南華大學科技學院永續綠色科技碩士學位學程

碩士論文

Master Program of Green Technology for Sustainability

College of Science and Technology

Nanhua University

Master Thesis

再生材料及超塑化劑在透水路面施工中的應用

Application of Recycled Material and Super Plasticizer on the Construction of Pervious Pavement

阿尼爾

Anil Kumar Sah

指導教授：洪耀明 博士

Advisor: Yao-Ming Hong, Ph.D.

中華民國 109 年 6 月

June 2020

南 華 大 學

科技學院永續綠色科技碩士學位學程

碩 士 學 位 論 文

再生材料及超塑化劑在透水路面施工中的應用

Application of Recycled material and Super Plasticizer on the construction of Pervious Pavement

研究生：ANIL KUMAR SAH

經考試合格特此證明

口試委員：

指導教授：

系主任(所長)：

口試日期：中華民國 109 年 6 月 29 日

ACKNOWLEDGEMENT

I would first like to thank my thesis consultant Professor Hong Yao-Ming of the Department of Green technology for sustainability from Nanhua University for his patience, motivation, and precious suggestion. His education helped me in all the time of research and writing of this thesis. The door to Prof. Hong Yao-Ming workplace used to be usually open each time I ran into any doubt or had a query about my research or writing. He persistently allowed me to assume the new thought about the topic and guided me on how to put in force that thinking into reality.

I would additionally like to thank my friends and classmates, who had been additionally reachable for all of my desirable and terrible times. They have been continually equipped to assist in any way in my research.

I would additionally like to renowned our department assistant who usually motivates me to work challenging in the course of my experiment. She usually takes care of all the regulations and guidelines I want to observe to entire my thesis in a guided way. She was once constantly prepared to locate the first-rate feasible answer on every occasion I get hassle in the lab about equipment. I additionally thank all those who have immediately or circuitously helped in the completion of this work.

Author

Anil Kumar Sah

中文摘要

透水混凝土是水和空氣通過其中的混凝土。滲透性混凝土由很少或幾乎沒有的細骨料組成，會產生 10-25％的空隙以使水易於排出，考慮到其出色的抗壓強度性能，儘管其具有很高的抗壓強度，但其卓越的特性卻與傳統方法相似，主要目的是獲得足夠的孔隙率和良好的抗彎強度。不同比例的細骨料粉為水泥混凝土重量的 0％，5％，10％，15％，20％，25％，30％和 35％，該研究中使用了少量的高效減水劑。研究發現，透水路面的雨水管理和環境效益是無可辯駁的，它們反映了低影響發展（LID）的原理。對獲得的變化進行了壓縮，滲透性，滲透和磨損測試。將樣品保存在室溫下固化

關鍵詞：混凝土的抗壓強度、滲透係數、滲透率

ABSTRACT

The pervious pavement concrete is the concrete that approves water and air passing through it. pervious concrete consists of little or fine aggregates, which create voids 10-25 percent to enable the ease drain of water, considering its exceptional characteristics in terms of good compression strength and overall performance regardless of increased interconnected voids porous interlocking blocks is developed in a similar way to the common method.

The fundamental purpose is to acquire enough porosity with properly flexural strength. The best combination powder in various at the proportion is 0%, 5%, 10%, 15%, 20%, 25%, 30% and 35% by means of weight of cement concrete, a small quantity of superplasticizer is used in this investigation. The find out about observed that storm water administration and additionally advantages for environmental, the preceding pavements are irrefutable and they reflect the principals of low impact development (LID). The bought editions have been examined for compression, permeability, and infiltration and abrasion test. The samples are kept for curing at room temperature.

Keywords: Compression Strength of concrete, coefficient of permeability, and Infiltration rate

TABLE OF CONTENT

LIST OF FIGURE

LIST OF TABLE

LIST OF ABBREVIATION

1. American Society for Testing and Materials (ASTM)

2. Aluminum oxide (Al_2O_3)

3. Calcium carbonate ($CaCO_3$)

4. Carbon dioxide (CO_2)

5. Calcium oxide (CaO)

6. Calcium hydroxide (CH)

7. Calcium silicate hydrate (CSH)

8. Dicalcium Silicate C2S ($2CaO.SiO_2$)

9. Fly Ash (FA)

10. High calcium Fly Ash (Class C)

11. Iron oxide (Fe_2O_3)

12. Low calcium Fly Ash (Class F)

13. Magnesium oxide (MgO)

14. Potassium oxide (K_2O)

15. Silicon dioxide (SiO_2)

16. Sodium oxide (Na_2O)

17. Sulphur Trioxide (SO_3)

18. Tetra calcium alumina-ferrite C4AF ($4CaO.Al_2O_3.Fe_2O_3$)

19. Tricalcium Aluminate C3A ($3CaO.Al_2O_3$)

20. Tricalcium Silicate C3S ($3CaO.SiO_2$)

Chapter-1 Preface

1.1 Introduction of previous concrete

Pervious concrete pavement (PCP) is one-of-a-kind and nice capability to handle crucial environmental troubles and help green, sustainable growth. By capturing storm water and allowing it to seep into the ground, porous concrete is instrumental in recharging groundwater, lowering storm water runoff. The U.S. Environmental Protection Agency (EPA) storm water regulations, the uses of pervious concrete is amongst the Best Management Practices (BMPs) recommended with the useful resource of the EPA—and exceptional businesses and geotechnical engineers at some point of the U.S. for the administration of storm water runoff on a regional and close by basis. This pavement science creates increased surroundings pleasant land use through eliminating the desire for retention ponds, swales, and one-of-a-kind storm water administration devices. In doing so, pervious concrete can reduce standard mission prices on a first-cost basis. Pervious pavement is made of both pervious asphalt and pervious concrete. Both substances resemble traditional asphalt and concrete, however, they have extra air areas that enable water to pass by through the pavement into a reservoir base of overwhelmed aggregate, then infiltrate into the ground. The impenetrable surfaces such as pavements and roofs can additionally stop precipitation from recharging the soil and this can decrease the infiltration charge of the floor water

