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Installation Process and Development Idea of Interlocking Concrete Paving Stones in Buildings

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Bachelor’s Thesis

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Bachelor’s degree (UAS).

SAVONIA UNIVERSITY OF APPLIED SCIENCES **THESIS**
Abstract

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Abstract

This project was carried out at Juurikantie 10 B 3, 78300 Varkaus, Finland. For korjausrakentamiisessa as Oy under the supervision of Tapio Toivanen the client of the project and this was done during the summer 2011 from May 2nd 2011 – July 29th 2011.

The aims and objectives of the project were based on interlocking concrete paving stone in general which includes: the installation process of the concrete paver with the pattern chosen by the client (stretcher bond), modification and development idea for the concrete paver mold to improve the product.

A general description and history of concrete paving stones is provided, as well as detailed discussions of the design and construction techniques used for the project. The current ASTM of engineers guide specification for the construction of concrete stones pavements is provided and followed during the installation. By monitoring the performance of the concrete stone pavement for the first three months, it was determined that the design and installation methods demonstrated by this study were valid. After a few months of service, the concrete stone pavement continues to perform satisfactorily under daily tracked footpath traffic. Additional recommendation section and demonstration projects are proposed to validate the use of concrete stone pavement on airfield and port facilities.

The idea of developing the concrete paver's mold is to improve the concrete paver by minimizing the materials used for the production and by keeping quality constant which lead to reduction in cost of production and it will be advantageous to the manufacturing companies. The idea suggested has been discussed in this report with full details of cross sectional diagram which gives a full explanation about the improvement idea and is to achieve a durable, reliable and nice aesthetic view for installed interlocking concrete paving stone.

Keywords:
Installation, concrete paver, plate compactor, specification, mold, computer aided design, modification

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APPENDICES

Symbols and Abbreviations:

ICPS: Interlocking Concrete Paving stone

CAD: Computer Aided Design

ASTM: American Society for Testing and Materials

CAM: Computer Aided Manufacturing

PCC: Portland concrete cement

1 Introduction

This project was carried out for the purpose of installing and developing of interlocking concrete paving stones. Most of building owners value an aesthetic view of the building, quality of the building, and also take into consideration maintenance cost and initial cost of the project. One important way of satisfying these tastes is by using concrete paving stones which are elaborately discussed in the study.

Since people are always looking forward to seeing the latest development in daily life activities, the manufacturers of some products are also trying to improve or develop their products to meet up with the high level standard of customers' taste in the markets. Many manufacturers try to be up-to-date in their products improvement without thinking about the effect on the cost of selling the products in the market.
Some building owners appreciate aesthetic view of their buildings, to increase the living standard of their buildings or conveniences of their building, quality of the building and durability of the building as far as the building surrounding is concerned and making use of interlocking concrete paving stones is one of the main ideas of achieving all these goals mentioned above.

This thesis is based on Interlocking concrete paving stones in general, including: the installation and development or improvement of interlocking concrete paving stones. The great idea of modifying and improving the mold of interlocking concrete pave stones will increase its aesthetic view and keep its qualities constant and at the same time lower the cost of producing it by reducing the quantity of the materials used to produce it. The modification of the mold for the interlocking concrete stones will not reduce its strength but only reduce the cost of production.

1.1 Aim and objectives of the thesis

Interlocking concrete paving stone (ICPS) can be economically used in private and public building surroundings or compounds: Motor Park, garage, foot pathway, filling station, companies and firms etc. It brings good look or appearance to the floor finish and gives an aesthetic value to the building so as to bring or give conducive environment for the occupants or clients.

The project was carried out in order to affirm and to make it clear to the builders and civil engineers that installation of interlocking concrete paving stones (ICPS) can be improved economically, structurally and functionally in our daily use within our environment. Flexible road construction is pronounced in this part of continent and its' initial cost and maintenance cost is very high. Hence, the need for rigid construction by the use of interlocking concrete paving stones must be considered.

Nowadays, in construction industries, the interlocking concrete paving stones are used for road construction especially in filling or gas stations and in some airports so also as running ways for the aircrafts. They are perfectly constructed into the needed shape with mold and well installed to increase the durability of the road.

Limitations to the study are not far-fetched:

- Inadequate textbooks to make research on or review in order to have comprehensive knowledge of the subject matter but I make this with the help of my own technical know-how.

- Inability to gather enough information from experts in the town due to time constraint, financial inadequacy and language barrier.

1.2 Methodology

The installation process part of the project developed or improved practicalities of the writer of this thesis and technical knowhow which developed in some techniques taught in some courses in the school, most especially maintenance ideas given in maintenance course to conquer little problems faced during the project.

The project was successfully carried out by gathering useful information from lecturers' notes, companies' websites and other few places in the cities of Finland. It was carried out by consulting past reports, engineers, publications and past projects to review so as to have comprehensive pre-knowledge of the subject matters.
Some materials like sand, equipment such as hand tools, mold and simple machines which were not available were sourced for in order to satisfactorily carry out the installation of the interlocking concrete paving stones and modification of the mold.

The aim of this study was to make clear to all builders and engineers, the importance and function of interlocking concrete paving stones in rigid road construction. The study also makes clear that the cost of using these interlocking concrete paving stones in construction is relatively low and economical. The project also clarifies that interlocking paving stones have high resistance against compressive stress and significant resistance against tensile stress.

2 General information about the thesis

Interlocking concrete pavers' mould

Some vital information concerning this thesis is stated and explained below:

Concrete is cast into position or required shape by the means of mold to form paver. Formwork is the general term used to describe the preparation and erection of concrete in which it gives the required shape according to formation of this formwork while molds are boxes or casting to which concrete or any other liquid form is poured to form a pre-cast unit. It should be strong, rigid, less costly and easily stripped off after concreting and it can be made of concrete, metal, plastic fibre and timber. Each of these elements has its advantages and disadvantages like cost, weight, manipulation and maintenance as shown in figure 1.

2.1 Types of interlocking concrete pavers' mold

The interlocking concrete pavers' molds are normally made of four materials which are mentioned below:

- Metal mold: This type of mold is made of metals to give the required shape of the concrete paver. It is most used in producing concrete paving stones in big companies.

- Concrete mold: This type of mold is made of concrete to give the required shape of the concrete paver. It is not commonly used because of its disadvantages and some companies prefer to use other means to produce their product.

- Plastic fibre mold: This type of mold is made of plastic fibre to give the required shape of concrete paver. It is a popular type and commonly used in some companies.

- Timber mold: This type of mold is made by carving timber to give the required shape of concrete paver. It is common in local production of paving stones.

Wood mold (Timber)

Metal mold

Plastic mold

Figure 1: Different types of mold material

There are two main methods of manufacturing interlocking concrete pavers in manufacturing industries

1. Mechanical: Mechanical method is the method of using a machine in the production process of interlocking concrete paver.

2. Manual: Manual method is the method of using labor (human) in the production process of interlocking concrete paver.

2.1.1 Mold modification design process

In order to have a good design for the product, the designer needs to start with a so called design brief which can be gathered within the company itself and from the existing or potential customers who wish to satisfy market's demand by developing a new product. A design brief is just what your clients really need from you. It includes:

- Client’s requirements
- Functional requirements
- Maximum permissible project and product costs based upon the perceived market
- Market details
- Quality requirements

After the design brief has been evaluated, the key design features will be known and concerned with:

- Aesthetic requirements
- Contextual requirements
- Performance requirements
- Production parameters and constraints such as availability of labour, materials, technology and health and safety requirements. [*Timings, R. L. and S. P. Wilkinson. 2000. Manufacturing Technology Vol. 2, page 4 & 5*]

Alternatively, while proposing design feasibility studies are also needed to be carried out in order to give a realistic presentation to the client. The final design will be planned in accordance to associated quality specifications requirements given by national and international standards organizations, safety and environmental legislation and legally binding notes of guidance for the category of product concerned. Although it may be a bit costly at the end but those requirements have to be met.

Naturally, manufacturing engineers usually have problems in doing their job be-cause they do not participate in the designing stage which makes the designers’ work to be termed as over-the-wall approach. To overcome this, a team has to be built. There are so called Concurrent Engineering Teams and they will give some criteria for manufacturability and assembly for the proposed design.

The criteria are:

- Functionality
- Manufacturing issues
- Handling and Assembly. [*Timings, R. L. and S. P. Wilkinson. 2000. Manufacturing Technology Vol. 2, page 4 & 5*]

Facts and figures about mold modification:

Facing the challenge of old product design and manufacturing lead time. Many mold companies are more reliant on 3-D CAD/CAM systems in design and manufacturing.
A new concrete product or plastic product file is often passed to the mold design department before it is completely finalized but the product design may have to be modified many times during the mold design and manufacturing processes due to the improvement in product to soothe the customers' needs. In research, if a mold has been modified, all the tool paths that cover the modified region must be regenerated, no matter how small the modified region may be. If the tool path needs to be regenerated, all the cutter location points must be recalculated, and none of the generated cutter location points can be reused any more. A much time to regenerate the modified tool paths needed as for the original one. On the other hand, the region of the modification is usually small in comparison with the entire machine mold. If the generated cutter location points can be utilized in the new tool path for the modified mold, the tool path regeneration time can be greatly reduced, resulting in savings of NC-data preparation cost, minimizing possible reprogramming errors and increase in production quality and efficiency. [*Zhang, L.P., Fuh, J.Y.H., A.Y.C Nee .Tool Path Regeneration for Mold Design Modification. Page 1 & 2*]

2.1.2 Advantages and disadvantages of concrete paver

Advantages:

There are many advantages in using concrete paving stones under certain conditions. Weighing these advantages against the disadvantages of using concrete paving block is a much easier task when specific site conditions such as subgrade quality, material availability and cost, and traffic conditions are known. Although certain site conditions may create special benefits for using paving blocks, the following list comprises the major reasons for using paving stones as a pavement surfacing. Concrete paving stones:

A. Provide a flexible pavement surface which is composed of durable, rigid materials.

B. Provide a low-maintenance or zero-maintenance pavement surface.

C. Can support large, concentrated loads and heavy, abrasive traffic.

D. Can support heavy loads over relatively weak subgrades.

E. Are comparatively high-quality pavement materials as the blocks are centrally manufactured and tested before going to the job site.

