Designing a measurement system for HAMK Ohutlevykeskus

Designing a test system for concrete

Bachelor's thesis

Automation Engineering

BEAUNU10A7

Mihhail Lonkin

HAMK
UNIVERSITY OF APPLIED SCIENCES

ABSTRACT

Valkeakoski
Degree Programme in Automation Engineering

Author	Mihhail Lonkin	**Year** 2014
Subject of Bachelor's thesis	Designing a measurement system for HAMK Ohutlevykeskus	

ABSTRACT

The purpose of the thesis was to create a measurement system for HAMK Ohutlevykeskus. The commissioning company designed and created the test station for testing concrete beams, by applying force onto concrete. Force application onto concrete was performed by using a hydraulic jack, which was also provided by the commissioning company. The objective of the thesis was to measure the sound emitted by the concrete beam during loading.

The research question of the thesis was to define the possibility of recognizing the sound coming from the loaded concrete, to design a program that can detect the change in the sound and give an alarm when concrete breaks. The thesis examined alternative methods for performing this testing. These methods were described and analysed in this thesis.

Based on the measurement results it was stated that the method used in this thesis was not the perfect solution, and general the flexural test was recommended. In the current state, the test station is unable to perform the general the flexural test. With additional improvements to the station this might become possible. Even though the station was able to perform the required tasks some adjustments were made. With all these complications, the objective of the thesis was achieved, and the program is ready for use.

Keywords Concrete, concrete testing, concrete the flexural test, LabVIEW, sound measurements

Pages 32 p. + appendices 4 p.

CONTENTS

1 INTRODUCTION

Concrete is a very common and useful material. A lot of constructions are made using concrete. Therefore, it is required that the material should be reliable. For the material to be reliable testing is necessary and there are many different methods to test concrete. One of them is the flexural test, which is a test for flexural strength of concrete. In this thesis were researched about different way to perform the flexural test.

The main objective of this thesis was to design a measurement system for a concrete beam test station which would recognise the sound from concrete using a microphone and give the alarm when set sound level reaches the limit. The differences between systems are mechanical hydraulic jack and microphone in system used for this thesis and hydraulic press as well as force gauge for common the flexural testing. All the differences make this test a little different than the general flexural test and require other solution to achieve main goal of this thesis, which was to measure the signal emitted by the concrete.

1.1 Purpose of measuring system

The purpose of the measuring system is to measure the breaking point of the concrete beam using an electret condenser microphone from a headphone set. Using measurement data to set alarm for the user and stop the experiment after first breaking point of the concrete beam what will cause alarm event to acquire. In the same time, all measurement data will be recorded so user can access and use it further in user’s needs.

1.2 Commissioning company

The thesis was commissioned by HAMK Ohutlevykeskus and sent to the HAMK University of Applied Sciences. Ohutlevykeskus required a new system for their laboratory to perform concrete testing. HAMK Ohutlevykeskus is research and testing service company with experience over 10 years. The company is nationally recognized institute on the field of sheet metal research and education. The company has experienced personnel and guarantees high quality of their work. One of the main activities of the company is confidential customer-specific research and consulting services. The co-operation with other companies on the public project is present in the company. The principle of the company is to serve others by offering practical solutions, R&D projects, as well as different test methods.

1.3 Structure of thesis

At first in this thesis will be told about the concrete as a material that includes a short history of concrete, for what concrete used nowadays, different types of concrete and their comprehensive strengths. After that, there will be concrete testing, which will describe different methods and technics for concrete testing and what method was used and what method could be used for more practical use.

The preparation for the work will be following after the concrete testing and will explain the test station which was received from HAMK Ohutlevykeskus. The properties and dimensions of the test station will be shown and all the adjustments, which were made in that chapter. After that, problems with the test station will be discussed followed with solutions to the problems. In the same chapter will be the short description of the LabVIEW program used for measurements in this thesis.

Just before the end the entire testing process will be explained starting with setting the test station before testing. Then the view and explanation of designed program will be described, which was developed with Aleksandrs Petrovs whose thesis topic was called Measurement System for HAMK Ohutlevykeskus: Signal measurement and analysis. That will be followed with the results and conclusions of the measurements. The last part of the thesis will be conclusions of the work done, problems that arose during the thesis work. Future plans will be the last part of this thesis that will explain and suggest different solutions to the objective of the thesis.

2 CONCRETE AS MATERIAL

Concrete is artificial stone building material obtained by moulding and curing rationally selected and compacted mixture, according to the needs, which includes:

- cement or other binder
- aggregates(sand, gravel)
- water

- other elements for a particular use(for example colorant).

In some cases, concrete can consist of special additives with no need of water; for example asphalt concrete.

The history of concrete goes far back to Greece where traces of concrete usage were found. Concrete found bigger appliance in Roman Empire for around seven hundred years. For Romans concrete was new and revolutionary material which quickly hardened into a solid mass, free from many of the internal thrusts and strains that were troubling the builders of similar structures in stone or brick. Wide practice of concrete by Romans ensured that plenty of structures survived till nowadays. However after Roman Empire fall, utilization of building from concrete greatly reduced, and the recipe was forgotten for about eight hundred years. Return of concrete use begun in the fourteenth century and still is growing today. (Wikipedia 2014).

2.1 Use of concrete today.

Concrete is most used building material in the world. It is used twice more than steel, aluminium, wood and plastics combined. The Area of use covers: architectural structures, foundations, brick/block walls, pavements, bridges, overpasses, highways, runways, parking structures, dams, pools, reservoirs, pipes, footings for gates, fences, poles and even boats. (Wikipedia 2014).

2.2 Types of concrete

There are different types of concrete that is used nowadays, and each one of them has special properties according to the needs of the user and designer’s requests. These properties can be strength, workability, toughness, long-life and ability of concrete to withstand required environment conditions.

2.2.1 Regular concrete

The Regular concrete name comes from its common and easy production. This concrete is made according to commonly published recipes on cement packages using affordable and easy to find aggregate like sand or gravel, and then adding water into cement substance and mixing all ingredients together.

2.2.2 High-strength concrete

The High-strength concrete has a strength higher than 40 MPa. However by lowering the water/cement ratio to 0.35 or lower, stronger concrete can be made with lower elasticity. It is common to add silica fume for preventing formation of free calcium hydroxide crystals in the cement structure, which can cause loosening of concrete strength.

2.2.3 Stamped concrete

Stamped concrete is used for architectural proposes. It has superior surface finish than others. It also can be pigmented, and it is possible to provide same attractive looks such as wood, stone or brick materials.

2.2.4 High-performance concrete

High-performance concrete is made for special use cases which need more workability, durability or a higher strength than the common high-strength concrete. While all high-strength concrete can be high-performance, not all of high-performance concrete is high-strength.

2.2.5 Self-consolidating concretes

Self-consolidating concrete takes the required or set shape without any mechanical help. That means that there is no requirement for vibrators to compact the concrete. This concrete is easy to apply and place, and it does not have aggregate segregation.

2.2.6 Shotcrete

Shotcrete (also known as Gunite) is used for applying on vertical surfaces. That is a great advantage of this concrete type since concrete does not need to form, so does not require extra work and expenses. Common use of such concrete is to repair concrete buildings or structures where forming of the usual concrete is expensive, and installation is difficult.

2.2.7 Limecrete

Limecrete or lime concrete is a little different from the common concrete, the only difference being that the cement is replaced with lime. Limecrete is more environmentally friendly than the other concretes. At the same time other products can be reused after since Limecrete can be easily cleaned.

2.2.8 Pervious concrete

Pervious concrete consists of the network of holes that allows water and air to drain through it. It is used for permeable paving, so it is possible to replenish groundwater and possibly replace drainage infrastructure.

2.3 Reinforcement of concrete

The Concrete is strong in compression, as the aggregate efficiently carries the compression load. At the same time, it is weak in tension since the cement holding the aggregates can crack, which allows the structure to fail. Reinforced concrete adds reinforcing steel bars, fibers, plastic fiber/cross linking or glass fiber polymer to carry tensile loads.

2.4 Concrete strength

Concrete has a relatively high compressive strength, but much lower tensile strength. For this same purpose, it is usually reinforced with materials that are strong in tension such as steel. The elasticity of concrete is nearly constant at low stress levels but start to decrease at higher stress levels as matrix cracking develops. Concrete has a very low coefficient of thermal expansion and shrinks as it matures. All concrete structures crack to some extent, due to shrinkage and tension. Different mixtures of concrete ingredients produce other strengths, which are measured in psi or MPa.

Table 1 Concrete comprehensive strength according to concrete types

MPa	psi	Concrete type
12	2000	Lightweight
18	2500	
20	3000	Regular
25	3500	
30	4000	
35	5000	Durable
40	6000	High-strength
50	7000	
55	8000	
70	10000	High-performance

80	12000	
130	19000	
250	36000	

Tests can be performed to ensure that the properties of concrete respond to specifications for the application since some concrete is used for large projects and require being reliable for a long period. (Wikipedia 2014)

3 CONCRETE TESTING

The testing of concrete is a crucial procedure since poor quality concrete can cause different consequences varying from little disturbance in the pavement up to human casualties, for example, a collapse of the structure. Since human lives can be in danger, because of the poor concrete quality, concrete should be tested and correspond to concrete standards. There are different ways to measure the properties of fresh and hardened concrete and set test methods follows each of them. The best time to test concrete is after 28 days so that almost all moisture is gone and concrete has reached almost absolute strength.