and groundwater recharge. It can additionally extend the price of runoff of the storm water volumes and top waft fees from the catchment. Gradually growing impenetrable areas in city catchments can additionally purpose flooding in the course of intervals of heavy rainfall. When storm water drainage structures are working at potential and accelerated storm water runoff can additionally reason tremendous discount rates in the volume of water on the downstream. Approximately 50% of the world's population now residing in urban areas. Because of the tightly closed floor areas they are struggling with these environmental problems. Sustainable urban drainage system (SUDS) in Europe and Low impact development (LID) in the USA and Japan is comparable to a water sustainable urban drainage (WSUD) in Australia. All of these initiatives include the notion of built-in Land and water administration and built-in city water management. Low impact deployment (LID) primarily focuses on mitigating the unfavorable results of city storm water runoff and discovering the quality options for integrated water cycled management. Pervious pavements permit storm water to filter through voids in the pavement floor into an underlying rock reservoir the place it is quickly saved and infiltrated into the surrounding materials. While preceding pavement designs may additionally vary, they all have a comparable shape consisting of a floor pavement layer with an underlying reservoir layer PP can be described as porous or permeable pavement based totally definitely on the flooring type, and it can be each monolithic and modular. Porous pavements are developed with previous material, such as previous

concrete and porous asphalt, the vicinity water can infiltrate through the entire flooring area. However, for permeable pavements, the paver material is made out of tightly closed blocks even as the areas between the paver blocks are commonly stuffed with coarse-grained elements normally stone aggregate, which lets in water to pass by through. [Ferguson 2005, Zhang 2006, Kuosa et al. 2013a] There are moreover exceptional paver options, such as concrete grid pavers and bolstered turf pavers. These preferences are now no longer greatly covered by using way of this review. Open void fill media may additionally moreover be aggregate, topsoil, and grass. These constructions attribute in the equal hooked up manner as permeable pavement. [Kuosa et al. 2013a].

1.2 Objective of the research

The major goal of this thesis is to do the pervious pavement concrete (PPC) that is appropriate for a huge variety of functions like industrial, commercial, and residential for the light-duty and much less useful, even though these are can be used for a tons wider vary of usage. The pervious pavement concrete must be developed and infiltrated water need to be discharged through the appropriate drainage area and the place there is viable mitigation of pollution in the groundwater.

The following general applications of the previous pavement systems are:

<1>Roadway shoulders

<2>ervice and access driveways

<3>Residential driveway

<4>Parking areas such as car parking, bike parking, heavy-duty vehicle parking

<5>Jogging paths

<6>Slope stabilization and Erosion control

<7>Irrigation of the land

Chapter-2 Literature Review

2.1 Previous study about the previous concrete

Pervious permeable concrete (PPC) can maybe reduce roadway noise, enhance sprinkle and splash, and enhance contact as a floor carrying course. A previous design of concrete combine for a floor sporting direction must meet the guidelines of sample nice and solidness under the site-explicit stacking and natural conditions. An examination challenge on the freeze-defrost solidness of pervious strong mixture plans at Iowa State University (ISU) has as of late been finished (Schaefer et al. 2006). The aftereffects of this investigation have indicated that a solid, sturdy pervious strong mixture design that will face up to wet, hard-freeze prerequisites is conceivable. The first-class has finished the usage of a confined volume of best combination (i.e., concrete sand) and moreover latex admixture to improve the particle bond in the blend. The essential results had been accounted (Kevern et al. 2005).

The ongoing work has been restricted to laboratory trying out and simply a couple of mixes using two aggregates. Fundamental design facility checking out has indicated the magnitude of compaction vitality on the design and execution of the mixes, a problem that has an instantaneous bearing on the improvement approach used to put the substances in the field. An ongoing European Scan supported via the Federal Highway Administration (FHWA) confirmed that the utilization of pervious pavement as contact publications is

degrading, due to the fact of the European inclination towards an uncovered combination concrete. Additionally, stopping up, ravelling, and iciness guides have been proven as problem territories. Members in the Scan felt that the utilization of pervious concrete was once no longer given enough possibility to shape into a manageable paving elective.

The National Concrete Pavement Technology Centre (National CP Tech Centre) at ISU constructed up an exploration mission titled "An Integrated Study of Portland Cement Pervious Concrete for Wearing Course Applications." The goal of the examination used to be to lead an exhaustive record targeted on the development of pervious concrete combine layout having first-class satisfaction and power for carrying route pavement and having floor attributes that reduce noise and enhance slip resistance whilst giving adequate expulsion of water from the pavement floor and structure. The centre of attention of the National CP Tech Centre’s work on previous concrete used to be the enchantment of a sturdy carrying direction that can be utilized in dual carriageway functions for primary noise, sprinkle/shower, slip resistance, and ecological concerns.

2.2 Ratio of the Recycle material

Though there are so many fabric recycling schemes recommended, amongst all of these the authentic administering of construction and demolition (C&D) waste recycling substances is confined to a few kinds of solid wastes.

When we thinking about recyclable material, we have to rely on three main areas that want to be taken into account (Mindess et al, 2003): (i) economy, (ii) compatibility with other materials, and (iii) fabric properties. From a basically financial factor of view, the recycling of development and demolition(C&D) waste is solely appealing when the recycled product is aggressive with herbal assets about the value and volume of the materials. Recycled substances will be extra aggressive in areas the place shortage of each raw substance and landfilling sites exist. Utilizing recycled mixture is in reality an vital step in the direction of sustainable improvement in the concrete enterprise and administration of building west. Recycled mixture (RA) is a workable choice to herbal aggregate, which helps in the renovation of the environment. One of the imperative parameters that have an effect on to use of recycled combination is the variability of the mixture properties. Quality of the recycled combination is influenced by means of the best of substances being gathered and delivered to the recycling plants. Therefore, the manufacturing of recycled combination at an desirable fee fee and best is hard to attain due to contemporary barriers on the recycling plants. These troubles difficulty the customers about the steadiness of manufacturing and variability in combination properties. The predominant intention of the modern-day lookup challenge is to inspect the variability of mixture houses and there have an impact on on concrete produced with 50% recycled mixture have been investigated.

2.3 Ordinary Portland cement replaced by fly ash

The marketing of environmental administration and the mission of sustainable development has exerted the stress demanding the adoption of gorgeous methods to protect the environment in the course of all industries such as construction. Construction with the resource of nature is no longer an environmental-friendly activity. The hierarchy of disposal options, which categorizes environmental influences into six levels, from low to high; namely, reduce, reuse, recycle, compost, incinerate, and the landfill (Peng et al, 1997). Three predominant waste minimization strategies of reuse, recycle and reduction, are at the identical time recognized as the "3Rs". To restrict improvement waste generated on-site, coordination amongst all these worried in the design and constructing manner is essential. Recycling, being one of the methods in minimization of waste, offers three benefits (Edwards et al, 1999): (i) reduce the demand upon new resources, (ii) decrease down on transport and manufacturing electricity expenses and (iii) use waste which would in any different case be misplaced to landfill sites. Construction and demolition (C&D) waste which consists of demolished concrete(foundations, slabs, columns, floors, etc.), bricks and masonry, bushes, and one of a kind supplies such as drywall, glass, insulation, roofing, wire, pipe, rock, and soil (Coventry et al,1999) symbolize massive trouble of the entire waste.