F. Are resistant to environmental damage (e.g. freeze-thaw).

G. Are resistant to damage from fuel and oil spillage.

H. Allow for easy access to subsurface for utilities or subgrade repair.

I. Are reusable (90 to 95 per cent) after removing from an existing pavement surface.

J. Negate traffic delays because of curing (in relation to Portland concrete cement) (PCC).

K. Offer good skid resistance, wet or dry.

L. Are aesthetically pleasing. [*The Advantages of Interlocking Stone Pavers*]

Disadvantages:

There are some disadvantages in using concrete paving stones that must be addressed when considering the block pavement alternatives. Some of the potential disadvantages could be lessened in the future as research and market growth increase. The most prevalent disadvantages commonly attributed to the concrete paving block alternative are:

A. Sometimes higher initial cost, depending on job size, pavement thickness, location, etc.

B. Labour intensive construction process.

C. Ride ability (smoothness) problems at high speeds (greater than 40 mph).

D. Water infiltration of underlying layers; therefore, no moisture sensitive base materials may be used. (This problem is usually only significant at the start of the pavement's service life before solidification of the jointing material.)

E. Lack of experienced designers, contractors, and block suppliers.

2.2 Computer aided design/manufacturing (CAD/CAM)

This chapter deals with the use of computer hardware and graphics software to make design drawings. Nowadays CAD tools make the designer to produce a realistic image of a product to be manufactured with accuracy. It is a system that automatically produces finished products by using computer controlled production machines. Both CAD and CAM work together. A digital model will be generated in CAD which will be used as input in CAM software package after the physical shape of the product is known before composing a proper set of fabrication instructions to a production machine.

The CAD/CAM operators are very useful in every area of design with an architectural design background and creative talent because every design starts from a rough sketch and designer's own ideas. A CAD/CAM operator must be able to read and write with a college level of algebra, trigonometry, and manual drafting practices, the window operating system, 2D and 3D manual sketches. [*Timings, R. L. and S. P. Wilkinson. 2000. Manufacturing Technology Vol. 2, page 12 & 13*]

2.3 Interlocking concrete pavers' designing

The original paving stones were used by the Roman armies centuries ago. They built roads using an aggregate base with the placement of stones on top. These roads are still in place today and wind their way through the European countryside. Following World War II, there was a dire need for reconstruction. To facilitate the construction of roads, the Dutch recreated stone cobbles in concrete. In the 60's, Germany improved the rectangular "Holland Stone" by creating dentate shapes. In the early 70's the popularity of paving stones reached the shores of North America and the stores have gained in popularity ever since. [*Roman Armies History Street in Pompeii*]

The figures 2, 3 below diagrammatically show the rectangular Holland pave stones road in the early 60's and modern rectangular interlocking concrete paving stones respectively.

Figure 2: The rectangular Roman pave stones road in early 60's. [*Roman Armies History Street in Pompeii*]

Figure 3: Modern rectangular interlocking concrete paving stones road in South Africa. [*Tough Concrete Paver Meets Rural Road Challenge*]

Paver stones are individually precast concrete units produced on specially designed paving stone machines according to ASTM standard and specialized manufacturing process ensures an exacting quality controlled environment that produces paver of higher strength and durability than normal concrete. Interlocking concrete paving stones are placed on a one inch bed of sand over a compacted aggregate base and the thickness of the base will vary depending on its application. Paving stones are restrained using edge restraints.

2.3.1 Uses of interlocking concrete paver

Interlocking concrete paving stones are used at airports, container faculties; plazas, parks, driveways, walkways, and patios pavers are perfect solution for almost any application because of their high quality, aesthetic value and lower life-cycle cost in comparison to asphalt or concrete. There are different types of Interlocking concrete paving stones which are categorized with their colours and shapes given by their different kind of molds. [*Tough Concrete Paver Meets Rural Road Challenge*]

2.4 Concrete

Concrete is the mixture of cement, sand or fine aggregate, course aggregate and water in a proportion which when placed in forms and allowed to cure becomes hard like stone. The hardening is caused by chemical reaction between water and cement that continues for a long period of time after the concrete has achieved a sufficient strength for the work. [*Arthur H. Nilson, David Darwin, & Charles W. Dolan, 2003. Design of Concrete Structures Thirteenth Edition, page 36*]

Concrete can be plain or reinforced:

- Plain concrete has no reinforcement bar in it and it is used where it can be subjected to compressive force alone and it has little or no bearing function to perform.

- Reinforced concrete is a structural material most commonly used in engineering and building work. Reinforcement is mainly used for strengthening concrete.

2.4.1 Cement

Cement is a binder; a substance that sets and hardens independently, and can bind other materials together and cement used in construction is characterized as hydraulic or non-hydraulic. Hydraulic cements (e.g., Portland cement (PC)) harden because of hydration, chemical reactions that occur independently of the mixture's water content; they can harden even underwater or when constantly exposed to wet weather. The chemical reaction that results when the anhydrous cement powder is mixed with water produces hydrates that are not water-soluble. Non-hydraulic cements (e.g., lime and gypsum plaster) must be kept dry in order to retain their strength. [*Arthur H. Nilson, David Darwin, & Charles W. Dolan, 2003. Design of Concrete Structures Thirteenth Edition, page 32*]

2.4.2 Aggregate

Aggregate is a broad category of coarse particulate material used in construction including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates and these are the most mined materials in the world. Aggregates are a component of composite materials such as concrete and asphalt concrete; the aggregate serves as reinforcement to add strength to the overall composite material, due to the relatively high hydraulic conductivity value as compared to most soils. [*Arthur H. Nilson, David Darwin, & Charles W. Dolan, 2003. Design of Concrete Structures Thirteenth Edition, page 34*]

2.4.3 Water

Water is a chemical substance with the chemical formula H2O, its molecule contains one oxygen and two hydrogen atoms connected by covalent bonds. Water is a liquid at ambient conditions, but it often co-exists on Earth in its solid state, ice, and gaseous state (water vapour or steam).

Water has its own percentage ratio in weight of cement used in a concrete mix and has an important influence on the quality of concrete produced. A lower water-cement ratio leads to higher strength and durability, but may make the mix more difficult to place. Too much water will result in segregation of the sand and aggregate components from the cement paste. Also, water that is not consumed by the hydration reaction may leave the concrete as it hardens, resulting in microscopic pores that will reduce the final strength of the concrete. A mix with too much water will experience more shrinkage as the excess water leaves, resulting in internal cracks and visible fractures (particularly around inside corners) which again will reduce the final strength.

2.4.4 Sand

Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. The composition of sand is highly variable, depending on the local rock sources and conditions, sand particles range in diameter from 0.0625 mm to 2 mm. An individual particle in this range size is termed a sand grain and the next smallest size class above sand is gravel, with particles ranging from 2 mm up to 64 mm. The next smallest size class is silt: particles smaller than 0.0625 mm down to 0.004 mm in diameter.

Sand is a material that is used often for the sake of construction purposes and silt is made from cement and other such materials just like slag cement and fly ash, aggregate chemical admixtures and water.

3 Basic concept and definition of terms of interlocking concrete paver

3.1 Specification of interlocking concrete paving stone

All the specifications used in interlocking concrete paving stones manufacturing and installation are made by ASTM international body leadership standard with the contribution of more than 30,000 of the world's top technical experts and business professionals representing 135 countries. ASTM members deliver the test methods, specifications, guides and practices that support industries and governments worldwide. American Society for Testing and Materials (ASTM) is an international standards organization that develops and publishes voluntary consensus technical standard for a wide range of materials, products, systems and services. All the specifications mentioned below concerning the interlocking concrete paving stones conform to the ASTM international standards:

Concrete paver:

- The paver pattern mode and structure, thickness, colour, finish indicate the range of colour variation and texture expected in the finished installation. Colour(s) is/are selected by client from manufacturer's available colours and must have correlation with the environment to be installed.

- Tested and accepted samples become the standard of acceptance for the work and must be documented for future references.

- Test results from an independent testing laboratory with experts in line for compliance of concrete pavers with ASTM C 936.

- Manufacturer's certification of concrete pavers must meet applicable ASTM standards. Manufacturer's catalogue product data, installation instructions, and material safety data sheets for the safe handling of the specified materials and products must meet up with the standard.

- Manufacturer's feedback and records must be thoroughly checked before making any selection of concrete paver.

5. Making a sieve analysis per ASTM C 136 for grading of bedding and joint sand.

Paver Installation Subcontractor:

- A copy of Subcontractor's current certificate from the University offering the construction courses program in Finland or any recognized university in the world.

- Job references of subcontractor from similar projects of a similar size and complexity.