One of the most classic concrete tests is a slump test. In a slump test, concrete is shaped into a cone carefully, so it is slightly pressed, and then removed to see how far the concrete sinks or slumps without the support of the cone. Changes in slump height between batches of concrete can indicate a consistency problem. There are slump requirements for various constructions; low slump height concrete, for example, cannot be used to build roadways. Thus, the slump concrete test is a quality control measure and a consistency measure. (Ambuja Knowledge Center n.d.)

3.1 Destructive testing

Destructive testing or Destructive Physical Analysis is testing of specimen failure for the purpose of understanding a structural performance or object behaviour applying different loads. These tests are easy to perform, and they give more accurate and clear information than non-destructive test methods.

Destructive methods are best for mass-produced objects, since the cost of destroying one or more products can be neglected. There are different types of tests such as:

- Flexural test - involves testing beyond normal operational conditions, often to a breaking point, in order to observe the results;
- Crash test - a form of destructive testing usually performed in order to ensure safe design standards in crashworthiness and crash compatibility;
- Hardness test - a measure of how resistant solid matter is to different kinds of permanent shape change when a force is applied;

3.1.1 Suitable test method

The common flexural concrete test suits for the test station, received from HAMK Ohutlevykeskus, because it can provide an opportunity to control quality of the concrete. This method of testing can also be performed on the construction site because of the tests station's mobility and small requirements for extra equipment. However, since the chance of testing parts of a completed structure not always executable or the results of the test can be inaccurate. It is suggested to take in consideration, removing part of the structure that is easily replaceable. It is also preferable, that the test is carried out in the laboratory and carefully monitored. Crucial part of the test is to use carefully controlled hydraulic load application and recording system.

For small specimen, it may be possible to use standard testing machines, but for larger specimen a suitable frame or ring can be assembled. If the size of the test exemplar is preventing transportation to the laboratory, it can be possible to build or assemble a test frame on the spot, alongside of the structure from which the member has been removed. In that case load may be applied by manually operated jacks, with other similar techniques to those used in the laboratory. The control of load application and measurement would be less accurate. However the on spot tests should be avoided whenever possible.

The most common load arrangement for concrete beams consists of third point loading. The advantage of a large part of nearly uniform moment coupled with tiny shears enables the bending capability of the central portion to be assessed. If the shear capacity of the member is to be determining, the load would usually be concentrated at a suitable smaller distance from the support how it is shown on Figure 1.

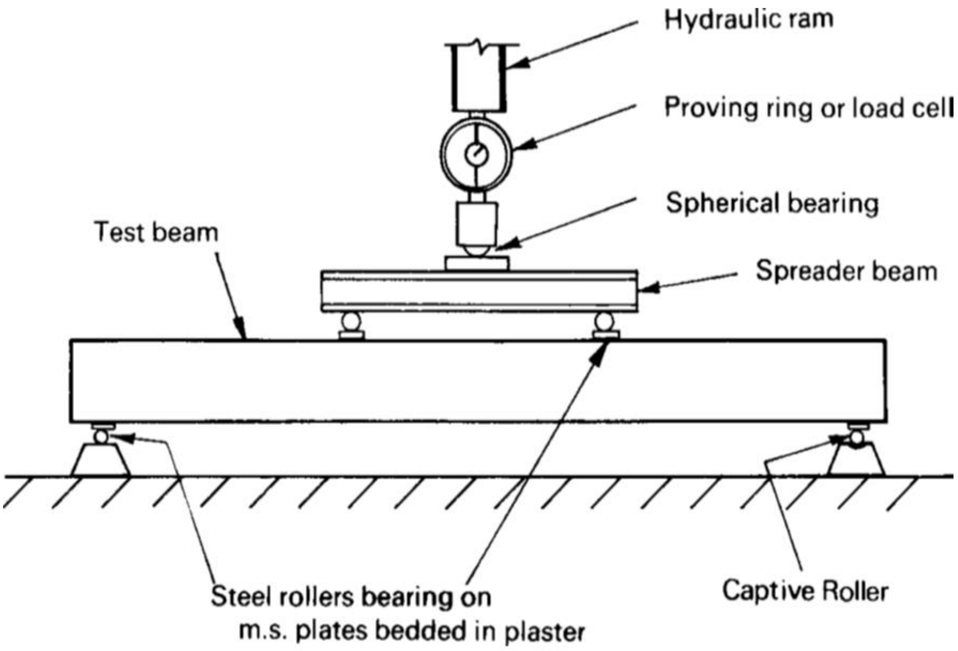


Figure 1 Laboratory beam load test arrangement in Bungey, Millard. and Grantham. 2006, p 172

The load is transmitted through a load cell or “proving ring” and spherical seating onto a spreader beam. This beam’s bears on rollers are seating on the steel plates, which bedded on the test member with mortar, high-strength plaster or some similar material. The test member is supported on roller bearings acting on similar spreader plates.

Parts of the test station would vary according to the available accessories and the size of loads involved. All parts must be capable of carrying the test loads without significant deformation. It is important to consider that access to the middle of the concrete beam is highly preferable for examining of cracks, strains and deflection readings. Stop mechanism may need to be installed to support the specimen after collapse of the concrete.

Several measurements can be taken such as crack width and depth, and the advancement of crack. Dial gauges would be more favourable for deflection readings unless automatic recording is required, in which case electrical displacement transducers may be beneficial. Strain measurements may not be required for straightforward strength tests, but are relevant for tests on prototype specimen or where detailed information about stress distributions required.

Before any testing, the specimen should be checked dimensionally, and a detailed visual inspection performed with all information carefully recorded. After reading gauges, the load should be increased incrementally, up to the calculated working load. Careful track of loads, deflections, and strains should be taken. Cracking should be checked visually, and a load/deflection plot prepared as the test proceeds. It will not usually be necessary to sustain the working load for any specific period, unless the test is being conducted as an overload test.

The load should be removed step by step, with recording of each step, and recovery of concrete checked. Loads will then usually be increased again in similar increments up to failure, with deflection gauges replaced by a suitably mounted scale as failure methods. It is necessary to avoid damage to gauges, and although precision is reduced, the deflections at this stage will usually be large and easily measured from a safe distance. Similarly, cracking and manual strain observations must be suspended as failure approaches unless special safety precautions are taken.

If it is crucial that precise deflection readings are taken up to collapse, electrical remote reading gauges mounted above the test member may be necessary. Crack development on concrete should be marked on the surface of the test specimen and crack widths recorded. The model and location of the failure should also be carefully recorded, photos taken to show the failure zone and crack patterns, and may prove valuable later. If the information is required concerning the actual concrete strength within the test member, cores may be cut after the completion of the flexural testing, taking care to avoid impaired zones. (Bungey, Millard and Grantham 2006)

3.2 Non-destructive testing

Material testing, in general, is designed to make sure that materials meet quality control standards, comply with any laws and include the components people claim they contain. If the concrete fails a concrete test, it may mean that part of a construction project needs to be redone to remove the faulty concrete or that a batch of concrete needs to be discarded.

3.2.1 Ultrasonic pulse velocity test

The ultrasonic pulse velocity test is based on using electro-acoustic transducers that offer strong control over pulse types and frequency produced.

Pulse frequency usually varies from 20 to 150 kHz, and it is created by electronic circuits. This testing is based around pulse wave velocity measurement applying through-transmission techniques. Three types of waves are emitted from transducers into a solid mass of specimen. These waves are; surface waves, the slowest with elliptical particle displacement; transverse waves with particle displacement at right angles; and Longitudinal waves with particle displacement in the direction of travel.

The velocity of wave depend on elastic and mass characteristics of the concrete, hence velocity of wave and mass are known it is possible to calculate the elastic properties with formula:

$$v = \sqrt{\frac{KE_d}{\rho}} (km/s) \qquad (1)$$

Where: E_d = Dynamic modulus of elasticity (N/mm^2)

ρ = density (kg/m^3)

$$K = \frac{(1-v)}{(1+v)(1-2v)} \qquad (2)$$

and v = dynamic Poisson's ratio

Then it is possible to find the wavelength of vibrations dividing pulse velocity by frequency of vibrations. After that, calculating difference between velocities can provide with required information for evaluating the inconsistency of the concrete, in other words defects of the concrete specimen. If this process performed accurately high amount of information can be acquired about the specimen. Nevertheless pulse velocities are relatively small from 3,5 to 4,8 km/s, must be important that the test would be performed in extreme care. Since, it is important to examine the relationship between modulus and strength when plotting measurement results.

3.3 Selected concrete test method

The method chosen for this thesis was destructive the flexural test with mechanically controlled hydraulic jack and microphone. The flexural test was selected because equipment provided was designed especially for this method of concrete testing and any other test could not be performed without completely redoing the test station.