The use of fly ash in Portland cement concrete (PCC) has many blessings and improves concrete average overall performance in the smooth and hardened state. Fly ash use in concrete improves the workability of plastics concrete and the electrical energy and sturdiness of hardened concrete. Fly ash used is moreover cost-effective. When fly ash is delivered to concrete, the volume of Portland cement can additionally be reduced. Therefore pervious concrete is to be considered, there are "no-fines" aggregates, a small share of best particles can be delivered to lengthen the compressive energy of the pervious concrete mix. The inclusion of exceptional particles has a direct correlation to the paste/mortar strength. Providing a thicker preceding layer spherical the coarse aggregates and consequences in increasing compressive of the concrete mix (Schaefer et.al. 2009).

2.4 Compressive strength development of pervious concrete

The most used way to the recycling of the concrete rubble is labelled as sure (natural combination replacement in new concrete) and unbound (road base, trench, etc.). Although unbound use is the most of the volumes of larger than 90%, modern papers have documented perfect concrete characteristics with combination choice up to 30% in new concrete mix layout (Coventry, 1999; Hendriks and Pietersen, 2000; Masters, 2001). An ongoing National CP Tech Centre file titled Mix Design Development for Pervious Concrete in Cold

Weather Climates (Schaefer et al. 2006) offers a rundown of the on handwriting regarding the improvement materials, fabric properties, floor attributes, pervious pavement plan, development, maintenance, and herbal problems for PCPC. The imperative goal of the examination led used to be to construct up a pervious concrete that would supply freeze-thaw obstruction whilst maintaining up fantastic nice and permeability for pavement applications.

The run of the mill combo shape of pervious concrete utilized in the United States involves concrete, single-sized coarse whole (i.e., someplace in the vary of 25mm and 100mm), and water to solidify share strolling from 0.27 to 0.43. The 28-day compressive first-rate of Pervious stable reach from 5 to 20 MPa, with a void percentage going from 14% to 31% and a porousness extending from 0.025 to 0.6 cm/sec. The advantages of pervious concrete contain enhancing slide resistance by way of expelling water that makes sprinkle and splashes throughout precipitation occasions, diminishing commotion, limiting warmness islands in tremendous city areas, safeguarding neighborhood organic systems, and limiting the rate at times. Surface coarse pervious stable asphalt frameworks have been accounted for to be utilized in Europe and Japan. Studies have validated that pervious concrete with the aid of and massive provides a calmer than normal concrete with noise ranges going from 3% to 10% decrease than these of traditional concrete.

The lookup directed at ISU protected investigations of the substances utilized in the previous concrete, the combined share and specimen preparation,

the subsequent fine and penetrability, and the influences of freeze-thaw cycling. An assortment of whole sizes was once tried and each limestone aggregates and circulates run rock have been utilized. Appeared in the determination is a goal scope of void percentage someplace in the vary of 15% and 19% in which the great and porousness are ample for the anticipated reason. Ensuing freeze-thaw checks established that a sturdy combo can be created is key to the development of a combine that would supply enough quality, excellent permeability, and freeze-thaw opposition was once the growth of a modest volume of sand, about 5% to 7%, that elevated the bonding of the aggregates. A few area locales have moreover been examined and the consequences are accounted for in the ace's thought through Keven (2006). Tests from a Sioux City, Iowa website indicated increasingly more uniform compaction in the pinnacle 150mm, with low compaction inflicting excessive voids and low first-class in the base layer.

Chapter-3 Theory of previous concrete pavement

3.1 Materials and Methods

3.1.1 Recycled materials:

Among all special industries, the improvement organization is the largest consumer of the easy resources of every natural one (like stone, sand, clay, lime) and manufactured and synthetic ones. During the ultimate 50 years or so, there has been some unplanned, unchecked, and haphazard exploitation of mineral sources like limestone, clay, iron ore, bauxite, coal, etc. Further, the make bigger of industries is continually throwing large parts of the wastes and byproducts such as fly ash from the thermal energy plant industries & blast furnace slag from the iron industry, pink mud from the aluminum industry, etc. Also, a huge extent of Municipal waste is generated every day in each and every Indian city and all over the world. For example, the Indian town of Delhi generates about 650 heaps of garbage every day. By 2025 this extent would possibly additionally reap 1,800 tones. Generally, the disposal areas are an outside town that is miles apart. Such an extent of waste disposal is a Herculean mission and needs a location for dumping and fuel for transportation. As waste continues to accumulate and availability and plausible of landfill areas diminish, so it is vital to recycle and use it as constructing material more often than not for

sustainable development goals (SDG). Infrastructure construction makes use of the first-rate extent of material which can moreover be recycled materials.

3.1.2 Ordinary Portland cement:

Among all varieties of cement, the regular ordinary Portland cement (OPC) is the most regularly utilized in almost every and each area of the world. The grasp of the embodiment of everyday Portland cement is greater sustainable for the mixing of the concrete and mortar design. It chemically reacts with water to reap preliminary placing time and hardening properties, when used in the building of the buildings, roads, bridges, and extraordinary structures. The daily Portland cement was once as soon as patented by means of the use of Joseph Aspdin in 1824 and was once as soon as named after the cliffs on the isle of Portland in England.The manufacturing of Ordinary Portland cement (OPC) is made by means of the usage of the calcination of a mixture of a calcareous and an argillaceous cloth at a temperature spherical 1450°C. Calcareous aspects are of calcium oxide starting place typically observed in limestone, chalk; components are of silicate and aluminate beginning predominantly discovered in clays, shale, and slags. The calcination manner between well-proportioned argillaceous and calcareous components leads to the manufacturing of clinker. Ordinary Portland cement is bought when the produced clinker is blended collectively with a predefined ratio of gypsum and milled collectively in a ball

mill. The chemical composition of Ordinary Portland cement includes each principal and minor oxide.