- Provide Owner or Client or General Contractor names, postal address, phone, fax, and email address.

Quality assurance

Paving Subcontractor Qualifications:

- Utilize an installer who has successfully completed concrete paver installation similar in design, material, and extent indicated in this project.

- Utilize an installer holding a current certificate of civil Engineering or Building technology/Engineering Certification program. [*Annual Book of ASTM Standards, Volume 04.02*]

Regulatory Requirements and Approvals:

Specify applicable licensing, bonding or other requirements of regulatory agencies.

Mock-Ups:

- Install a 2 x 2 m paver area.

- Use this area to determine surcharge of the bedding sand layer, soil types or soil condition, joint sizes, and lines, laying pattern, colour and texture of the job.

- This area will be used as the standard by which the work will be judged.
- Subject to acceptance by owner, mock-up may be retained as part of finished work
- If mock-up is not retained, remove and properly dispose of mock-up.

Delivery, storage & handling

General:

- The delivery, storage and handling must comply with Division 1 Product Requirement Section.
- Comply with manufacturer's ordering instructions and lead-time requirements to avoid construction delays.

Delivery:

Deliver materials in manufacturer's original, unopened, undamaged containers packaging with identification labels intact.

- Coordinate delivery and paving schedule to minimize interference with normal use of buildings adjacent to paving.
- Deliver concrete pavers to the site in steel banded, plastic banded or plastic wrapped packaging that capable of transfer by forklift or clamp lift to the place needed.
- Unload pavers at job site in such a manner that no damage occurs to the product.
- Any broken concrete paver must be removed and changed by the supplier or manufacturer. [*Annual Book of ASTM Standards, Volume 04.02 & Application Guide for Interlocking Concrete Pavement*]

Storage and Protection:

- Store materials protected so that they are kept free from mud, dirt, and other foreign materials. [Store concrete paver cleaners and sealers as per manufacturer's instructions.]

- Cover bedding sand and joint sand with waterproof covering if needed to prevent exposure to rainfall or removal by wind. Secure the covering in place.

- The concrete paver must be put in the storage to avoid any defect that might occur in future due to climatic attacks. [*Application Guide for Interlocking Concrete Pavement*]

Project/Site conditions

Environmental requirements:

1. Do not install sand or pavers during heavy rain or snowfall.

2. Do not install sand and pavers over frozen base materials or debris or snow.

3. Do not install frozen sand or saturated sand.

4. Do not install concrete pavers on frozen or saturated sand.

Maintenance

- Extra Materials: Provide manufacturer's additional material for the use of the owner for maintenance and repair.

- Pavers shall be from the same production run as installed materials.

- Any further maintenance must be done according to the manual.

- In case of any deterioration in installation, the broken paver must be removed and replaced by a new paver.

Products

The manufacturer's name must be written on the product's package

The manufacturer's contact information must be written on the product's package
Paver type must be stated on the product by the manufacturer

1. Material Standard must comply with material standards set forth in ASTM C 936. Colour Pigment Material Standard must comply with ASTM C 979.

Note: Concrete pavers may have spacer bars on each unit. Spacer bars are recommended for mechanically installed pavers and for those in heavy vehicular traffic. Manually installed pavers may be installed with or without spacer bars. Verify with manufacturers that overall dimensions do not include spacer bars.

3. Size: The size of the concrete paver must be specify and boldly written on the package for installer to see.

Note: If 80 mm thick pavers are specified, their compressive strength test results per ASTM C 140 should be adjusted by multiplying by 1.18 to equate the results to that from 2 of 60 mm thick pavers.

5. Average Compressive Strength (C140): 55 MPa with no individual unit under 50 MPa per ASTM C 140.

6. Average Water Absorption (ASTM C 140): 5% with no unit greater than 7%.

7. Freeze/Thaw Resistance (ASTM C 67): Resistant to 50 freeze/thaw cycles with no greater than 1% loss of material. Freeze-thaw testing requirements shall be waived for applications not exposed to freezing conditions. [*Annual Book of ASTM Standards, Volume 04.02 & Application Guide for Interlocking Concrete Pavement*]

Bedding and joint sand

A. Provide bedding and joint sand as follows:

1. Washed, clean, non-plastic, free from deleterious or foreign matter, symmetrically shaped, natural or manufactured from crushed rock.
2. Do not use limestone screenings, stone dust, or sand for the bedding sand material that does not conform to the grading requirements of ASTM C 33.

3. Do not use mason sand or sand conforming to ASTM C 144 for the bedding sand.

Note: If the pavement is exposed to heavy traffic with trucks, i.e., a major thoroughfare with greater than 80 KN equivalent single axle loads, contact your technical expert for test method and criteria for assessing the durability of bedding sand.

4. Where concrete pavers are subject to vehicular traffic, utilize sands that are as hard as practically available.

5. Sieve according to ASTM C 136.

6. Bedding Sand Material Requirements: Conform to the grading requirements of ASTM C 33 with modifications as shown in table 1.

Table 1: Grading Requirements for Bedding Sand (ASTM C 33)

Sieve size	**Passing percent**
9.5 mm	100
4.75 mm	95 to 100
2.36 mm	85 to 100
1.18 mm	50 to 85
0.600 mm	25 to 60
0,300 mm	10 to 30
0.150 mm	2 to 10
0.075 mm	0 to 1

[*Annual Book of ASTM Standards, Volume 04.02 & Application Guide for Interlocking Concrete Pavement*]

Note: Coarser sand than that specified in Table 2 below may be used for joint sand including C 33 material as shown in Table 1. Use material where the largest sieve size easily enters the smallest joints. For example, if the smallest paver joints are 2 mm wide, use 2 mm sand grade and smaller in particle size. If C 33 sand is used for joint sand, extra effort may be required in sweeping material and compacting the pavers in order to completely fill the joints.

Joint Sand Material Requirements:

Conform to the grading requirements of ASTM C 144 as shown with modifications in Table 2 below:

Table 2: Grading Requirements for Joint Sand (ASTM C 144, ASTM C 144)

Sieve size	Natural sand Percent passing	Manufactured sand Percent passing
4.75 mm	100	100
2.36 mm	95 to 100	95 to 100
1.18 mm	70 to 100	70 to 100
0.600 mm	40 to 75	40 to 100
0.300 mm	10 to 35	20 to 40
0.150 mm	2 to 15	10 to 25
0.075 mm	0 to 1	0 to 10

Edge restraints

Provide edge restraints installed around the perimeter of all interlocking concrete paving unit areas as follows:

1. Manufacturer: The product must specify the manufacturer.

2. Material: The type of materials used must be indicated and stated on the product package.

3. Material Standard: The material standard must be specified and it must conform to the ASTM international standard. [*Annual Book of ASTM Standards, Volume 04.02 & Application Guide for Interlocking Concrete Pavement*]

Execution

Pre-installation protection:

1. Complete grading, utility installation and other earth disturbing operations prior to excavating for the permeable paver system.
2. Prior to placing permeable interlocking concrete pavers, install sediment control practices upstream to protect the area from sediment in storm water runoff from disturbed soil.

Sub-grade preparation for permeable interlocking concrete pavers:

1. Do not compact or subject subgrade area under proposed permeable paving area to excessive construction equipment prior to placement of the storage aggregate.

2. Excavate area to the elevations and grades specified in the contract documents.

3. When under drain is specified, excavate a trench of at least 305 mm wide by 203 mm deep at locations specified in the contract documents.

4. In areas where cuts are required, do not compact the surface. After final elevation is achieved, scarify surface to a minimum depth of 76 mm to reduce compaction caused by construction equipment.

5. Where fill materials are required, compact materials to 92% of maximum Standard Proctor Density. Do not over-compact.

6. Fill and lightly re-grade any areas damaged by erosion, ponding, or traffic compaction prior to placing the engineering fabric.

Engineering fabric:

1. Install engineering fabric over completed subgrade, including trench for under drain when specified.

2. Overlap adjacent strips of fabric of a minimum of 152 mm over the proposed pavement.

3. Extend fabric up the sides of the sub base trench to the bottom of the proposed pavement.

Preparation for installation:

A. Verify base is dry, certified by General Contractor as meeting material, installation and grade specifications.

B. Verify that base [and geotextile] is ready to support sand, [edge restraints,] and, pavers and imposed loads.

C. Edge Restraint Preparation:

- Install edge restraints per the drawings and manufacturer's recommendations at the indicated elevations.

- Mount directly to the finished base. Do not install on bedding sand.

- The minimum distance from the outside edge of the base to the spikes shall be equal to the thickness of the base.

Installation

A. Spread bedding sand evenly over the base course and screed to a nominal 25 mm thickness, not exceeding 40 mm thickness. Spread bedding sand evenly over the base course and screed rails, using the rails and/or edge restraints to produce a nominal 25 mm thickness, allowing for specified variation in the base surface.

- Do not disturb screened or screeded sand.

- Screeded area shall not substantially exceed that which is covered by pavers in one day.

Do not use bedding sand to fill depressions in the base surface. [*Annual Book of ASTM Standards, Volume 04.02 & Application Guide for Interlocking Concrete Pavement*]

Note: When initially placed on the bedding sand, manually installed pavers often touch each other, or their spacer bars if present. Joint widths and lines (bond lines) are straightened and aligned to specifications with rubber hammers and pry bars as paving proceeds.

B. Lay pavers in pattern(s) shown on drawings. Place units hand tight without using hammers. Make horizontal adjustments to placement of laid pavers with rubber hammers and pry bars as required.