4 PREPARATION FOR WORK

At first, sketches and drawings of concrete or other solid material testing station were received. These drawings show the basic concrete the flexural test principle. The main idea of these concrete testing systems is to apply force in the middle of the concrete beam with a hydraulic press and take the required measurement according to the needs of the user. Onwards, the system was developed and designed by HAMK Ohutlevykeskus. After the completion of the test station, the station was delivered to HAMK Valkeakoski department for further development. On Figure 2 and 3 it is possible to see similar testing devices to the test station form Ohutlevykeskus.

Figure 3 represents a concrete testing device where the force is applied with two hydraulic presses. The concrete beam is held in place by two clamping devices. On top of the device, three different measurement gauges are located. The dimensions and parts of the test station as well as purpose for using and the general description of the LabVIEW will be described further in this chapter. Adjustments that were done to the test station were included in this chapter. After that, the problems of the test station will be discussed, and possible solution will be provided.

Figure 2 Material testing device with applied force indicator. Force is applied manually using a lever.

Figure 3 Concrete testing device.

4.1 Dimensions of test station

The dimensions of the test station are 1201 width 128 depth and 511mm height. Test station is separated onto three parts not including concrete beam. On Figure 4 is shown the upper part, with dimensions 99*82*492mm, of the station that is placed on the body. For durability of the system and the inability of the upper part to move, two bolts were installed from both sides of the station as shown in Figure 5.

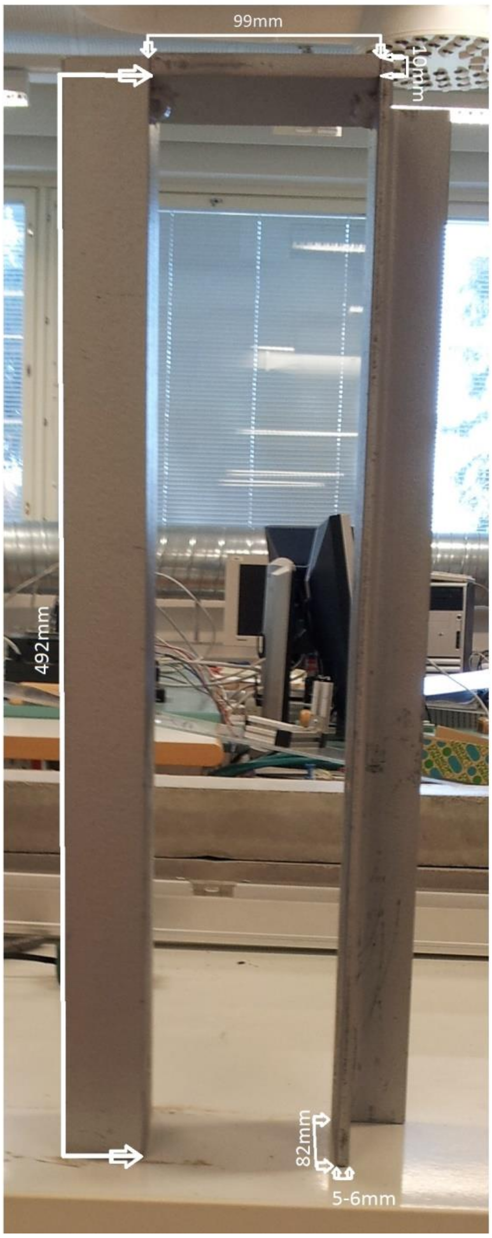


Figure 4 Upper part of the station

Figure 5 Location of bolts

The body part of the test station, with dimensions 1201*128*100 mm, is represented on Figure 6. The body part of the station is important and most durable part of the test since it needs to hold the concrete, which is under pressure during the test.

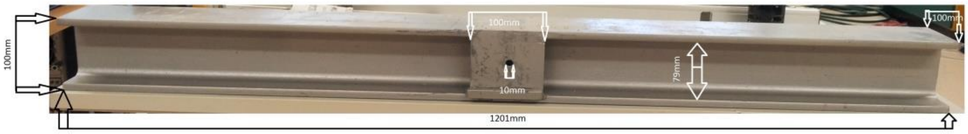


Figure 6 Body part dimension

4.1.1 Hydraulic jack

The hydraulic jack is combination of two cylinders connected between each other with pipe. Inside cylinders is liquid, the most commonly used liquid is oil. A small cylinder is controlled with mechanical lever that is used for pumping and rising the pressure inside the cylinders. This will happen only, if force is applied onto the lever by human hand or another object.

Applied force makes the small cylinder move and the pressure increases inside the cylinders what is causing bigger cylinder to move up. This phenomenon is possible to explain by Pascal low “Pressure exerted anywhere in a confined incompressible fluid is transmitted equally in all directions throughout the fluid such that the pressure variations (initial differences) remain the same."(Wikipedia 2014) However, since pressure is increased inside the cylinders, the bigger cylinder is rising with much higher force.

However since there is a difference between cylinders area big cylinder is rising with less speed but more force the small cylinder was pushed. As a result, it is possible to lift heavier objects on a short distance. (McGraw-Hill 2005)

Figure 7 Hydraulic jack

4.1.2 Changes to test station

Improvement of the station was demanded because of the poor initial design and failure of performing required tasks. Two adjustments were made. The first change was made for the support bolts of the upper part of the station. The holes in which bolts needed to be installed were smaller than holes in the base part. In this instance, upper part was taken to the university workshop and holes were made wider so that the bolts can be fit inside. This change made possible to connect upper and base part of the test station together.

The second change was applied as well to the upper part. Demand of this change appeared after installing the hydraulic press inside the station. Release valve of the hydraulic press was stuck inside of the station and was impossible to reach without taking apart the whole system piece by piece or breaking concrete completely. A required marking was made on the upper part of the station, and it was taken to university workshop again. Using a drill, necessary holes where made in the side wall of the upper part of the station, as it is possible to see on Figure 8a. This change leads for chance of reaching release valve of the hydraulic press without any complications during testing.

Since the thesis focuses on a sound analysis a special box surrounding the microphone was made. The box was made of carton bubble wrap and tape. All materials were supplied by HAMK University of Applied Sciences. Main purpose of the box was to reduce the noise coming to the microphone. The test station was improved and adjusted according to further development demand.

Figure 8 a,8 b The hole made for hydraulic jack and skeleton of the test station

4.1.3 Problems of test station

The test station which was received from HAMK Ohutlevykeskus was poorly designed. Correct and efficient testing of concrete was impossible to perform, and little to no adjustments could be made to improve test station for a substantial level. According to Ohutlevykeskus sound recording of concrete should have been made, but because of poor design of the test station, concrete and the iron upper part were in full contact. That caused considerable noise and disturbance, while recording sound from concrete beam, which made all measurement nearly counterproductive.

Not only this but the problem with inserting concrete inside the upper iron part, what could take up to 2 hours since concrete beam was 1 to 2 mm wider than the space between walls of this iron part of the station. These problems would be possible to bypass by designing upper iron part wider than concrete by at least 5 mm from each side. Further, it could be possible to make that iron part taller by 400mm so there would be the place for steel roll bearings, spreader beam, proving ring or load cell. If there were the place for all this equipment, it would be possible to make the flexural test measuring force applied to concrete with a hydraulic jack. That would lead to better and more general results for concrete the flexural test.

4.2 Designing measuring system

Designing measurement system included different aspects like choosing the right or acquiring available microphone, creating a program in LabVIEW for measuring and recording sound, and establishing a connection between microphone and program in LabVIEW. Creating a program in LabVIEW for this thesis was the hardest and the longest part since the understanding of LabVIEW was poor in the begging but learning the program further, made creating the program less difficult and on decent knowledge level.

4.3 Installing measuring system into test station

Main steps of installing measurement system into test station was installing microphone on the concrete beam on the opposite side of the hydraulic jack since sound is transmitted through the concrete beam from the point of possible cracking and breaking to the outside surface of the concrete. The point closest to cracking is located under the hydraulic jack where force is applied to concrete. Microphone should be situated as close to cracking point as possible. Second step was to establish a connection between microphone and computer with LabVIEW so it would be possible to transmit and record data from a microphone directly to LabVIEW.

4.4 Program used for measuring system

The program used in this thesis was LabVIEW from National Instruments because choice of program was not specified by HAMK Ohutlevykeskus. LabVIEW was chosen because of a variety of functions and easy to use interface; also special course to learn how to use and get familiar with LabVIEW was taken. LabVIEW stands for Laboratory Virtual Engineering Workbench. This program is used for system-design and development environment for visual programming language.

Visual programming language is any programming language that lets users create programs by manipulating program elements graphically rather than by specifying them textually. LabVIEW is used for industrial automation, instrument control and data acquisition.

National Instruments (2014) stated that “LabVIEW is a graphical programming platform that helps engineers scale from the design to test and from small to large systems. It offers unprecedented integration with existing legacy software, IP, and hardware while capitalizing on the latest computing technologies. LabVIEW provides tools to solve today’s problems—and the capacity for future innovation—faster and more efficiently”.