The principal oxides encompass CaO, SiO2, Al2O3, and Fe2O3 whereas the minor oxides additionally encompass MgO, SO3, and some alkali oxides (K2O and Na2O) and every now and then the inclusion of different compounds, P2O5, Cl, TiO2, MnO3, and so forth. Each of the oxides performs special work at some stage in cement hydration; however, every content material of the oxide has to be in the proper volume at some point of the proportioning of uncooked substances or raw material of the cement. Cement is the way in to the framework business and it utilized for different purposes and furthermore made in masculine creation for a wide assortment of utilization.

Table 3- 1 Typical composition of ordinary Portland cement

Name of compound	Chemical Composition	Abbreviation
Tricalcium Silicate	3CaO.SiO2	C3S
Dicalcium Silicate	2CaO.SiO2	C2S
Tricalcium aluminate	3CaO.Al2O3	C3A
Tetracalcium aluminum ferrite	4CaO.Al2O3.Fe2O3	C4AF

The ordinary Portland concrete (OPC) is fluctuated in-kind altering the general extents of its 4 dominating artificial compounds and through the degree of fineness of the clinker grinding.

Figure 3. 1 Ordinary Portland cement

A little variety in the piece of its raw materials prompts a huge variety in the compound structure of the potential arrangement of Portland concrete is commonly founded on the Bogue organization (R.H Bogue). In addition to the primary mixes, there exist minor mixes, for example, MgO, TiO2, K2O, and Na2O; they for the most part add up to not be progressively a couple of percent's of the mass of the concrete. Two of the minor mixes are specifically compelling, the oxides of sodium and potassium known as the antacids. They have been found to respond with certain totals, the result of response causing the crumbling of the concrete and have likewise seen to influence the pace of increase of solidarity of cement.

3.2 Aggregates:

3.2.1 Fresh Coarse aggregates:

The coarse aggregates have been first viewed to truly filter for concrete to reduce the volume of cement required. However, the form of combination used for concreting has to massive effect on the plastic and hardened kingdom residences of concrete. They can shape 80% of the concrete mix so their homes are necessary to the properties of concrete. The coarse mixture can be mostly categorized into four wonderful categories: heavyweight, ordinary weight, lightweight, and ultra-weight coarse aggregate. However, we used most concrete particles entirely normal weight and lightweight coarse aggregate. The specific kinds of mixture totally for expert makes use of such as nuclear radiation shielding provided by means of heavyweight concrete and lightweight concrete the utilization of for thermal insulation.

- Classification of the coarse aggregate:

  The preference used for the manufacture of top wonderful concrete is to be offered a coarse combination in at least two dimension groups.

- The Fine combination generally is referred to as sand which is a good deal much less than 4.75mm in size..

- Coarse aggregate, which includes material large than 4.75mm in size.

  Then again, there are a few properties managed by using the combination but lacking in the dad or mum rock: particle size, floor texture, and absorption.

Every one of these houses influences the concrete, both in the new or in the solidified state. It used to be been considered that whole can also exhibit up as inadmissible on some take a look at but no challenge want be skilled when it is utilized in concrete.

3.2.2 Properties of the aggregate

By choosing various sizes and sorts of aggregate and various proportions of aggregate to cement proportions, a wide scope of cement can be delivered financially to suit various necessities.

Figure 3. 2 Coarse aggregate

3.2.3 Fine Aggregates:

The pervious concrete is additionally viewed as a "no-fines" mixture in the concrete; we can add a small proportion of fine aggregate. That will be

Increase the compressive strength of the pervious concrete mix. The inclusion of fine aggregate particles has a direct correlation to the paste/mortar strength. Providing a thicker preceding layer spherical the coarse aggregates consequences in increasing compressive strength of the concrete combine (Schaefer et.al. 2009). When the sand to gravel ratio multiplied to 8%, the mortar bulks up and will increase the strength. When the sand to gravel ratio is increasing beyond the 8% mark, the 7-day compressive strength starts to fall (Schaefer et.al 2009). Both Europe and Japan have been the usage of smaller aggregates as properly as the inclusive of sand for their combined design. An optimization of 10%-20% of great sand to coarse combination has been proven to enlarge compressive strength from 14 to 19 Mpa. A mild minimize in permeability correlates to the make bigger in fine particles.

Figure 3. 3 Fine aggregates

3.3 Fly ash:

It is the waste fabric extracted from the gases emanating from coal-fired furnaces, usually from the thermal electricity plant, which is referred to as fly ash, and indifferent words, the mineral residue that is left at the back of after the burning of coal is referred to as fly ash. With the assist of the Electro Static Precipitator (ESP) of the strength, vegetation collects these fly ashes. Essentially it is consisting of alumina, silica, and iron, fly ashes are micro-sized particles.The fly ash particles are typically spherical in the size, due to the fact of this property makes it convenient for them to combination and flow, to make an appropriate connection. Both amorphous and crystalline nature of minerals is the content material of fly ash generated. Its content material varies with the trade-in nature of the coal is used for the burning process; however, actually, it is non-plastic silt. For the investigations in this study, the fly ash has to be amassed from a thermal energy plant. ASTM C618 defines two instructions of fly ash for use in concrete: 1) Class F, commonly derived from the burning of anthracite or bituminous coal, and 2) Class C, normally derived from the burning of lignite or sub-bituminous coal. ASTM C618 moreover delineates requirements for the physical, chemical, and mechanical properties for these two types of fly ash. Class F fly ash is pozzolanic, with little or no cementing rate alone. Class C fly ash has self-cementing properties as properly as pozzolanic properties. Hence to supply greater stability and binding property to the soil, in our investigation we will be

the utilization of classification C fly ash. The imperative constituent in Fly ash is silica and alumina up to 85% and the specific is 15%.

Table 3- 2 Constituents of fly ash

Constituents of fly ash(%mass)	Values
Silica(SiO_2)	60
Alumina(Al_2O_3)	25
Ferric oxide(Fe_2O_3)	8.12
Calcium oxide(CaO)	2.9
Magnesium oxide(MgO)	0.82
Titanium oxide(TiO_2)	0.24
Free lime content	0.75

Fly ash can be significantly improving the workability of concrete. Recently, techniques have been developed to replace partial cement with high-volume fly ash at the Ghatghar dam project in Maharashtra, India.

Figure 3. 4 Fly ash used as cement replacement

Due to the spherical structure of fly ash particles, it can increase the workability of cement whilst reducing water demand. Proponents of fly ash declare that altering Portland cement with fly ash reduces the greenhouse gasoline "footprint" of concrete, as the manufacturing of one ton of Portland cement generates about one ton of CO2, in distinction to no CO2 generated with fly ash. New fly ash production, i.e., the burning of coal, produces about 20 to 30 ton of CO2 per ton fly ash.