Note: Contact the manufacturer of interlocking concrete paver units for recommended joint widths.

C. Provide joints between pavers 2 and 5 mm in width. No more than 5% of the joints shall exceed 6 mm in width to achieve straight bond lines.

D. Joint (bond) lines shall not deviate more than ±15 mm over 15 m from string lines.

E. Fill gaps at the edges of the paved area with cut pavers or edge units.

F. Cut pavers to be placed along the edge with a double blade paver splitter or circular hand saw machine or masonry saw.

Note. Specify requirements for edge treatment in paragraph below.

G. Adjust bond pattern at pavement edges so that cutting of edge pavers is minimized. All cut pavers exposed to vehicular tires shall be no smaller than one-third of a whole paver. Cut pavers at edges as indicated on the drawings.

H. Keep skid steer and forklift equipment off newly laid pavers that have not received initial compaction and joint sand.

I. Use a low-amplitude plate compactor capable of at least minimum of 18 KN at a frequency of 75 to 100 Hz to vibrate the pavers into the sand. Remove any cracked or damaged pavers and replace with new units.

J. Simultaneously spread, sweep and compact dry joint sand into joints continuously until full. This will require at least 4 to 6 passes with a plate compactor. Do not compact within 2 m of unrestrained edges of paving units.

K. All work within 2 m of the laying face must be left fully compacted with sand-filled joints at the end of each day or compacted upon acceptance of the work. Cover the laying face or any incomplete areas with plastic sheets overnight if not closed with cut and compacted pavers with joint sand to prevent exposed bedding sand from becoming saturated from rainfall.

L. Remove excess sand from surface when installation is complete.

Note: Excess joint sand can remain on surface of pavers to aid in protecting their surface especially when additional construction occurs after their installation. If this is the case, delete the article above and use the article below. Designate person responsible for directing timing of removal of excess joint sand.

M. Allow excess joint sand to remain on surface to protect pavers from damage from other trades. Remove excess sand when directed in the instruction document.

N. Surface shall be broomed clean after removal of excess joint sand. [*Annual Book of ASTM Standards, Volume 04.02 & Application Guide for Interlocking Concrete Pavement*]

Field quality control:

Note: Surface tolerances on flat slopes should be measured with a rigid straightedge. Tolerances on complex contoured slopes should be measured with a flexible straightedge capable of conforming to the complex curves on the pavement surface.

A. The final surface tolerance from grade elevations shall not deviate more than ±10 mm under a 3 m straightedge.

B. Check final surface elevations for conformance to drawings.

Note: For installations on a compacted aggregate base and soil subgrade, the top surface of the pavers may be 3 to 6 mm above the final elevations after compaction. This helps compensate for possible minor settling normal to pavements.

C. The surface elevation of pavers shall be 3 to 6 mm above adjacent drainage inlets, concrete collars or channels.

D. Lippage: No greater than 3 mm difference in height between adjacent pavers. [*Annual Book of ASTM Standards, Volume 04.02 & Application Guide for Interlocking Concrete Pavement*]

Note: Cleaning and sealing may be required for some applications. Cleaning and Sealing Interlocking Concrete Pavements for guidance on when to clean and seal the paver surface, and when to stabilize joint sand.

Cleaning, sealing and joint sand stabilization:

Clean, seal and apply joint sand stabilization materials between concrete pavers in accordance with the manufacturer's written recommendations.

Protection:

After work in this section is complete, the General Contractor shall be responsible for protecting work from damage due to subsequent construction activity on the site. [*Annual Book of ASTM Standards, Volume 04.02 & Application Guide for Interlocking Concrete Pavement*]

3.2 Definition of important terms of interlocking concrete paver

The important terms and definitions section gives the meaning to terms and scientific words mentioned in the third chapter of this thesis report and the definitions of scientific words that will be mentioned in the third chapter are given below:

3.2.1 Compressive strength

This is the resistance of paving stones to crushing. The compressive strength of concrete is the most common performance measure used by the engineer in designing buildings and other structures, measure by breaking cylindrical concrete specimens in a compression-testing machine and is calculated from the failure load divided by the cross-sectional area resisting the load and reported in units of megapascals (MPa) in SI units. Concrete compressive strength requirements can vary from 17 MPa for residential concrete to 28 MPa and the higher in commercial structures, higher strength up to and exceeding 70 MPa are specified for certain applications.

3.2.2 Tensile strength

Tensile strength is the resistance of paving stones to beading, the tensile strength of concrete can be expressed as follows:

1. Flexural tensile strength: It is measured by testing beams under 2 point loading and also called 4 point loading including the reactions.

2. Splitting tensile strength: It is measured by testing cylinders under diametral compression.

3. Direct tensile strength: It is measured by testing rectangular specimens under direct tension. *[Arthur H. Nilson, David Darwin, & Charles W. Dolan, page 48*]

3.2.3 Bedding sand

The sand bed, along with full joints of sand, creates friction between individual pavers producing vertical and rotational interlock. The sand joint also plays a “cushioning” role in preventing paver to paver contact and resulting damage. Angular or course sand works the best in creating interlock patterns. Round particle sand, like mason’s sand, complicates this process because the particles don’t want to stay together, reducing friction, leading to sand loss. The sand bed needs to function as a drainage layer for water penetrating through the joints. A saturated sand bed can create what Knapton and Cook refer to as “lubricating slurry” destabilizing the bed and reducing the amount of load transfer capability. Therefore, washed sand, void of fine material (< 3% passing 200 sieves), is necessary to allow for free flow of water and the prevention of sand segregation.

3.2.4 Edge restraint

Edge restraint prevents the horizontal movement of the pavers along the perimeter, maintaining the integrity of the pavement. There should always be an edge restraint installed along the entire perimeter or where there is a change in the pavement material, unless the pavers are installed along a fixed edge, such as a building, a retaining wall, a curb or a planter. Restraints should also be selected, designed and installed to remain stationary under the occasional impact from wheels.

3.2.5 Jointing sand

Most often, ASTM C33 is specified for joint sand because it compacts better and it is more convenient/ economical to have one sand type at the job. However, there are particle sizes of C33 that will not fit into a 3 mm joint and can wedge at the joint top, preventing other smaller particles from filling the joint. In general practice, the installer works around the larger particles through extra sweeping and sand applications till the joints are full. The larger particles are then swept off at the end along with any excess sand. Some installers avoid extra sweeping by sieving the sand onsite or having the sand sieved by the aggregate supplier.

Some specifications allow finer sand (ASTM C144) to be used to fill the joints. The main reason is that finer sand is easier to get into the interlocking paving stone’s joints and it helps to insure that the joints will be completely full. However due to the rounded and finer nature of the particles, joint sand retention problems can create loss of interlock, sand tracking and sand reapplication. As a result, do not specify finer joint sands, particularly on vehicular pavements.

4 Installation process and development of concrete paver

Steps taken:

4.1 Step 1: Planning and preparation

Planning:

The project started with good level measurement and drawing of the proposed area for the paving stones with the aid of measuring tool, the selection of the best suitable design and good colour for paver made by the client, the consideration of each size and interlocking of paving stones based on the proposed area for installation of the concrete paving stones. Little calculation was made based on the proposed area for the project to know the amount of chosen design stones will be needed for the project and the order was made after the whole planning. The ordering of the pavers was made by the client and delivered by the manufacturer. It came according to the specification, the pack of pavers was partially covered by transparent plastic to protect the pavers and all were placed on a pallet at the place of use.

Preparation:

Moving the material onto the site before the job commence to complete the job without delays and efficient handling of the pavers affected the length of time taken to complete the moving of material onto the appropriate place on job area because there was no use of forklift to move the whole section of pavers at once. For the personal safety of the worker and the people living in the building, all the underground utilities like irrigation and drainage piping, water supply pipe and gully pipe etc. were located and clearly marked. Before the exaction began, the parameters were staked out and some parts were made a bit larger than the area for the installation area while some foot path areas were at the exact size of the proposed area. A slope was made and directed from the building to the drainage, to avoid or protect the building from any kind of dampness that might be caused by stagnant water to the building.

4.2 Step 2: Excavation and installing the base

Excavation:

The installation was designed for footpath area of the building so, it cannot bear heavy load. The soil and organic materials was excavated from proposed area for the installation of the interlocking concrete paving stones. Because the proposed area for the installation is a well-drained area for the type of installation pattern chosen by the client, the thickness for the granular base (sub base), bedding course and the paver was made 175 mm deep to give room for all the materials that were to be installed in the excavated area.

Installing the base:

The excavated area was backfilled with gravel and compacted with the aid of plate compactor and hand roller compactor shown in figure 4 below, and later wet gravel was put on it and was compacted again until the gravel was thoroughly levelled and drained without causing any indentation with the required finished grade thickness of 100 mm. Level line was installed across the area by using a line level and it was sure that on the stake, slope goes towards the drainage to give easy access of water running into the drainage and the string was moved down 2 mm for every foot of pavement. The distance from the line to the base was measured and the distance was equal all along the line.

Figure 4: Hand roller compactor Plate compactor

4.3 Step 3: Installing the restraints and screening the bedding sand

Installing the restraints:

Installation of edge restraints was made when installing interlocking concrete pavers while some other edges which don't have fixed edge restraint were installed after the installation of the pavers. Edge restraints were applied to the edges by the means of another special type of interlocking pavers design, block walls and building foundation.