Using LabVIEW in thesis as main programming tool was being possible to design a program to work with the measured signal. Operations like recording, analyzing and measuring sound signal from the microphone were applied to the program for this thesis. In the topic 5.2, will be discussed the readily designed program with the aid of which all the data was collected.

4.4.1 General description of LabVIEW

LabVIEW is graphical programming platform which is using visual objects to build a program that is called visual instruments (VI) in LabVIEW. In LabVIEW, possible to build quite big and complex projects but it is suitable as well for medium and small size projects. The Figure 8 below shows the look of the new VI design. On the left side of the Figure 8, is the front panel of LabVIEW program and on the left is block diagram.

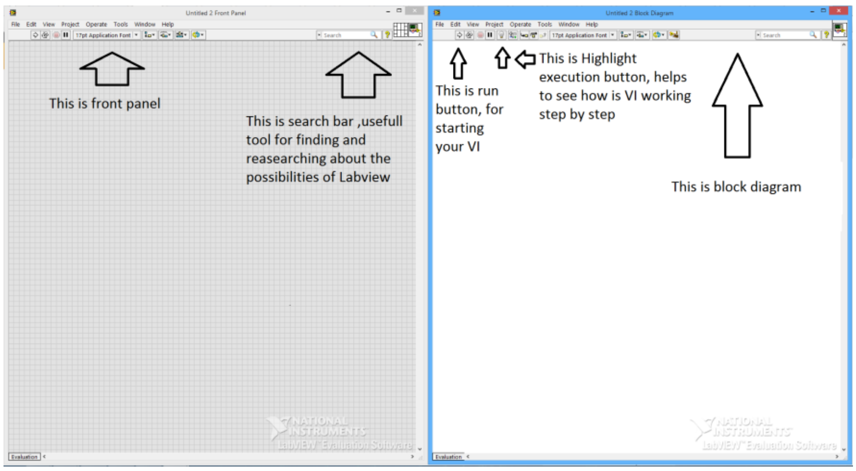


Figure 9 Front panel and Block diagram of LabVIEW

The design of the front panel is mainly control and indication of process and process variables. There is quite wide variety of indicator and representation of process variables as Boolean indicators, numeric controls, graphs, etc.

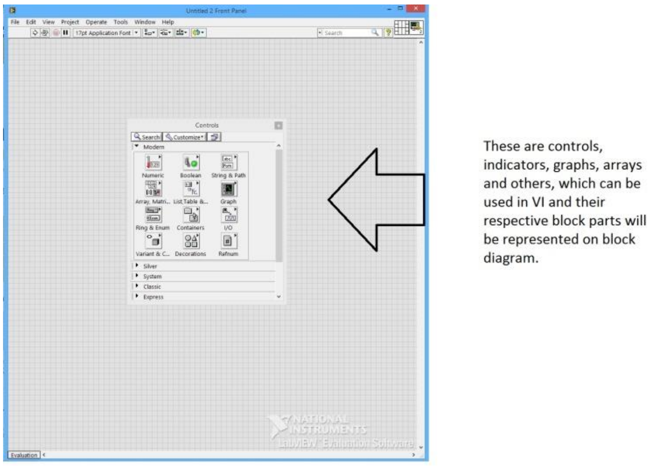


Figure 10 Front panel and controls of LabVIEW

On block diagram, it is possible to observe representatives of controls in front panel and actual program. In the same time, possibility of following the step by step is present, which can help to identify problems or track the process value of any part of the VI, which is called Highlight execution.

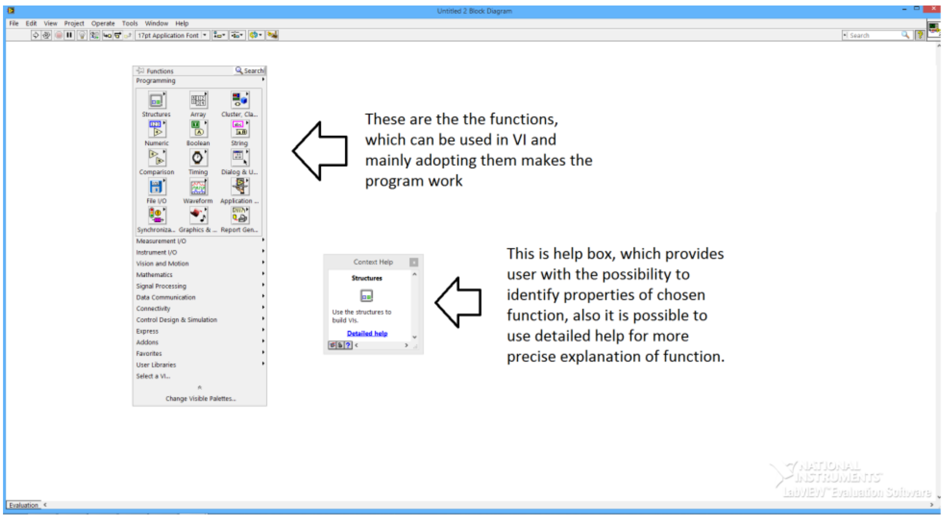


Figure 11 Block diagram and functions of LabVIEW

In the end, LabVIEW is a user-friendly program which is easy to learn, but hard to master. More detailed explanation and presentation of designed VI for this thesis is described in topic 5.2.

5 TESTING

In this chapter is described how the test station was set, what testing method was used and how the testing process performed, the results of the measurements and conclusion of the performed test.

5.1 Setting of test station

Before any measurement could be taken, the test station had to be prepared for testing concrete. At first, test station was checked for any dirt so that nothing would disturb installation and measurement afterwards. All dirt was cleaned so that installation could begin. The next step was to check if all parts are available and in an operating condition. After that, the upper part of the station was installed onto base so that all the bolt holes are matching from base and upper part of the station.

Figure 12 Connection between the upper and body parts with bolt

The next step was to insert the bolts into the holes and to start tightening them, however since the distance between the walls of the upper part is smaller than the concrete beam width there should have been left space for the bolt to move as shown on Figure 11. Afterwards, insertion of the concrete beam into test station opening, which was made especially for concrete, was performed on Figure 12. That was physically exhausting procedure since concrete is wider than the opening in the station and some force to fit concrete in was applied.

Figure 13 Insertion of concrete into test station

After the concrete installation is complete, and it is placed on the bearings, as shown on Figure 13, installation of hydraulic jack is possible to execute. A Hydraulic jack is placed inside the upper part of the station onto concrete beam. With attention to sound measurements, rubber pad was added between these two objects so that there will be almost no extra noise coming from the rubbing between those. When all the important components were installed pumping of the hydraulic jack could be started to the point where hydraulic jack’s upper cylinder was in touch with the roof of the upper part of the station, as shown on Figure 14.

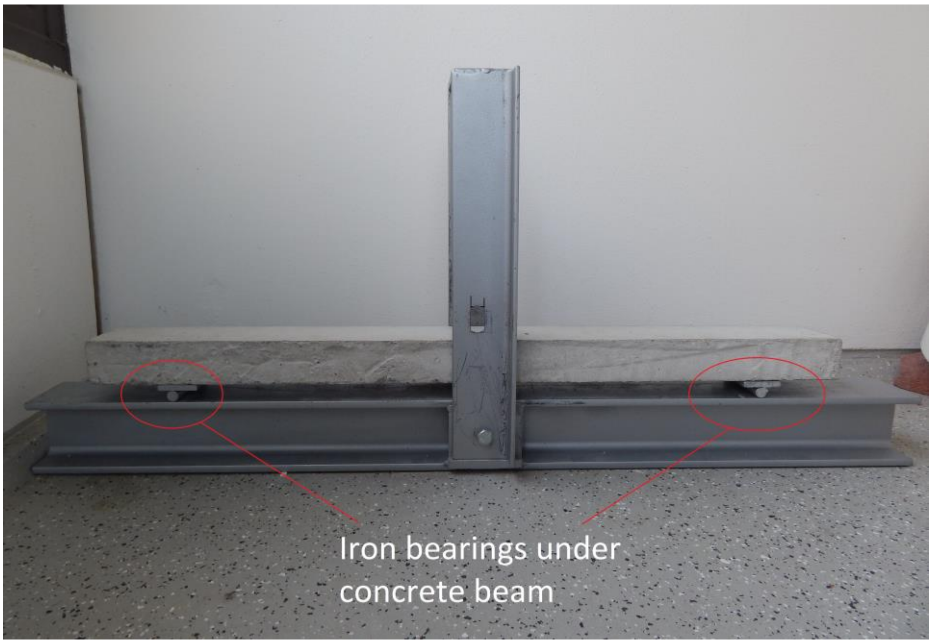


Figure 14 Concrete standing on iron bearings

Before starting to apply force, onto concrete, microphone should have been installed. The microphone was installed in close contact with the concrete beam under it which provided the best measurement result. After that connection between the microphone and the computer with LabVIEW program was established, and measurement process could be started. Before testing the specimen should be checked dimensionally, and a detailed visual inspection made with all information carefully recorded.