3.4 Advantages and disadvantages of fly ash using in pervious concrete pavement

The advantages of using fly ash in pervious concrete	The disadvantage of using fly ash in pervious concrete
• Use of Fly Ash is environmentally friendly as the waste materials from industries because it reduces the Portland cement (a major contributor of CO2) required in concrete. • Fly ash in the concrete mix efficiently replaced by cement that in turn can aid in making big savings in concrete material prices. • Fly Ash has very small particles that make the concrete highly dense and reduces the permeability of concrete. It can add greater strength to the compressive strength of pervious concrete.	• The quality of fly ash can affect the quality and strength of Cement concrete. • Poor quality fly ash can increase the permeability of the concrete and cause damage to the concrete. • Slower strength gain in the concrete. • Increased need for air-entraining admixtures in the concrete. • Increase of salt scaling produced by higher proportions of fly ash.

The advantages of using fly ash in pervious concrete	The disadvantage of using fly ash in pervious concrete
• It is also helpful in reducing the heat of hydration. The pozzolanic reaction in between lime and fly ash will significantly generate less heat and thus, prevents thermal cracking. • Fly Ash concrete is resistant to acid and sulphate attacks. • The shrinkage of fly ash concrete is very less. • The use of fly ash gives concrete good workability, durability and finish	

- Hence the advantages of using fly ash in previous pavement concrete are more than the disadvantages.

3.5 Mix design and proportions of concrete

Concrete mix design is the process of finding the right proportions of cement, fine aggregate, Fly ash, Admixture, Water and coarse aggregates for concrete to achieve target strength in structures. So, the concrete mix design can be stated as Concrete Mix = Cement: Sand: Aggregates.

3.5.1 Compressive strength of the normal Concrete:

So many tested to apply to the concrete, the most important which gives an idea about all the characteristics of concrete is called compressive strengths test. By this single test, we can judge whether Concreting has been done the

proper way or not. The Compressive strength of concrete depends on so many factors such as fineness of cement, water-cement ratio(w/c), cement strength, quality of concrete material, and quality control during production of concrete, etc. therefore compressive strength is carried out two ways either on cube or cylinder. Various standards codes are recommended for a concrete cylinder or concrete cube as the standard specimen for the test.

This concrete is poured in the mold and tempered at 25 blows at a three different equal layer properly so as not to have any voids. After 24 hours these molds are removed and the test specimen is put in water at room temperature for curing. The top surface of theses specimen should be made even and smooth. This is done by putting cement paste and spreading on whole are of a specimen.

Figure 3. 5 Standard compressive strength cylinder mold

These specimens are examined through a compressive strength testing machine after 7 days curing or 28 days curing. Loads must be utilized steadily at the rate of 140kg/cm2 per minute until the specimen fails. Load at the failure uniformly distributed via surface area of the specimen and give the compressive strength of concrete.

3.5.1.1 Preparation of cylinder specimens

The amount and proportion of the ingredient for making the cylinder specimens the same as using concrete in the field.

3.5.1.2 Mixing of the ingredient

- Mix the concrete either by hand or concrete mixture machine in the laboratory.
- The main power switch should be turned on, then the red power button should be pressed to start the machine.
- The same red button is used to stop the machine.

Figure 3. 6 Power switch for operating the machine

- The drum of the machine can be rotated in 360 degrees with the help of a handle/driver.
- There are specific degrees of rotation for each activity.

Figure 3. 7 Handle for operating the concrete mixture machine

- The drum should be kept at 60 degrees to load the drum with materials.
- The drum should be kept at 90 degrees for mixing and 45 degrees to unload the machine.

Figure 3. 8 loads the drum with the material

3.5.1.3 Sampling of the concrete cylinder

- Clean the cylinder and put the grease inside the surface of the cylinder..
- Fill the concrete in the cylinder in three equal layers.
- Compact each and every layer with no longer a good deal much less than 25 strokes per layer the use of a tamping rod with bullet-pointed at the decrease end.
- Level the pinnacle ground and handy with a trowel

Figure 3. 9 Cylinder mold with a smooth surface

3.5.1.4 Curing of the concrete cylinder

According to (Portland cement association, 2014), curing can be defined as providing the required amount of moisture, temperature and time to allow the concrete to gain the strength quicker. Curing improves concrete short term strength, eliminates surface drying shrinkage crack and reducing long term drying shrinkage cracking. The pozzolanic reaction of fly ash in concrete is slower than the hydration process of cement, and therefore the setting time becomes longer, and the early age strength gets reduced. Due to these reasons, fly ash concrete requires to be properly cured if the early age compressive strength is desired to be achieved.

According to (kholia, 2013), curing techniques and duration significantly affect efficiency. Several curing techniques are used such as; membranes curing self-curing, dry-air curing, and water curing.

The test specimens are stored in moist air for 24hrs and after this period the specimens are marked and removed from the molds and kept submerged in clear freshwater until taken out before the test.

3.5.1.5 Procedure for testing compressive strength

- Remove the specimens from the water after targeted curing time and wipe out extra water from the surface.
- Take the dimensions of the specimen to the nearest
- Clean the bearing floor of the compressive strength testing machine.
- Place the specimen in the compressive strength testing machine in such a manner that the load shall be load uniformly distributed on the cylinder.
- Aline the specimen centrally on the base plate of the machine.
- Rotate the movable component gently via hand so that it touches the upper and lower floor of the specimen.
- Apply the load steadily besides shock and continuously at the rate of 140kg/cm2/minute till the specimen fails.
- Recorded the most load and be conscious of any individual factors in the type of failure.

3.5.1.6 Note:

A minimum of three specimens has to be examined at every chosen age. If the strength of any specimen varies with the greater than 15 percent of average strength, the consequences of such specimens need to be rejected. The common of these specimens offers the crushing or compressive strength of concrete. The compressive strength of concrete gradually increasing with age. The following table indicates the compressive strength of concrete at extraordinary a long time in evaluation with the strength at 28 days after casting.

Table 3- 3 Compressive strength of concrete at various ages

Age(day)	Compressive Strength (%)
1	16
3	40
7	65
14	90
28	99

3.5.2 Compressive strength of pervious concrete:

In the laboratory, pervious concrete combinations are growing compressive strength range from 3.5Mpa to 28Mpa, which is fantastic for a good-sized range of applications. Typical values are about 17Mpa. As with any concrete, the properties and aggregate of special materials, as precise as placement techniques and environmental prerequisites will dictate the actual in-

place strength. However, currently, there is no ASTM check conventional for compressive strength of pervious concrete.