Screening the bedding sand:

Before laying the paver, bed sand was prepared, adjusted, levelled and smoothed in order to give rhymes surface for interlocking concrete pavers when installing it. During the installation, 51 mm by 102 mm board was dragged across the top of the bed sand to smooth and level the surface, filled in the low spot and the indentation with sand, as the pavers' installation was going on, the hand trowel was used to smoothen the bed sand surface to give accurate surface for the pavers. The below diagram shows how the bed sand was laid before it was started to drag the board on it:

Figure 5: Bed sand before the installation of concrete paver

4.4 Step 4: Laying pavers and cutting pavers

Laying pavers:

When installing the pavers, the pavers were made to maintain consistent joint widths. Tight joints, with sand in them which spread load to the other pavers and the consistent joint widths also give a neat and orderly visual appearance. During the installation, the sand did not slide across the paver but down in the side of the previously installed unit, building up the sand between paver caused the alignment to go askew and some pavers have spacers built into the unit that assist in maintaining the required 3 mm gap in between each interlocking concrete paver.

Starting laying the first few rows required a lot of attention to the order of placing the units and it established the rhythm, pattern for the remaining courses. The installation of the pavers started from the middle gave enough spaces for the pavers to move close to the installation area and allowed to operate at the wide range during installation of the pavers and finally, starting installation at the middle was necessary because there were no perpendicular corners from which to begin the installation laying pattern chosen by the client. Any adjustments or rectifications were made by screwdriver to put pavers in their appropriate position and make pavers to sit right on the bed sand.

The pattern of the installation was made in such a way that the pavers laid interlocked and keyed to one another which gave a nice view of floor finishes in the building area, the figures 6, 7, 8, 9 and 10 below show the installation pattern.

Figure 6: The front view during installation

Figure 7: cross-sectional view during installation

Figure 8: The plan view during the installation

Figure 9: Complete installation pattern

Laying the concrete pavers in the pattern the client has chosen for the installation and outwards keeping all the joint lines between concrete pavers interwoven and interlocked with others which gave nice aesthetic view to the floor area of the building.

Figure 10: Final installation of the pavers without compaction

Cutting of pavers:

Circular handsaw cutting machine was used based on the size of the project and it disallowed spraying of dust to the atmosphere at the work place during cutting. The paver unit pattern was laid to the outer most edge, then a row of soldier pavers was placed directly on top of the installed area in the same relative position that they will be once the cuts are made. Then, a chalk was used to make a mark along the edge of the soldier course and the static edge restraint for a perfect fit. The circular handsaw machine diagram is shown below for the recognition of the machine:

Figure 11: Circular handsaw machine

4.5 Step 5: Compacting, setting and finishing

Compacting and setting:

Sweeping the surface of the installed paving stones was done to remove debris from the surface, spread surplus sand over it and sweep to fill the joints in between the installed paving stones. After the sweeping, the plate compactor was used again to vibrate and compact it which assisted the sand to fill the joints of the installed interlocking paving stones and put all the stones in place firmly to avoid shaking in the installation in future.

Finishing:

Finally, sweeping of the remaining excess dry sand over the surface filling the joints was done very well and this was repeated over for two to three days as the dry sand settled in the joints and rain also helped in compaction.

These above steps helped in the successful installation of interlocking concrete paving stones mini project the safety and precautions were followed, also the health insurance was taken during the project in case of any danger or hazard that might occur during the installation.

5 Development of concrete pavers

Product development:

In business and engineering, product development has to be done at some intervals. It is a complete process of bringing a new idea into an existing product in the market. As it is known product can be tangible (that is, something physical you can touch) or intangible (like a service, experience, or belief) but in this case PAVING STONE can be regarded as a tangible product. The process is in paths: (1) idea generation (2) product design and detail engineering.

The process:

1. Idea Generation is to reduce the materials quantity and maintain the current quality by changing the mold's shape. Mold changing can bring some kind of waste of energy and resources but it has to be kept in mind that this is just one time change that will be used to produce thousands of products as long as demand lasts.

    - By analysing the SWOT of the developed product, it will be seen that since concrete is good as compressive structural member it will have no effect on maintaining the strength of the previous product. The only weakness that has to be kept in mind is that care must be taken while transporting it and this is one of the general precautions for transporting concretes. Opportunity got is that there is decrease in production cost because less quantity of materials will be used.

    - Lots of ideas are generated about the new product. Out of these ideas many ideas are implemented. The ideas use to generate many forms of new product and their generating places are also various. Many reasons are responsible for generation of an idea and store concepts and techniques are also put into consideration in the process.

Basic facts on product development

- Customer must also benefit from the product
- There must be a better market forecast for the product
- Competitive pressure for the product must be dealt with
- Product must be technically sound and profitable

2. Concept Development and Testing

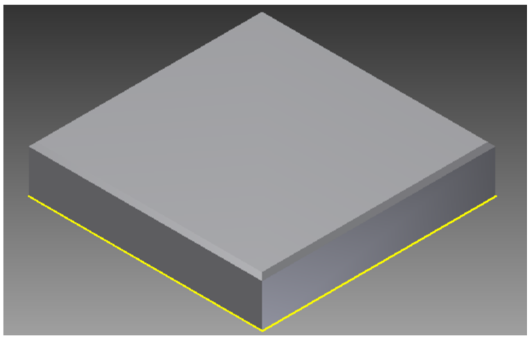



Figure 12: A unit of 60 mm thick concrete paver before development

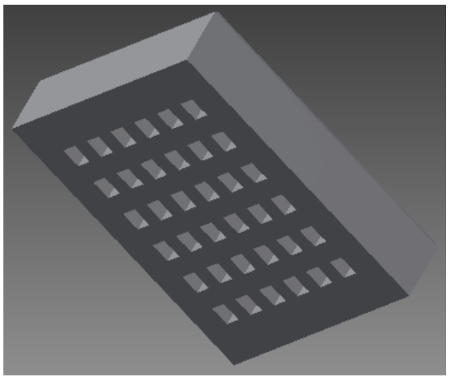
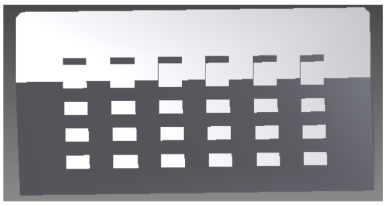



Figure 13: A unit of concrete paver after development

The diagram below (Figure 14) shows the cross-sectional area of newly developed concrete paver and it gives the explanatory of how the product will look like, shows the deepness of the void in the new developed product.

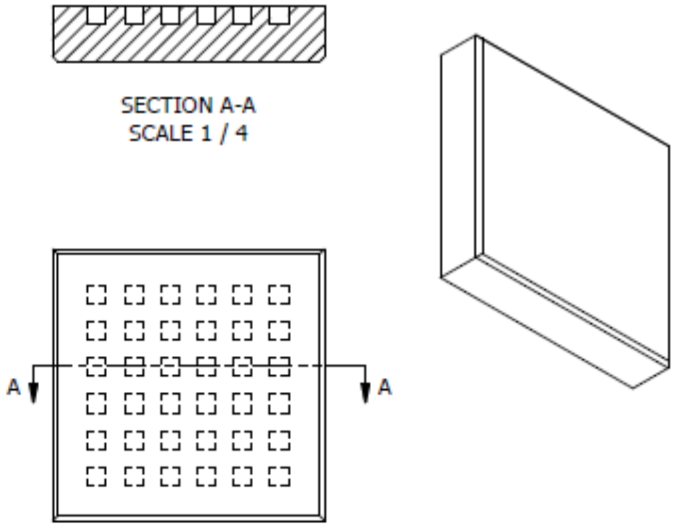


Figure 14: The cross-sectional area of new developed concrete paver

Concrete paver mold development diagram:

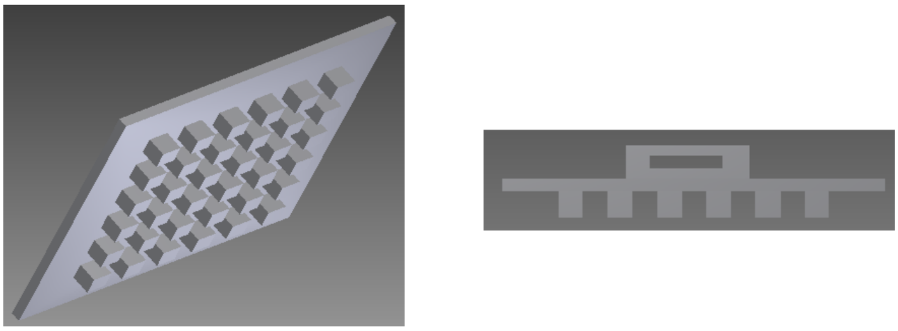


Figure 15: concrete paver mold cover

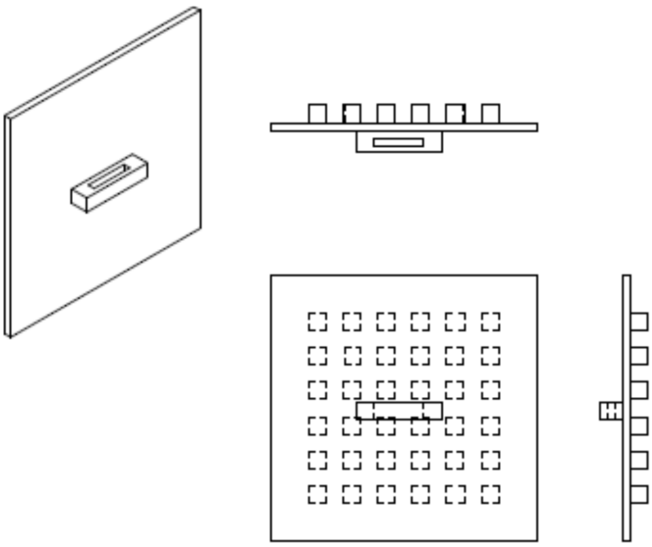


Figure 16: The sections diagram for concrete paver mold cover of new developed product

