggle clamp		puuilo	15,98 €
Sum						668,90 €

13 ANNEX 8 : Safety Description Sheet for Fiskars press

USING THE FISKAR MACHINE

The Fiskar Machine should only be operated by qualified personnel



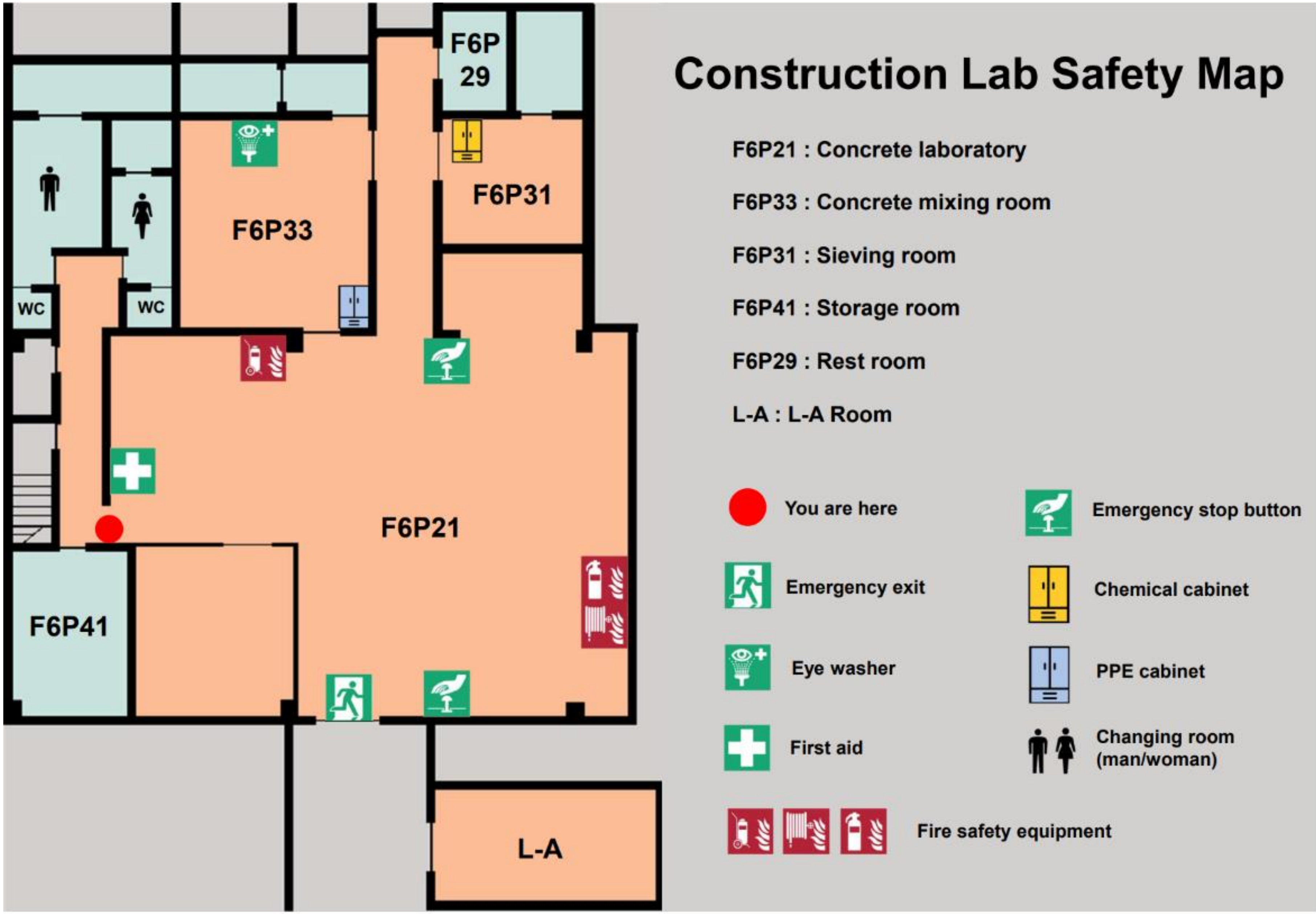
HAZRADS	PROTECTIVE MEASURES
Ejection hazard	Wear protective eyewear
	Wear protective shoes
	Put on the safety screen for the students, if applicable
	Put on the safety screen (rubber) for the operator, if applicable
Crushing hazard	Follow safety instructions

Refer to the machine's instruction manual.
Before any maintenance, disconnect the power supply.
REPORT any malfunction to your supervisor.