Figure 3. 10 Cylinder tested for compressive strength

Figure 3. 11 Compressive strength testing machine with sample

Testing variability measured with various draft test methods is high and therefore compressive strength is not recommended as an acceptance criterion. Rather, it is recommended that a target void content (between 15% to 25%) as measured by ASTM C 1688: Standard test method for density and void content of freshly mixed previous concrete is specified for quality assurance and acceptance.

Density and porosity:

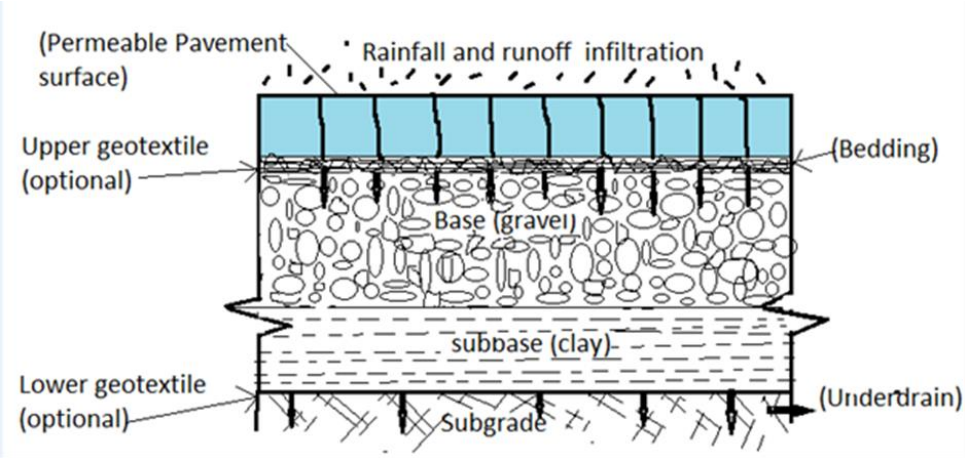


Figure 3. 12 Typical cross section of pervious concrete for pavement.

The density of pervious concrete depends upon on the residences and proportions of the resources used, and on the compressive strategies used in placement. In area densities on the order of 1600 kg/m3 to 2100 kg/m3 are common, which is in the greater range of lightweight concrete. A pavement 125mm thick with 20% voids will be in a function to maintain 25 mm of a sustained rainstorm in its voids, which covers the huge majority of rainfall things to do in the U.S.

3.6 permeability of pervious concrete:

The permeability of pervious concrete was once decided the usage of constant head permeability set up figure 3.7. Water used to be allowed to go with the flow through the coarse combination sample, via a linked standpipe which affords the water head. Before beginning the float dimension the samples had been put higher and decrease porous plates. Then the test started the water to flow through the sample until the water in standpipe reached a given steady state. The permeability of the coarse aggregate was once evaluated from the expression given below

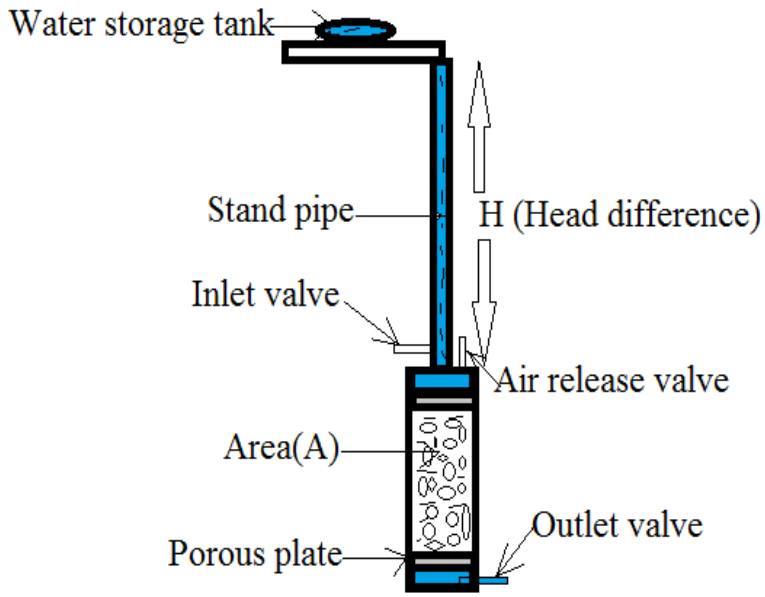


Figure 3. 13 Constant head permeability test apparatus

Coefficient of permeability (K) =

QL/A*t*h in cm/sec

Where:

K = coefficient of permeability, cm/sec.

L = size of the specimen in centimetres

t = time for discharge in seconds

Q = quantity of discharge in cm3 (assume 1 mL = 1 cm3)

A = cross-sectional location of permeameter (= [(π D2)/4]

D= interior diameter of the permeameter)

h = hydraulic head distinction throughout size L, in cm of water; or it is equal to the vertical distance between the steady funnel head degree and the chamber overflow level.

The permeability of the pervious concrete issue is no longer an indispensable format criterion. Consider as pervious concrete pavement device overlying a true drainage soil. The fashion designer has to make certain that permeability is adequate to accommodate all rain falling on the floor of the pervious concrete. However, the charge via the subgrade may also be greater restrictive.

3.6.1 Storage capacity of the pervious concrete

The storage manageable of a pervious concrete device is normally designed for specifics rainfall events, which are dictated by means of the usage of close by requirements. The entire extent of rain is important, however, the

infiltrations charge of the soil ought to be considered. The complete storage was achievable of the pervious concrete pavement (PCP), the functionality of any sub-base used, and the extent of water that leaves the machine thru infiltration into the underlying soil. If the previous concrete has 15% extraordinary porosity, then every and each 25mm of pavement depth can preserve 4mm of rain. For example, a 100mm thick pavement with 15% of high-quality porosity on the pinnacle of impenetrable clay may additionally prefer to keep up to 16mm of rain previously than contributing to more rainfall runoff. Another vital furnish of storage is the bub base. A common combination of sub-base, with excessive exceptional content, will have decrease porosity (about 20%).The excessive float rate that can end result from water flowing downslope additionally plenty wash out subgrade materials, weakening the pavement

3.6.2 Improvement the compressive strength of previous concrete

- The fundamental intention of our project is to use recycled and west material that can increase the compressive strength of the pervious concrete.
- The compressive strength of the previous concrete enhancement can be carried out by

  <1>Addition of the small variety of fine aggregates

  <2>Addition of small volume of cementitious materials

  <3>Uses an exceptional kind of mixture like the small and medium size of the coarse aggregate

<4>Using low water-cement (w/c) ratio etc.