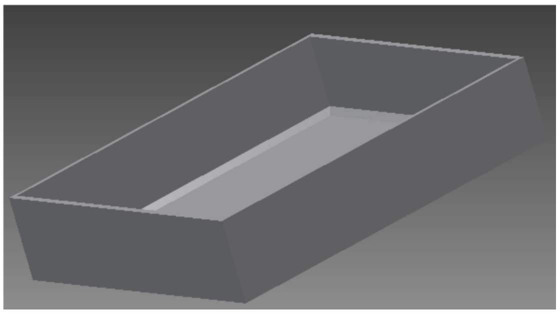


Figure 17: The concrete paver mold designed for developing product

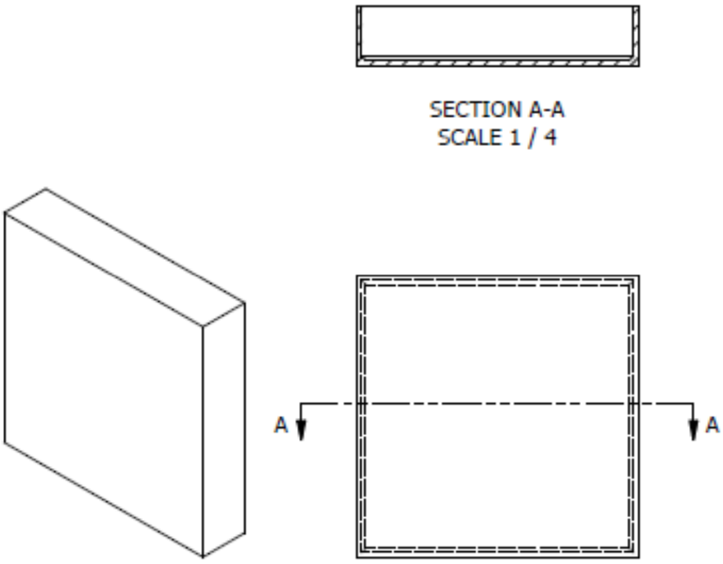


Figure 18: The sections diagram for concrete paver mold of new developing product

Figure 19: The complete set of mold for new developed concrete paver

By analysing the drawings, it will be seen that void creation

- Has nothing to do with its structural strength as it is known that concrete is a very strong compressive member.
- Adds more to its grip ability.
- Reduces the production cost and materials quantity.
- Has nothing to do with customers because it is rarely seen
- Reduces cost and this will attract customers.

The cost of production for the new developed product will be lower than the previous product because the little void underneath the product will accumulate to make another unit of the product and the materials used to produced 5 units of previous product will be used to produced 3.5 of the newly developed product, and this will turn to huge advantage to the manufacturer when producing large amounts of this product.

3. Beta Testing and Market Testing

- Producing a physical prototype or mock-up
- Testing the product (and its packaging) in typical usage situations
- Conducting focus group customer interviews or introductions at trade show
- Making adjustments where necessary
- Producing an initial run of the product and selling it in a test market area to determine customer acceptance.

4. Technical Implementation

The newly developed product will need a logistics plan with the Engineering operation system to achieve better quality management system and resources estimation with supplier collaboration.

5. Commercialization:

- Launch the product
- Produce and place advertisements and other promotions
- Fill the distribution pipeline with product
- Critical path analysis is most useful at this stage

6 Information gathered and conclusions

The information gathered concerning the project is that the total cost of the paving stone project was catered for by the client. Costs included all sub-base and base course work, the geotextile placed beneath the sub-base, and all related incidentals and miscellaneous expenses and the cost of obtaining and placing the paving stones including all stones and sand materials, labour and equipment charges. The elimination of continual maintenance on this intersection (including re-grading, drainage re-construction, and other work) will result in long-term savings for the installation. In general terms, the cost of paving stones varies considerably due to local differences in labour, material, block quality and size, and transportation costs. For large scale applications in the European countries, stone pavements are usually more expensive than conventional paving materials in terms of construction costs. Under some conditions, such as those of the demonstration site, the maintenance cost savings realized by using paving stones instead of conventional paving materials give the paving stone alternative the economic advantage.

The market for concrete stone pavements is currently growing in Europe. More manufacturers are producing paving stones to meet the increasing demands, thereby reducing freight costs in many areas. The number of stone paving contractors is also increasing, creating a more competitive market. It is anticipated that as the concrete paving block market grows in the European countries, the relative cost of materials and construction for block pavements will decrease.

Conclusions:

The following conclusions were made, based on the findings of the demonstration project:

A. The 60 mm-thick rectangular concrete paving stones laid in the stretcher bond pattern (interlocking) can withstand the light and medium load, abrasive loading conditions of footpath traffic.

B. A concrete stone pavement can support heavy loads over weak subgrades when constructed with appropriate base and sub base courses.

C. The current method of using of the Engineers standard flexible pavement design with a 165 mm, equivalent thickness ratio is a conservative but valid design method.

6.1 Results and recommendations

Results:

The results of the project meet up with the aims and objectives of the work, client expectations and satisfaction of the project, although edged restraints used for some parts of the practical work not comply enough with the specified specification standards because another designed pattern of interlocking concrete paving stones was used in replacement of the specified specifications of ASTM standard. Also, since there were two different sizes of designed pattern of concrete pavers used in the installation project, the thickness of both paver patterns were not at the same level and it gave little difficulties in achieving the aim and objectives of the project.

The use of hand roller compactor was first a bit difficult because it required lot of strength to operate but it was later a bit easier to use with the aid of plate compactor. The hand saw machine was tricky and delicate when used to cut the concrete pavers to put in place during the installation by the means of proper safety precautions and protectors for the user, the project was accomplished without any injury or wound during the practical project work.

Modification and development of interlocking concrete stone mold will keep the quality of the concrete stone constant and reduce the quantity of the materials used to produce it, 30% of the material to produce a unit of the concrete will be gained according to the new improvement of mold shown above. The modification of the mold for the interlocking concrete stone will not reduce its strength but only reduces the quantities for production.

Recommendations:

The following recommendations are made:

A. Concrete paving stones should be considered as a pavement surfacing alternative when traffic demands and other site conditions make them economically feasible.

B. The concrete stone pavement guide specification found in pages from 20 to 31 should be used in future stone pavement construction.

C. Additional test sections and demonstration projects are needed to develop other concrete paving stone uses such as for airfields, port facilities, schools, gas stations, and motor-pool areas.

D. Additional material research is needed in the areas of block strength requirements and joint sealants for stabilizing jointing sands.

6.2 Maintenance

The paving block demonstration site was monitored during its first two months of service to evaluate its field performance capabilities. Initial communications with client indicated that the concrete block pavement was performing exceptionally well with no reported block failures or rutting problems. The only maintenance performed during the first few months of use was sweeping of shit of the dog moving around the premises from the installed concrete pavers.

The dog shit was scraped off the pavement surface using spade or shovel. Although this is not a recommended practice, no damage to the paving blocks was reported as a result of this maintenance procedure. In case of any damage in the paving stones in future, the paving stones can be easily removed and replaced by new ones without so much stress to regain its previous state.

References

Textbook:

Arthur H. Nilson, David Darwin, & Charles W. Dolan, 2003. Design of Concrete Structures Thirteenth Edition, Published by McGraw-Hill.

Timings, R. L. and S. P. Wilkinson. 2000. Manufacturing Technology Vol. 2, Second edition, Published by LONGMAN.

Zhang, L.P., Fuh, J.Y.H., A.Y.C Nee. 2002. Tool Path Regeneration for Mold Design Modification, Department of Mechanical Engineering, National university of Singapore, A Thesis, Page 1 - 2.

Others:

Application Guide for Interlocking Concrete Pavement, Searched date: 19.06.2011, Available: http://pavingstones.com/spec-docs/TechSpec-10.pdf.