Figure 15 Test station ready for testing

5.2 Created program for measurements

The program for LabVIEW was made especially for this thesis before measurement process started. Everything, that was used for creating the program was provided by and included in LabVIEW program, which are standard controls and functions of LabVIEW. The information acquired during Raine Lehto’s “Measuring and Automation Programs” lectures was widely used during creation of the program (Lehto 2014, lectures).

5.2.1 Working principle of designed program

The working principle of the program was to get data from the microphone, which was installed on concrete, and record data received in two different formats binary “tdms” and sound “wav”. While the data was received it was plotted on the graph, and it was possible to see the data in the form of signal.

In the same time, it was possible to turn on the alarm that would identify spikes of the signal higher then set on the front panel. Since the signal from breaking of concrete was with much higher amplitude, the alarm could detect this and give the alarm sound to the user. After alarm sound, the user could stop the program immediately.

After recording had been done, program was able to read recorded signal and plot it to graph by pressing following button. After pressing listen to the sound of the signal and plotting full signal into graph, so it would be possible to read and recognise when the cracking happened.

5.2.2 Front panel of designed program

On the front panel of the designed program are mostly Boolean controls, additional buttons, and numeric controls. The purpose of buttons in the program is to control the flow of events in the block diagrams. Every button is responsible for event or part of the event. This designing strategy is easy to understand, and failure finding becomes quicker. Even though, using highlight execution button on the toolbar helps to find the problem fast sometimes it can take quite a long time. The figure below explains the controls in the programs front panel.

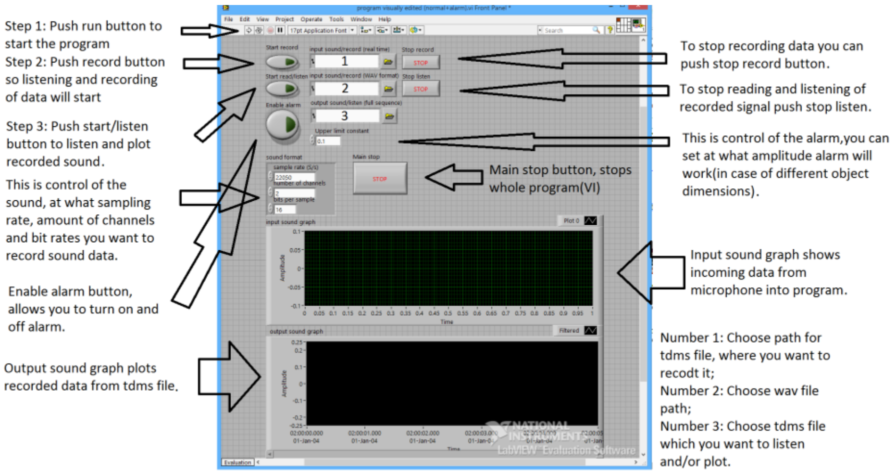


Figure 16   Front panel of designed program

As it is possible to see from Figure 16 that different data types can be chosen depending on what kind of data is required, be it “wav” or “tdms” file type. In the same time, it is possible to read the data coming from the microphone on the input sound graph in real-time. Below the “input sound graph” is “output sound graph” which shows recorded data from chosen file in output sound field (number 3). Sound format control allows for setting the desirable sampling rate, number of channels and at what bit rate you want the signal to be represented. In the case of emergency during the program running, it is possible to use Main stop button to terminate ongoing program.

5.2.3 Block diagram of designed program

On Figure 17 is shown the recording part of the designed program “block diagram."

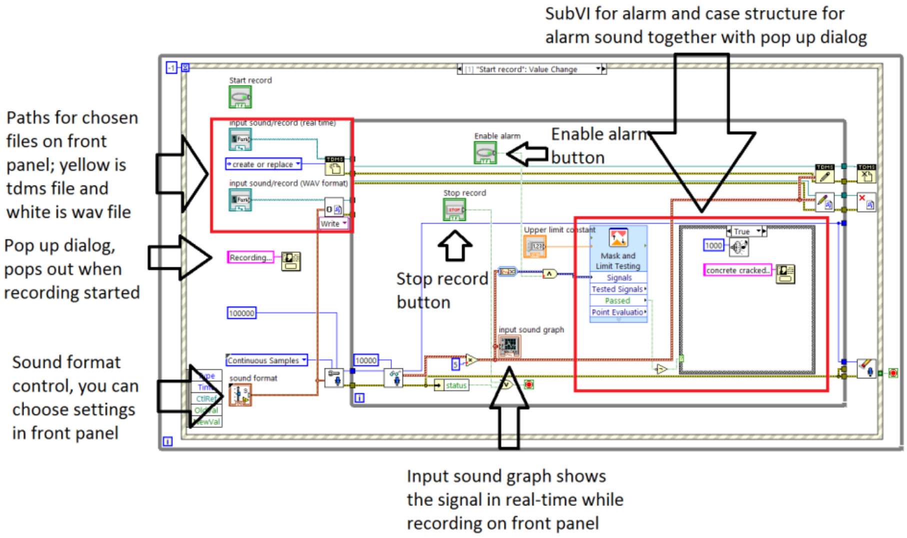


Figure 17 Block diagram of created program, recording part

The entire program was based on event structure inside the while loop, which let the program to run continuously only by pressing required buttons. As it is possible to see, there are the representatives of controls from the front panel. At first, “start record” button should be pressed, after program was started from toolbar. When “start record” button is pressed, the program starts to read data from the microphone in continuous samples with chosen sample rate.

In the same time files are opened and ready to be written or overwritten, both “wav” and “tdms” files, by the program. However before writing data into files program need to start acquiring data from the microphone that would be followed up with writing data into files and plotting the signal onto input sound graph.

During data acquisition, it is possible to turn on the alarm by pressing “enable alarm” button. “Enable alarm” turns on the alarm function which would play a sound when alarm limit is reached. Alarm function would send true or false to case structure, which would play sound and show message “concrete cracked...” in case of true state and would do nothing if false. The program would stop executing, if “stop record” button is pressed. In the same time data acquisition will be stopped, data will be saved into files and buffer will be cleared from recorded data, so new recording can be performed shortly after program is stopped.

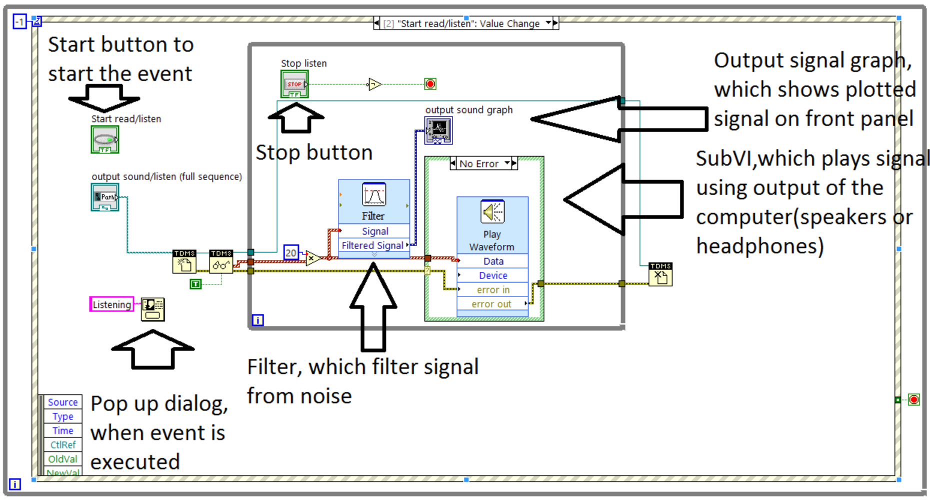


Figure 18 Block diagram of designed program, reading and listening part.

The Figure 17 represents reading and listening part of the program. As it was shown in “front panel”, it is possible to choose file path for reading and listening. The program starts to read signal when “start read/listen” button is pressed, in the same time message “Listening” is shown on “front panel”. When “start read/listen” button is pressed, program starts to read data from “tdms” file and plot it into “output signal graph” by passing through filter. The filter is responsible for clearing out the noise, which comes outside of the signal and applies disturbance in the signal.

In the meantime data is fed into subVI “Play Waveform”, which sends data to sound output device of the computer and plays the sound. This subVI is placed into error “case structure” which is playing the signal only when there is no error present and does nothing when there is an error.

To stop the reading and listening process button “Stop listen” can be pressed, and which will cause the process to complete and then stop the program.