- Among the above methods, we have chosen the addition of a small broad range of high-quality aggregates, the addition of the cementitious substances such as fly ash and recycled coarse aggregates.
- The compressive strength of the pervious concrete is inversely proportional to the permeability. As the compressive strength increased, the permeability will be reduced and vice- versa.
- The most necessary purpose of pervious concrete is permeability. By bettering the strength we no want to longer forget about the effect on of permeability.
- Theoretically, it is referred to that the compressive strength traits will be improved if the fine combination is delivered 5-10% quantity of the coarse aggregates.

Chapter-4 Results and discussions

4.1 Outline

This Section incorporates the outcomes acquired from the compressive strength and the coefficients of the permeability test. It offers the results in a graphical to make the correlation between results much less intricate to be comprehended. Additionally, this segment talks about and investigates some plausible factors that can additionally have influenced the outcome

4.2 Expected results from the experiment

Incorporation of fly ash in the concrete combination changed as both substitution of cement or fine aggregate combination complete will have an impact on the mechanical properties of concrete. Coming up subsequent are the regular results from the evaluation due to the fact of changing cement with fly ash and reused materials with coarse aggregate. Utilizing fly ash in concrete as both substitution of concrete or high-quality mixture will enhance the workability of the concrete. The placing time of cement turns out to be longer when fly ash is accessible in the concrete mixture. Fly ash concrete will have decrease compressive strength than traditional concrete at an early age; anyway, it accomplishes greater excessive compressive strength than can be performed with traditional concrete.

4.3 Results

Compressive Strength of the concrete regate

The Compressive strength of the pervious concrete aftereffects of Cement replaced by west materials fly ash, all concrete blended except for the closing combined (50% FA) have greater compressive strength than the normal mixed. A combination of 33 concrete cylinders was used to be prepared; 4 of the concrete blended used to be made of a hundred percent traditional normal Portland cement (no-fly ash content). The remaining 29 concrete sample was set up by including fly ash content as a fractional replacing to cement for example 5%, 10%, 15%, 20%, 25%, 30%, 35%. According to the ratio of ingredient, amount of water, coarse aggregate, and the cement replaced by fly ash for all the mixed design.

4.1 Optimum Mix Design of pervious concrete (aggregate size 3/8 to1/2 inch), Tested at Dounan testing lab.

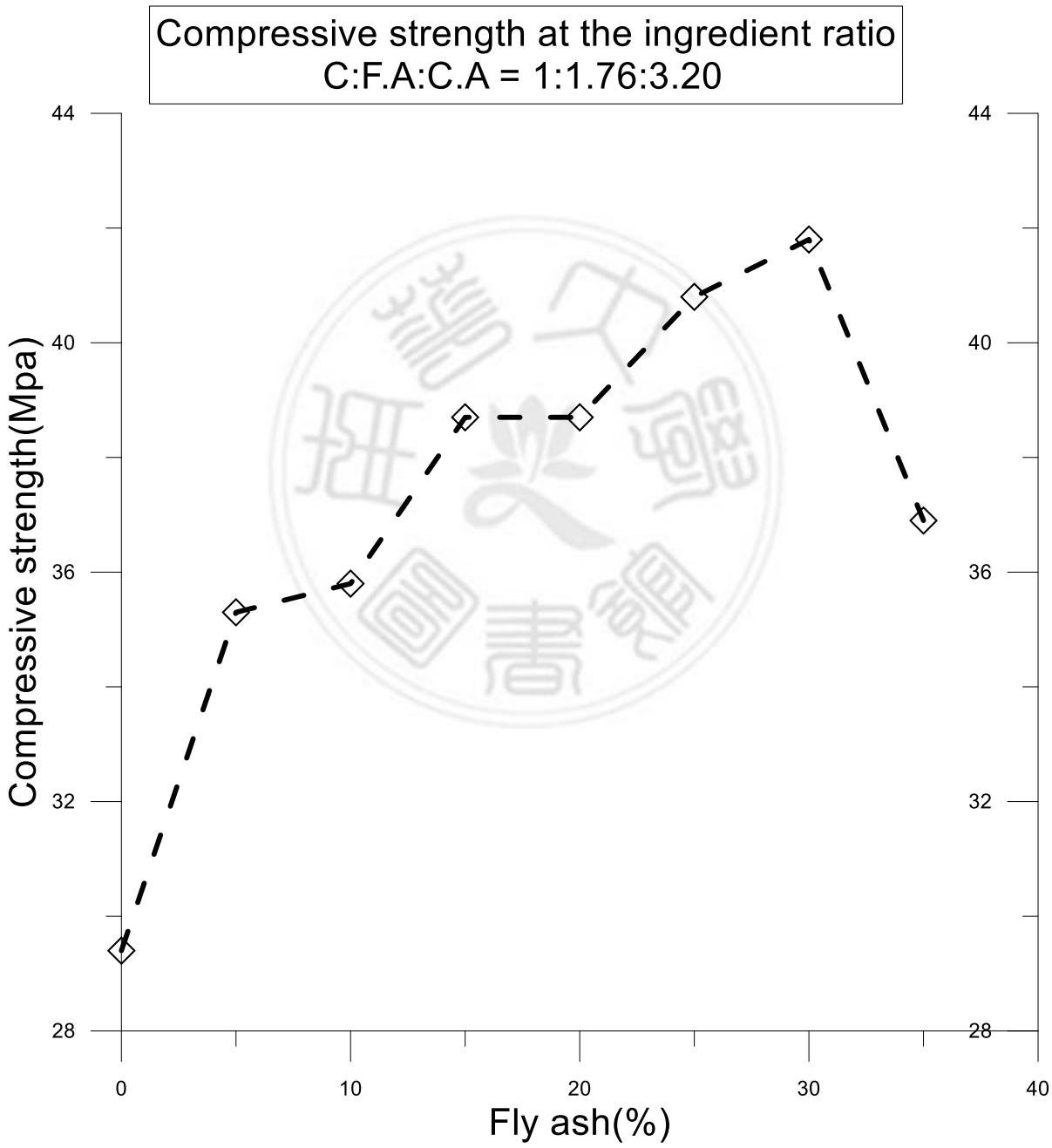
4.1.1 The ratio of ingredient for concrete (C:F.A:C.A) = 1:1.76:3.20