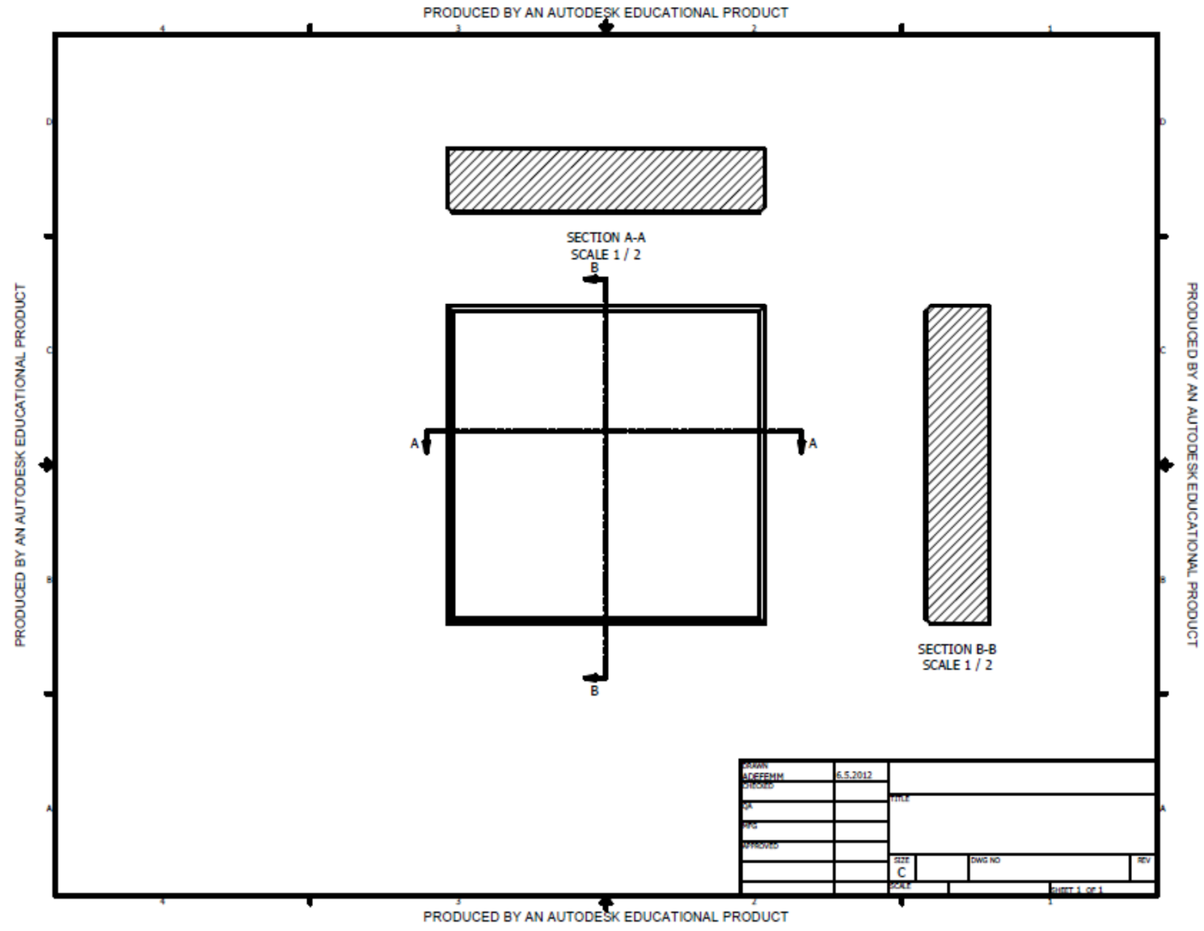
Annual Book of ASTM Standards, Volume 04.02, Searched date: 18.01.2012, Available: http://www.astm.org/BOOKSTORE/BOS/ORDER_OPTIONS/print_0403.htm.

Customer Guide for Paving Stones Installation, Searched date: 01.05.2011, Available: http://www.pavingstones.com/spec-docs/paver_install.pdf.

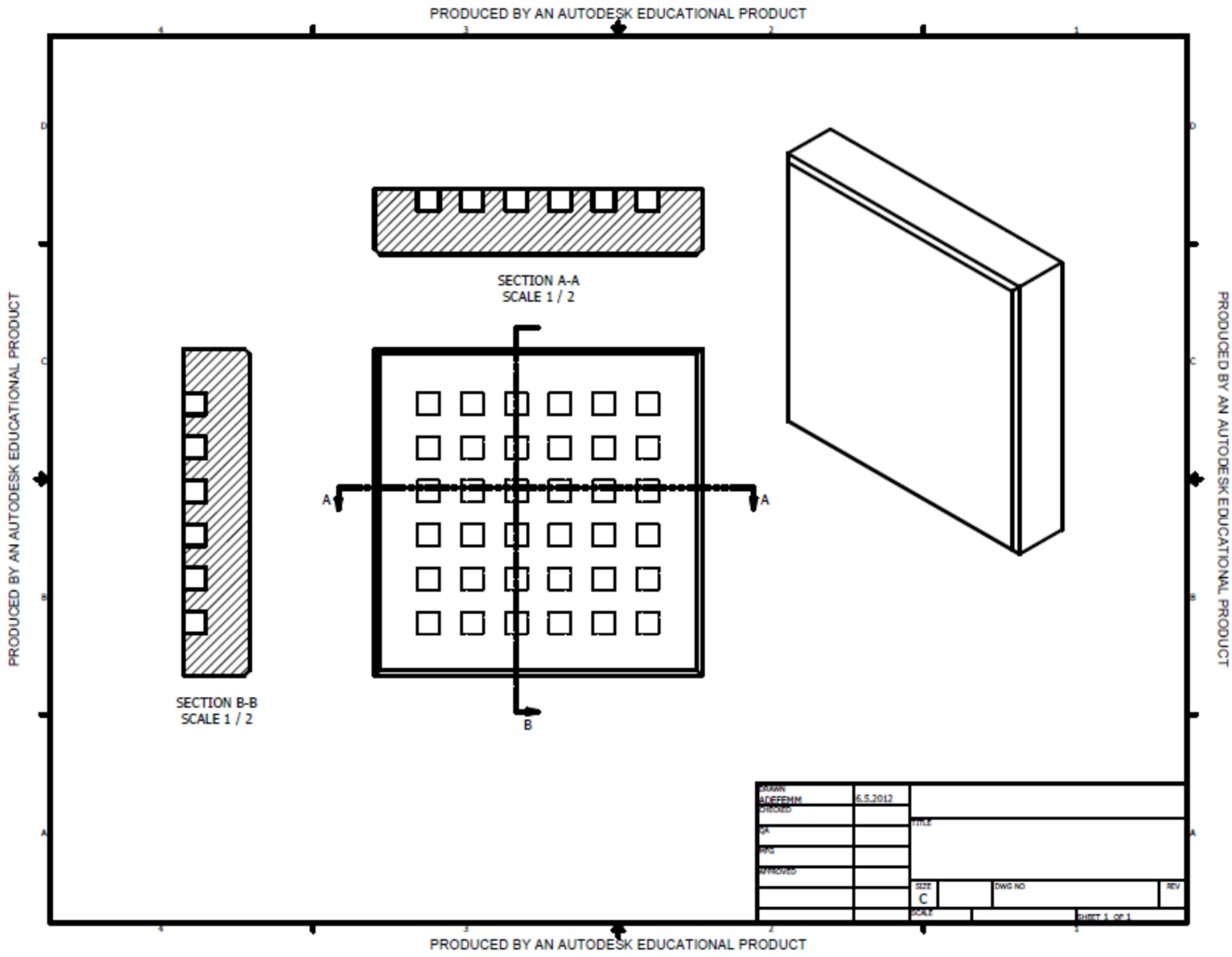
Roman Armies History Street in Pompeii, Searched date: 10.01.2012, Available: http://en.wikipedia.org/wiki/Roman_roads.

Tough Concrete Paver Meets Rural Road Challenge, Searched date: 18.01.2012, Available: http://www.specifile.co.za/specifier/index.php?option=com_content&view=article&id=526:tough-concrete-paver-meets-rural-roads-challenge&catid=12:flooring-and-paving.

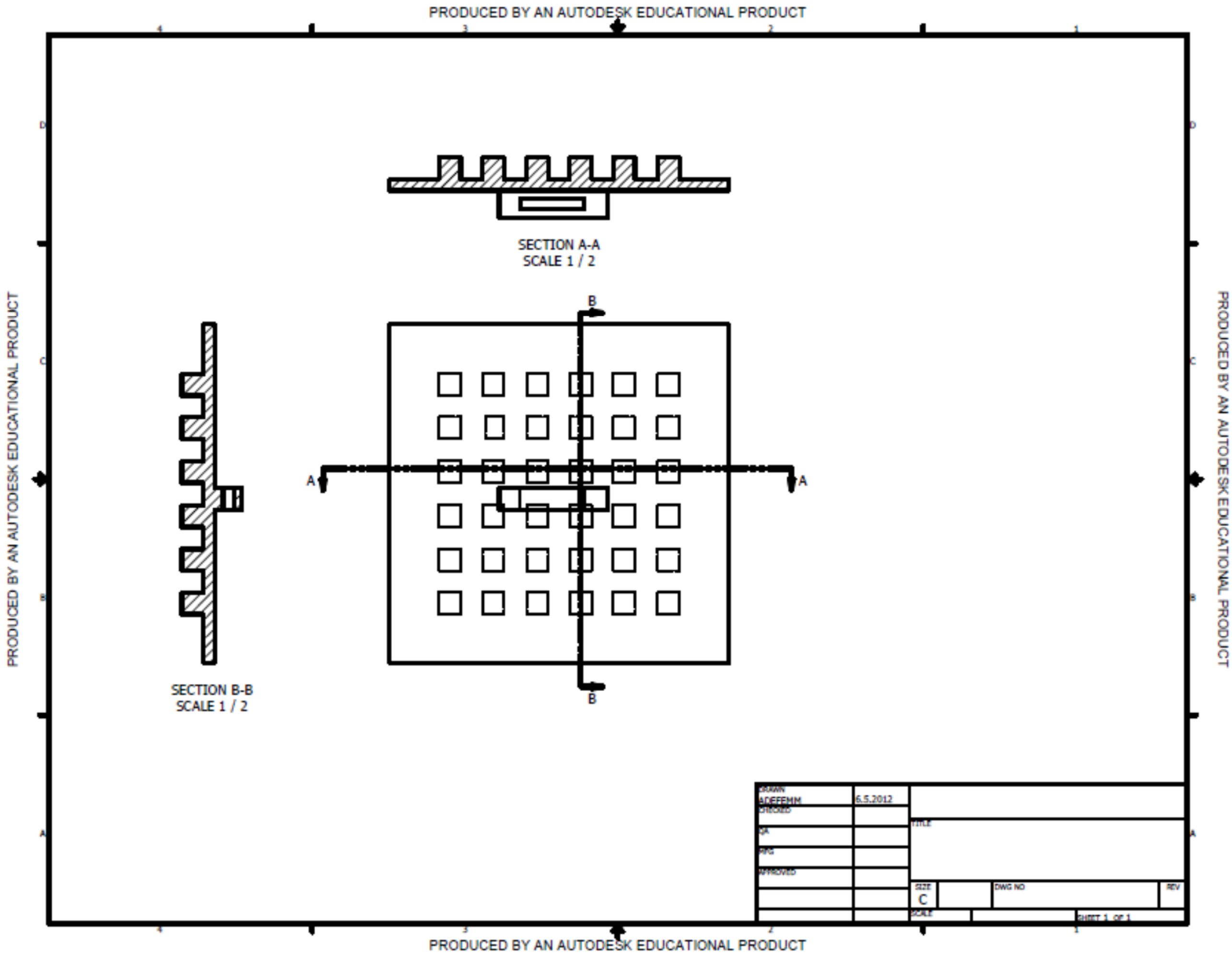
The Advantages of Interlocking Stone Pavers, Searched date: 27.02.2012, Available: http://bleustonepaving.com/advantages.html.