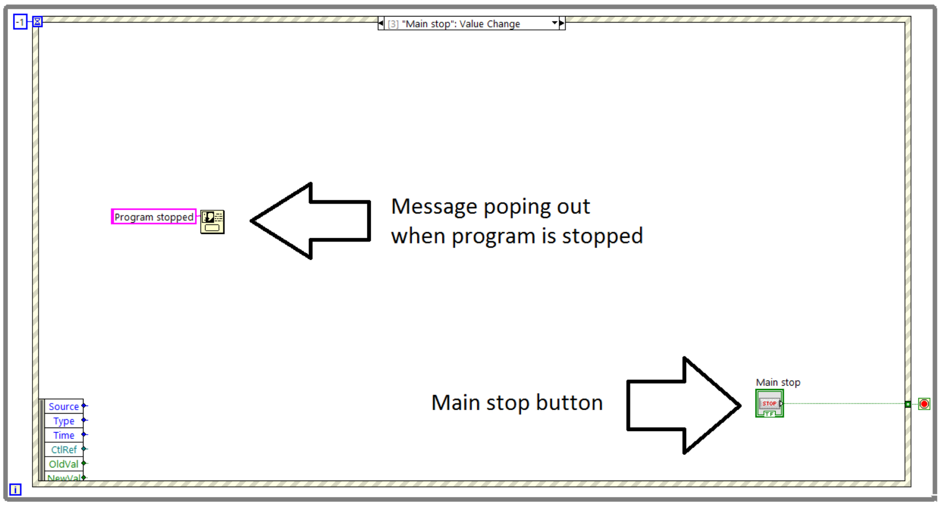


Figure 19 Block diagram, main stop part

The “main stop” button is responsible for terminating all ongoing processes and stops the program from further using unless user starts the program all over. The “main stop” button function is placed in stop event case and when the button is pressed the dialog window “Program stopped” will pop up. After that program is stopped and ready for a new cycle to start.

5.3 Measurement results

The purpose of the thesis was to measure sound coming from the concrete when load is applied. For the measurement of the sound, electret condenser microphone was used. It was the only available microphone which could be used in our project without any extra costs involved.

All measurements were taken in quiet and low noise environment, what improved results. Since any outside noise could reduce the quality of measured results special measures were applied. Results of the measurements are presented on Figure 20.

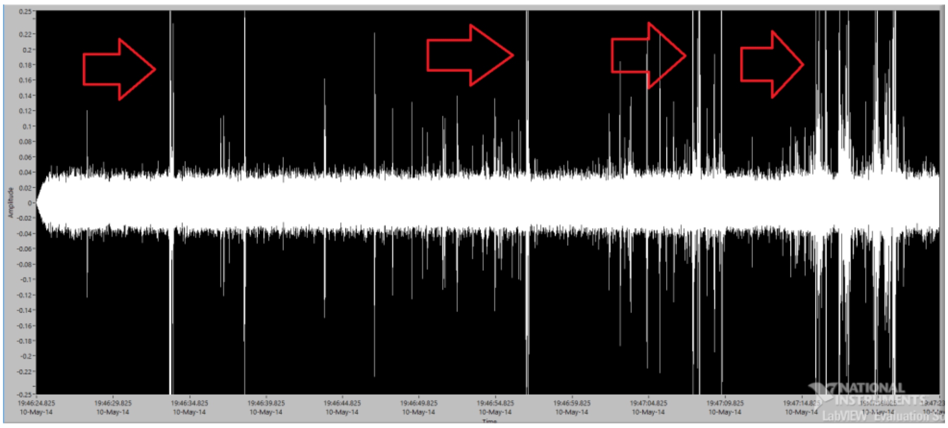


Figure 20 Sound graph of measured signal; red arrows – breaking points

On Figure 20 is a graph of x- and y-axis. The x-axis represents during what time measurements were taken, and y-axis represents amplitude of the measured signal. On Figure 20, it is possible to detect spikes in respect of amplitude, those spikes that are reaching amplitude 0.25 or more are concrete cracking and breaking points. In the same time, it is possible to find when cracking happened, how much time passed since begging of the test and how much time measurement took to perform. On Figure 20 is shown how broken concrete looks.

Figure 21 Broken concrete after testing

The measurement results were satisfying since the breaking point of concrete was possible to recognize. When concrete breaking amplitude was found, it became possible to set alarm in the program and finish program which could identify breaking point of concrete and give the alarm accordingly.

6 CONCLUSION

The objective of this thesis was to make a measurement system which could recognise the sound difference in measurement of sound and give the alarm when concrete was broken. The measurement was taken by the microphone using the LabVIEW program to record and replay the data. Even thought, the test station was similar to a common concrete the flexural test it had its differences. The main difference was that the microphone was used for taking the measurements not force gauge, which led to different measurements. At the end, all the measurements were quite successful, that led to proper design of the program and fulfilling the objective of the thesis.

6.1 Thesis project

This thesis was focused on describing the test process with its ins and outs. In the same time, the thesis were describing the main principles of the concrete testing as well as what is concrete, concrete types and some of its properties. Examples of different testing methods are present such as testing using ultrasonic pulse velocity to measure the disturbance in signal velocity to get required result. In the same time it was described the common the flexural test, which is the way to go in the future.

All the dimensions and parts of the measurement system together with the test station such as a hydraulic jack, parts of the test station and a general explanation of LabVIEW were described. The testing process was a significant part of this thesis where is described how the test station was set and the working principle of the created LabVIEW program. At the end of the thesis the measurement results and evaluation of them were talked about. The measurement results were successful, and the program is capable of giving alarm when concrete is broken with a right determination of the alarm level.

6.2 Difficulties

The main difficulty of the thesis work was the test station from HAMK Ohutlevykeskus, since it was not ready for testing concrete. The test station was poorly designed and the space between the walls of the upper part was smaller than concrete beam’s width. As also stated in the introduction this caused many complications with installing concrete beam into the station

The same design problem was causing a scratching noise when force was applied to the concrete beam. It was caused because concrete was in close contact with the iron walls of the test station, which was generating a disturbance in the measurements. Together with that the background noise was a serious problem for the test but adding a sound box for the microphone partly solved the problem. In the end the test process was quite successful but because of the poor design the objective of the thesis could not be performed perfectly.

6.3 Future possibilities

In the future, it is possible to redesign the test station so that the common the flexural test will be possible to perform. For that instance, the upper part of the station should be raised by about 400mm up and space between the walls could have more width for about 10mm, so that no noise will be produced while testing the concrete. At the same time the test station could be longer so that other concrete beams with different dimensions could be used. Also it is possible to design new system using machine vision for recognising cracks in the concrete during the test process.

SOURCES

ASTM C94 / C94M.2014 *Standard Specification for Ready-Mixed Concrete*. Volume 04.02 Concrete and Aggregates. ASTM International http://www.astm.org/Standards/C94.htm Accessed 10.05.2014

Ambuja Knowledge Center, n.d. *Concrete Tests*. [online] Avaliable at http://foundationsakc.com/process/concrete-tests Accessed 29.04.2014

Bungey J.H., Millard S.G. and Grantham M.G. 2006 *Testing of concrete in structures*. 4th edition. New York, NY: Taylor & Francis

FOLDOC. 1995. *visual programming language*. [online] Available at: http://foldoc.org/visual+programming+language Accessed 14.05.2014

International Journal of Advanced Technology in Civil Engineering. 2013. *Enhancement of flexural strength of rc beam using kevlar fabric*. [pdf] International Journal of Advanced Technology in Civil Engineering. Available at: http://www.interscience.in/IJATCE_Vol2Iss1/paper26.pdf Accessed 14.05.2014

Lehto, R. 2014. *Measuring and Automation Programs* lecture series. HAMK University of Applied Sciences 02. January.- 30.04.2014.

McGraw-Hill, Geller E., Weil J., Blumel D., Rappaport A., Wagner C., Taylor R. eds., 2005 *McGraw-Hill concise encyclopedia of science & technology*. 5th edition. United States of America: RR Donnelley, The Lakeside Press.

National Ready Mixed Concrete Association. 2001. *Concrete in Practice, What, why & how?* . [pdf] National Ready Mixed Concrete Association. Available at: http://www.nrmca.org/aboutconcrete/cips/33p.pdf Accessed 02.05.2014

National Instruments. 2014. *LabVIEW System Design Softwar*. [online] Available at: http://www.ni.com/LabVIEW/ Accessed 14.05.2014

The Aberdeen Group. 1993. *Getting started with high-strength concrete* . [pdf] The Aberdeen Group. Available at: http://www.theconcreteproducer.com/Images/Getting%20Started%20with%20High-Strength%20Concrete_tcm77-1305608.pdf Accessed 12.05.2014