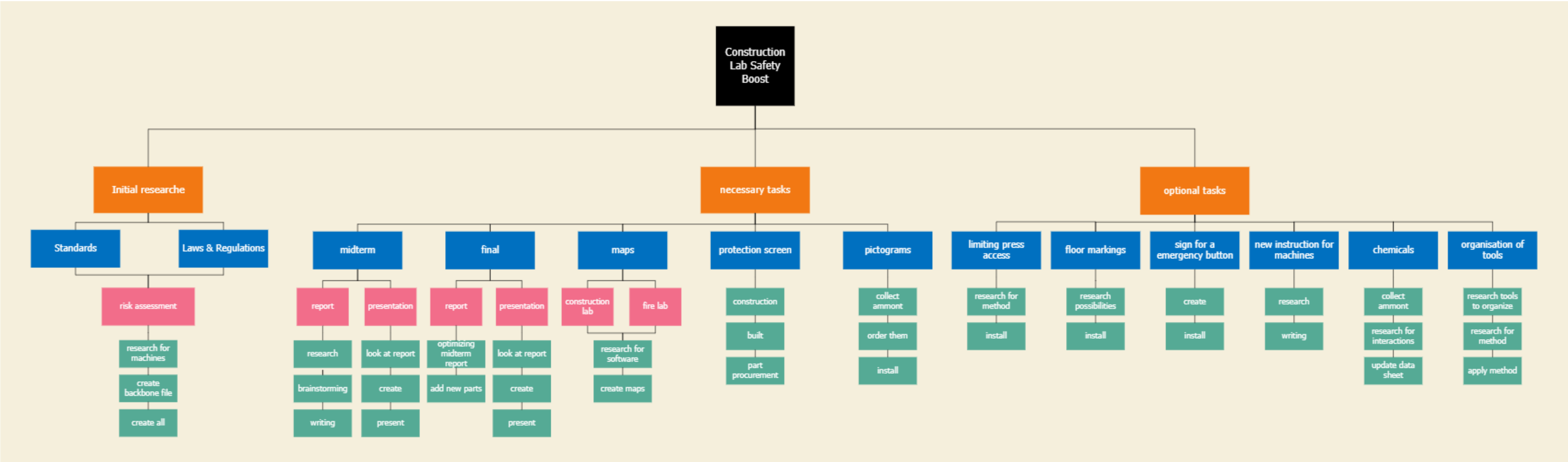
14 ANNEX 9 : Extract of the standard ISO 7010 (table 4, P98)

	**Reference No.** **ISO 7010-F001** **Referent** **Fire extinguisher** **Function** To indicate the location of a fire extinguisher **Image content** Fire extinguisher (profile) with label, flame determinant
Hazard Not being able to locate a fire extinguisher **Human behaviour that is intended to be caused after understanding the safety sign's meaning** Being aware of the location of a fire extinguisher **Additional information** Test data obtained according to ISO 9186-1 are not available. Consequently, a supplementary text sign shall be used to increase comprehension except when the safety sign is supplemented by manuals, instructions or training.	

15 ANNEX 10 : Map of the Construction Laboratory



16 ANNEX 11: WBS of the Project



RESUME

The Construction Lab – Safety Boost project is a project that was carried out at NOVIA University of Applied Sciences in collaboration with the Technobothnia construction laboratory in Vaasa (Finland). The project's objective was to review and improve the overall safety of the laboratory. This construction laboratory serves both educational purposes (with the university) and provides access to non-standard testing equipment for companies with some partnership if they want to use it.

In this way, a lot of this were implemented such as for example, a full safety analysis of the laboratory from the general instructions to the risk assessment of each machine. The analytical phase was then completed through a series of practical improvements, from the design of a modular protection system-named Safety Screen 2.0-to the updating of the safety signs and the creation of a detailed laboratory safety map among others.

Apart from the technical aspects, the management tools used in the project included Gantt charts, document tracking, and progress reporting to maintain a structured and professional workflow. Weekly meetings and guidance from the project coach, Mikael Renlund, served as essential components in steering the work and validating the results.

Ultimately, the project Safety Boost will combine engineering design, safety analysis, and the management practices to provide long-lasting improvements within the Construction Laboratory. The project shall nurture a better safety culture among students and staff to ensure that future learning and experimental activities are in an safer environment.