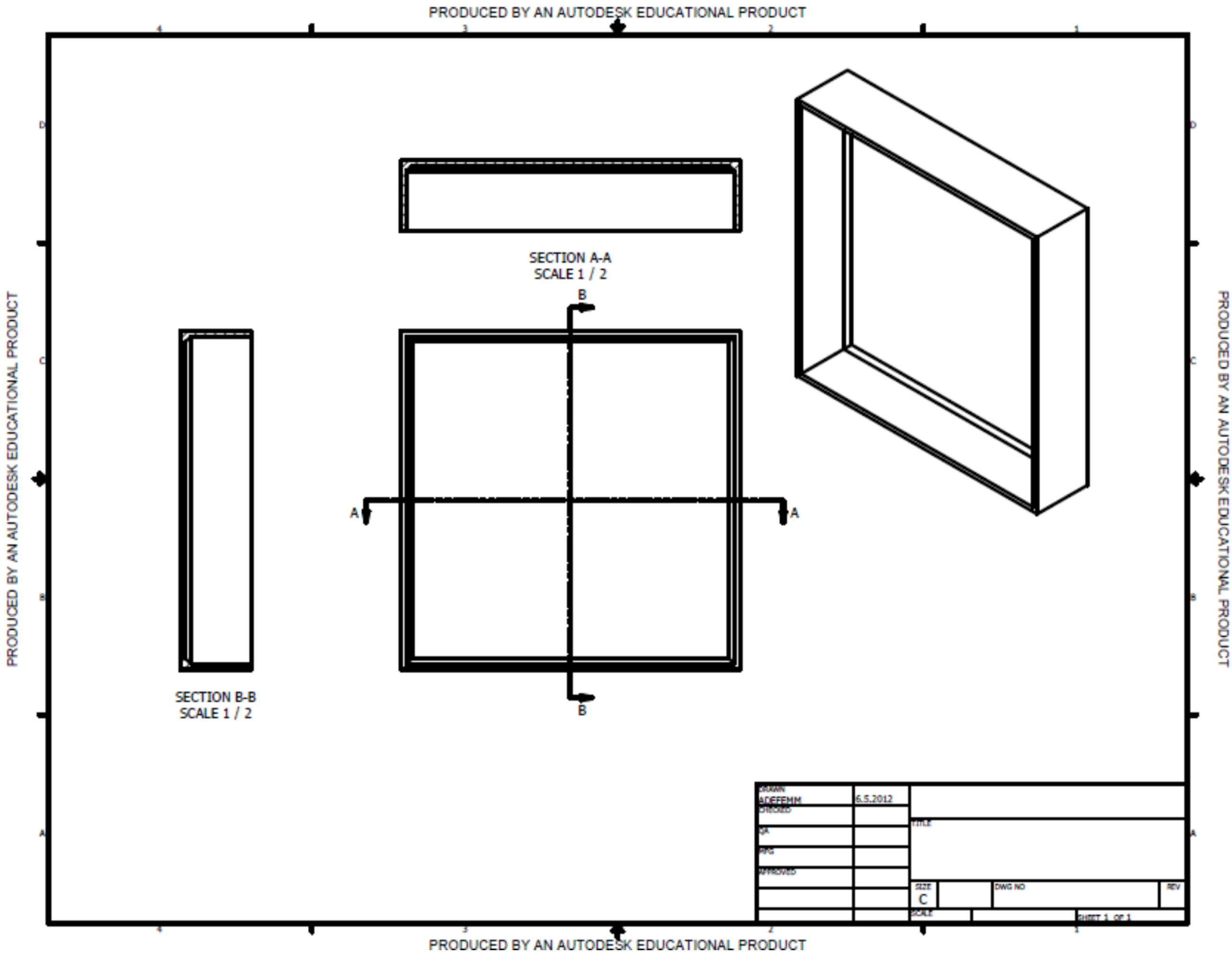
Drawing 1: 60 mm by 300 mm unit concrete paver before improvement



Drawing 2: 60 mm by 300 mm improved concrete paver unit

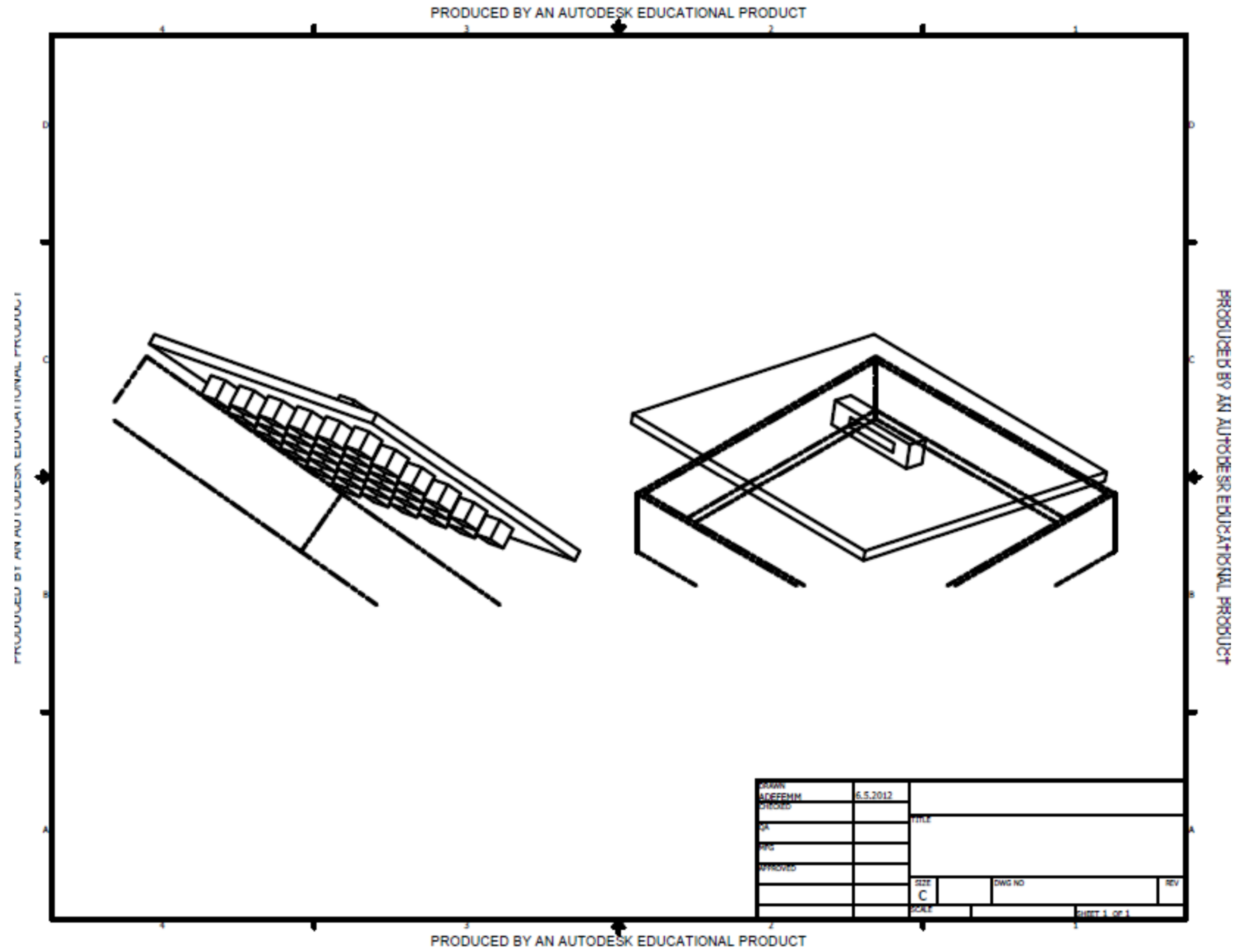


Drawing 3: Cover mold cross section for mold modification



Drawing 4: Bottom mold cross section for mold modification

Appendix 2



Drawing 5: Complete mold modification idea

SAVONIA