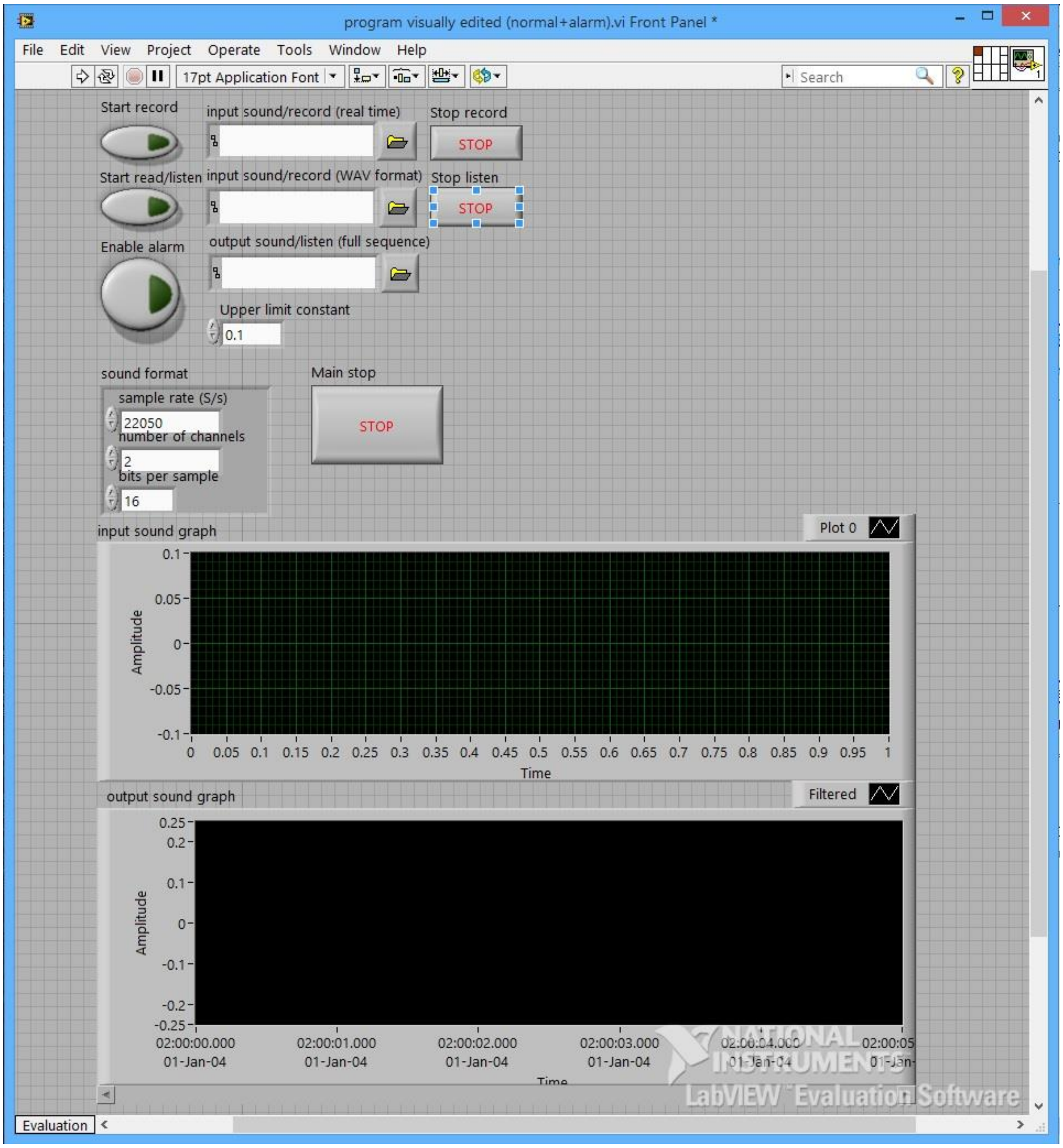
Technical talk. 1999. *Why use high-performance concrete?*. [pdf] Technical talk. Available at: http://www.silicafume.org/pdf/reprints-whyhpc.pdf Accessed 13.05.2014

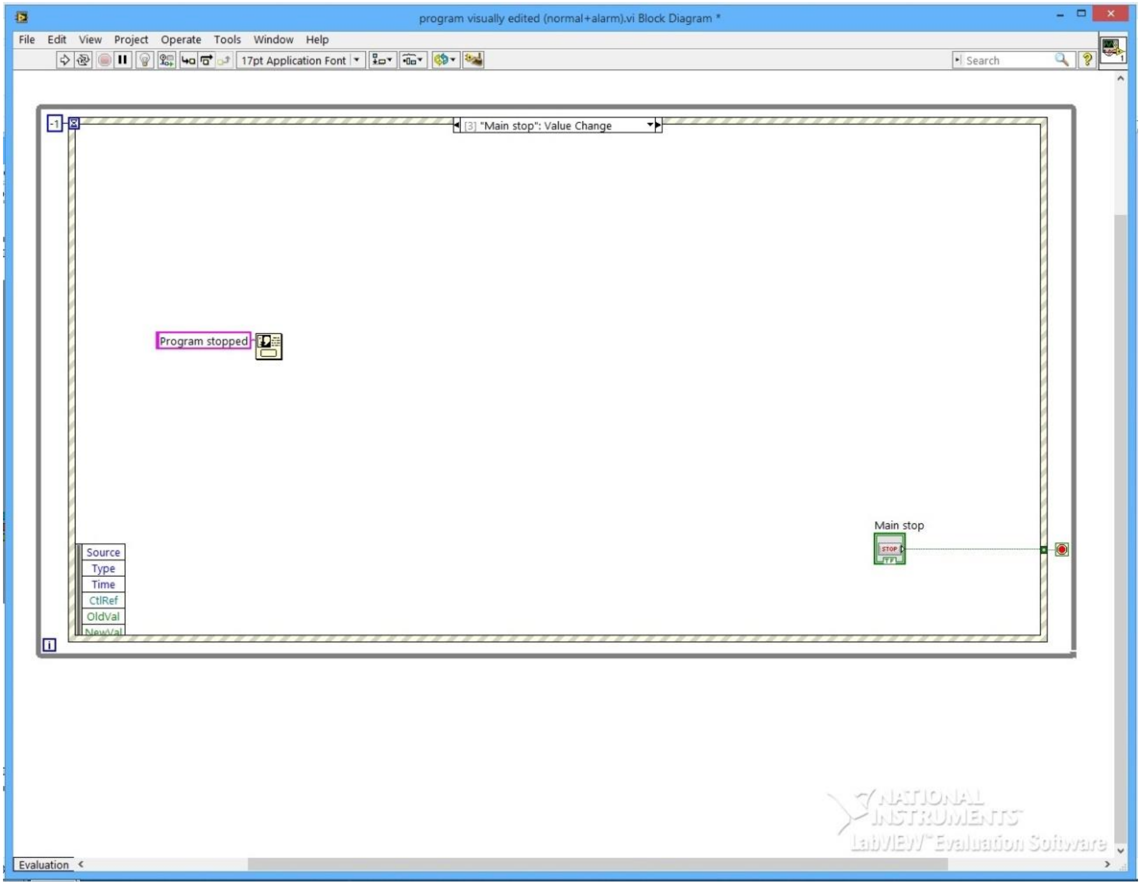
Wikipedia. 2014. *Pascal's law*. [online] Available at: http://en.wikipedia.org/wiki/Pascal%27s_law Accessed 14.05.2014

Wikipedia. 2014. *Concrete.* [online] Available at: http://en.wikipedia.org/wiki/Concreting Accessed 07.05.2014

Appendix 1

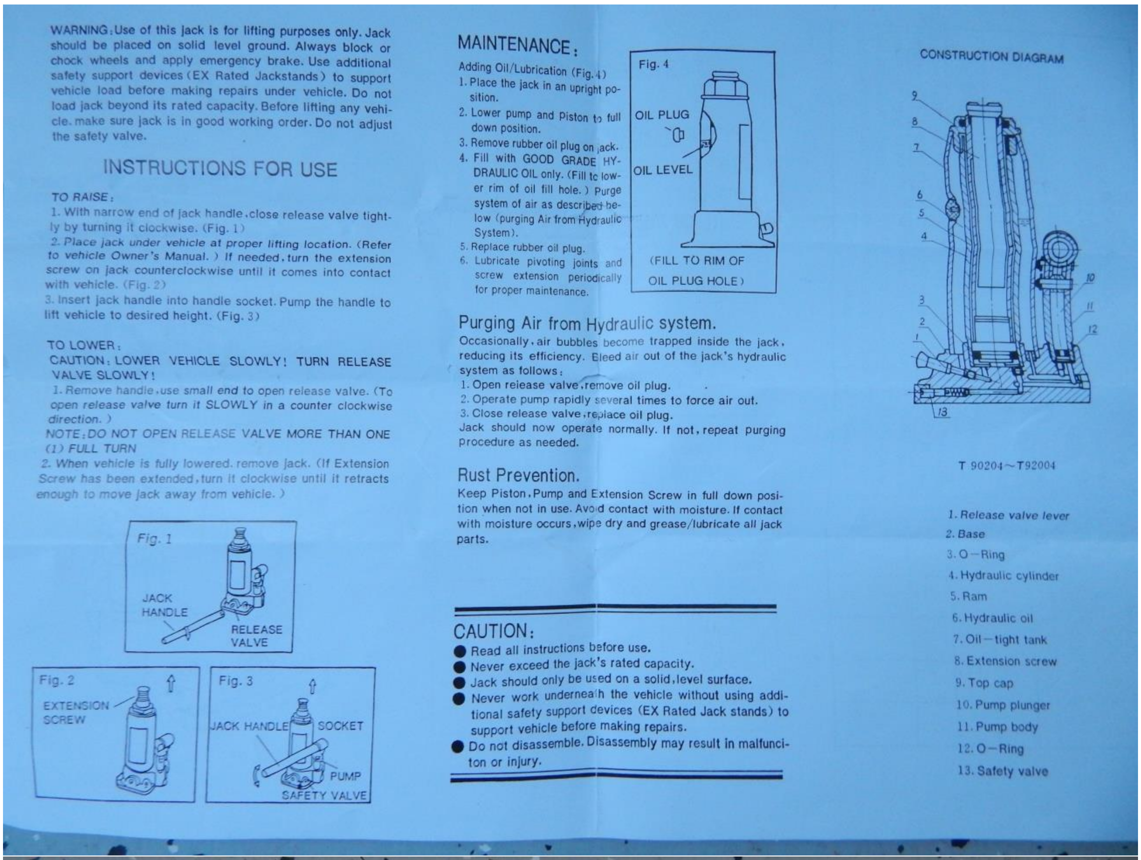
CREATED PROGRAM IN LABVIEW


program visually edited (normal+alarm).vi Front Panel *
File Edit View Project Operate Tools Window Help
17pt Application Font
Search
Start record
input sound/record (real time)
Stop record
STOP
Start read/listen
input sound/record (WAV format)
Stop listen
STOP
Enable alarm
output sound/listen (full sequence)
Upper limit constant
0.1
sound format
sample rate (S/s)
22050
number of channels
2
bits per sample
16
Main stop
STOP
input sound graph
Plot 0
Amplitude
Time
output sound graph
Filtered
Amplitude
Time
LabVIEW Evaluation Software
Evaluation



Appendix 2

HYDRAULIC JACK MANUAL



WARNING: Use of this jack is for lifting purposes only. Jack should be placed on solid level ground. Always block or chock wheels and apply emergency brake. Use additional safety support devices (EX Rated Jackstands) to support vehicle load before making repairs under vehicle. Do not load jack beyond its rated capacity. Before lifting any vehicle. make sure jack is in good working order. Do not adjust the safety valve.

INSTRUCTIONS FOR USE

TO RAISE:

1. With narrow end of jack handle, close release valve tightly by turning it clockwise. (Fig. 1)
2. Place jack under vehicle at proper lifting location. (Refer to vehicle Owner's Manual.) If needed, turn the extension screw on jack counterclockwise until it comes into contact with vehicle. (Fig. 2)
3. Insert jack handle into handle socket. Pump the handle to lift vehicle to desired height. (Fig. 3)

TO LOWER:

CAUTION: LOWER VEHICLE SLOWLY! TURN RELEASE VALVE SLOWLY!

1. Remove handle, use small end to open release valve. (To open release valve turn it SLOWLY in a counter clockwise direction.)

NOTE: DO NOT OPEN RELEASE VALVE MORE THAN ONE (1) FULL TURN

2. When vehicle is fully lowered. remove jack. (If Extension Screw has been extended, turn it clockwise until it retracts enough to move jack away from vehicle.)

MAINTENANCE:

Adding Oil/Lubrication (Fig. 4)

1. Place the jack in an upright position.
2. Lower pump and Piston to full down position.
3. Remove rubber oil plug on jack.
4. Fill with GOOD GRADE HYDRAULIC OIL only. (Fill to lower rim of oil fill hole.) Purge system of air as described below (purging Air from Hydraulic System).
5. Replace rubber oil plug.
6. Lubricate pivoting joints and screw extension periodically for proper maintenance.

Purging Air from Hydraulic system.

Occasionally, air bubbles become trapped inside the jack, reducing its efficiency. Bleed air out of the jack's hydraulic system as follows:

1. Open release valve, remove oil plug.
2. Operate pump rapidly several times to force air out.
3. Close release valve, replace oil plug.

Jack should now operate normally. If not, repeat purging procedure as needed.

Rust Prevention.

Keep Piston, Pump and Extension Screw in full down position when not in use. Avoid contact with moisture. If contact with moisture occurs, wipe dry and grease/lubricate all jack parts.

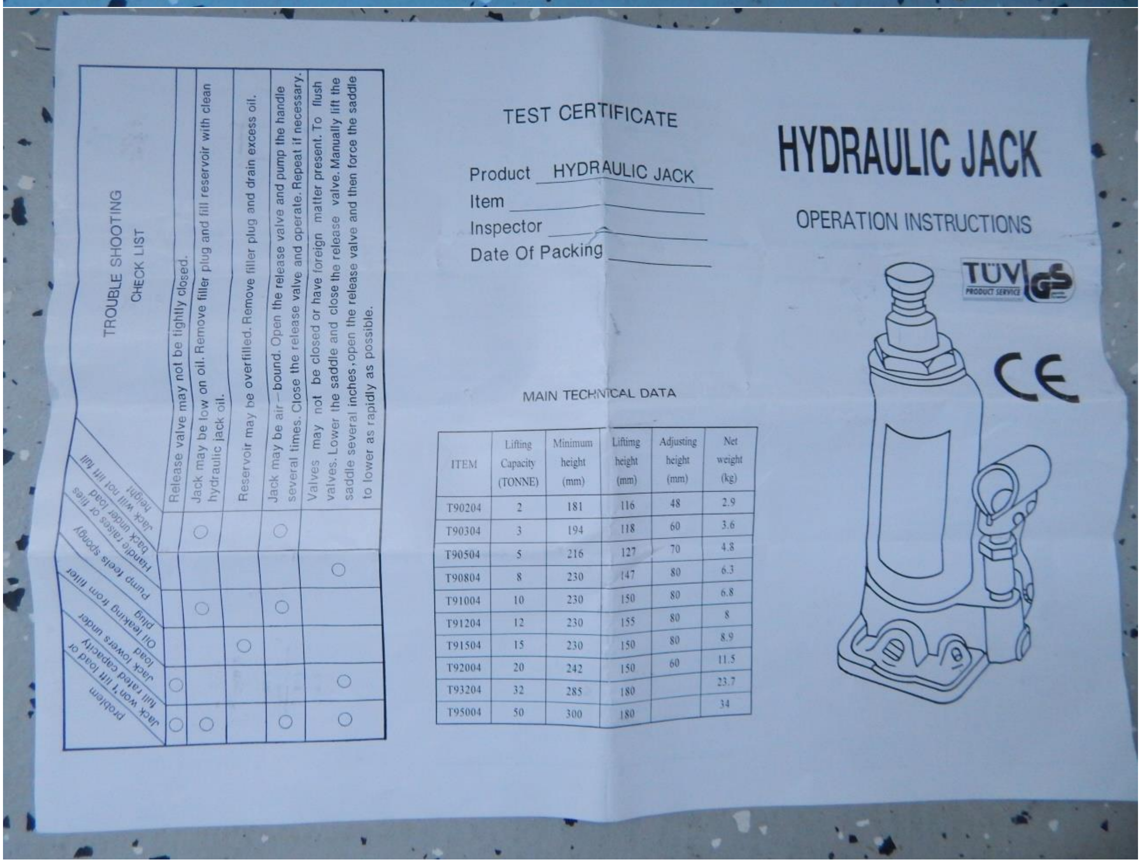
CAUTION:

- Read all instructions before use.
- Never exceed the jack's rated capacity.
- Jack should only be used on a solid, level surface.
- Never work underneath the vehicle without using additional safety support devices (EX Rated Jack stands) to support vehicle before making repairs.
- Do not disassemble. Disassembly may result in malfunciton or injury.

CONSTRUCTION DIAGRAM

T 90204~T92004

1. Release valve lever
2. Base
3. O-Ring
4. Hydraulic cylinder
5. Ram
6. Hydraulic oil
7. Oil-tight tank
8. Extension screw
9. Top cap
10. Pump plunger
11. Pump body
12. O-Ring
13. Safety valve



TROUBLE SHOOTING CHECK LIST

Problems: Jack will not lift full height; Jack under load, lifts or falls back; Handle feels spongy; Pump from filler; Oil leaking from plug; Jack lowers under load; Jack won't lift rated capacity full load or problem

- Release valve may not be tightly closed.
- Jack may be low on oil. Remove filler plug and fill reservoir with clean hydraulic jack oil.
- Reservoir may be overfilled. Remove filler plug and drain excess oil.
- Jack may be air-bound. Open the release valve and pump the handle several times. Close the release valve and operate. Repeat if necessary.
- Valves may not be closed or have foreign matter present. To flush valves. Lower the saddle and close the release valve. Manually lift the saddle several inches, open the release valve and then force the saddle to lower as rapidly as possible.

TEST CERTIFICATE

Product HYDRAULIC JACK

Item

Inspector

Date Of Packing

MAIN TECHNICAL DATA

ITEM	Lifting Capacity (TONNE)	Minimum height (mm)	Liftimg height (mm)	Adjusting height (mm)	Net weight (kg)
T90204	2	181	116	48	2.9
T90304	3	194	118	60	3.6
T90504	5	216	127	70	4.8
T90804	8	230	147	80	6.3
T91004	10	230	150	80	6.8
T91204	12	230	155	80	8
T91504	15	230	150	80	8.9
T92004	20	242	150	60	11.5
T93204	32	285	180		23.7
T95004	50	300	180		34

HYDRAULIC JACK

OPERATION INSTRUCTIONS

Appendix 3

MICROPHONE USED IN MEASURMENTS

Appendix 4

RUBBER PAD FOR PREVENTING SCRATCHING