Place-Sustainability center lab (Nanhua university, Taiwan), Date-2020/03/27

Table 4- 1 The ratio of ingredient for concrete (C:F.A:C.A) = 1:1.76:3.20

Replacement ratio of fly ash (%)	Coarse aggregate (kg)	Recycled coarse aggregate (kg)	Cement (kg)	Sand (kg)	Fly ash (kg)	28-d Compressive strength (Mpa)
0	3.840	3.840	2.400	4.224	0	29.4
5	3,840	3,840	2.400	4.224	0.120	35.3
10	3.840	3.840	2.400	4.224	0.240	35.8
15	3.840	3.840	2.400	4.224	0.360	38.7
20	3.840	3.840	2.400	4.224	0.480	38.7

Replacement ratio of fly ash (%)	Coarse aggregate (kg)	Recycled coarse aggregate (kg)	Cement (kg)	Sand (kg)	Fly ash (kg)	28-d Compressive strength (Mpa)
25	3.840	3.840	2.400	4.224	0.680	40.8
30	3.840	3.840	2.400	4.224	0.720	41.8
35	3.840	3.840	2.400	4.224	0.840	36.9



C- Cement; F.A. - Fine aggregate; C.A. - Coarse aggregate

Figure 4. 1 Compressive strength Vs fly ash

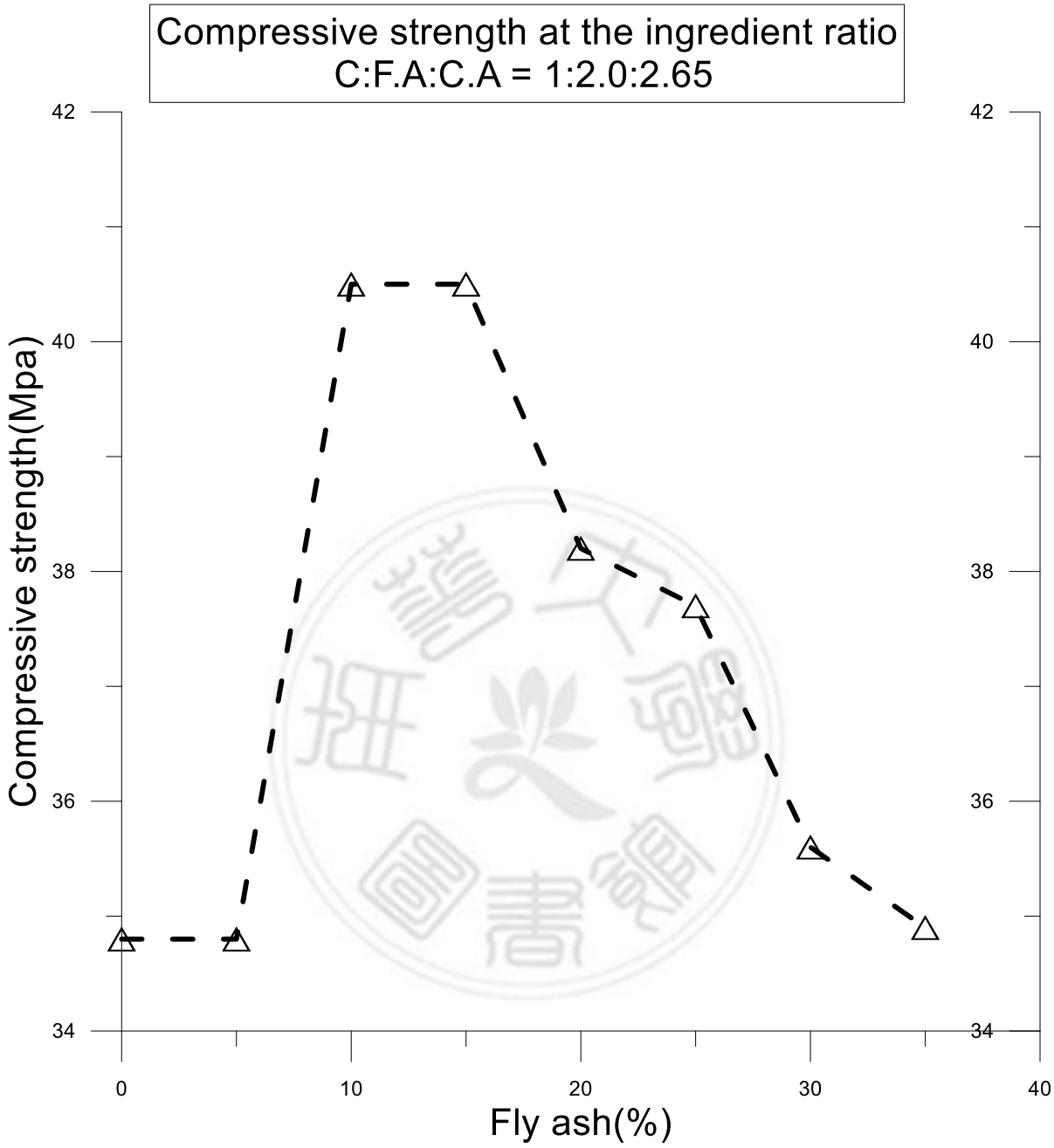
From the above table and figure 4.1.1 and 3.15, we found that the maximum compressive strength of the concrete is 41.8Mpa as the 30% of fly ash.

4.1.2 The ratio of ingredient (C:F.A:C.A) = 1:2:2.65

Place-Sustainability center lab (Nanhua university, Taiwan), Date-2020/03/27

Table 4- 2 The ratio of ingredient (C:F.A:C.A) = 1:2:2.65

Replacement ratio of fly ash (%)	Coarse aggregate(kg)	Recycled coarse aggregate (kg)	Cement (kg)	Sand (kg)	Fly ash (kg)	28-d Compressive strength (Mpa)
0	3.350	3.350	2.5	5	0	34.8
5	3.350	3.350	2.5	5	0.125	34.8
10	3.350	3.350	2.5	5	0.250	40.5
15	3.350	3.350	2.5	5	0.375	40.5
20	3.350	3.350	2.5	5	0.50	38.2
25	3.350	3.350	2.5	5	0.625	37.7
30	3.350	3.350	2.5	5	0.75	35.6
35	3.350	3.350	2.5	5	0.875	34.9



C- Cement; F.A. - Fine aggregate; C.A. - Coarse aggregate

Figure 4. 2 compressive strength Vs fly ash

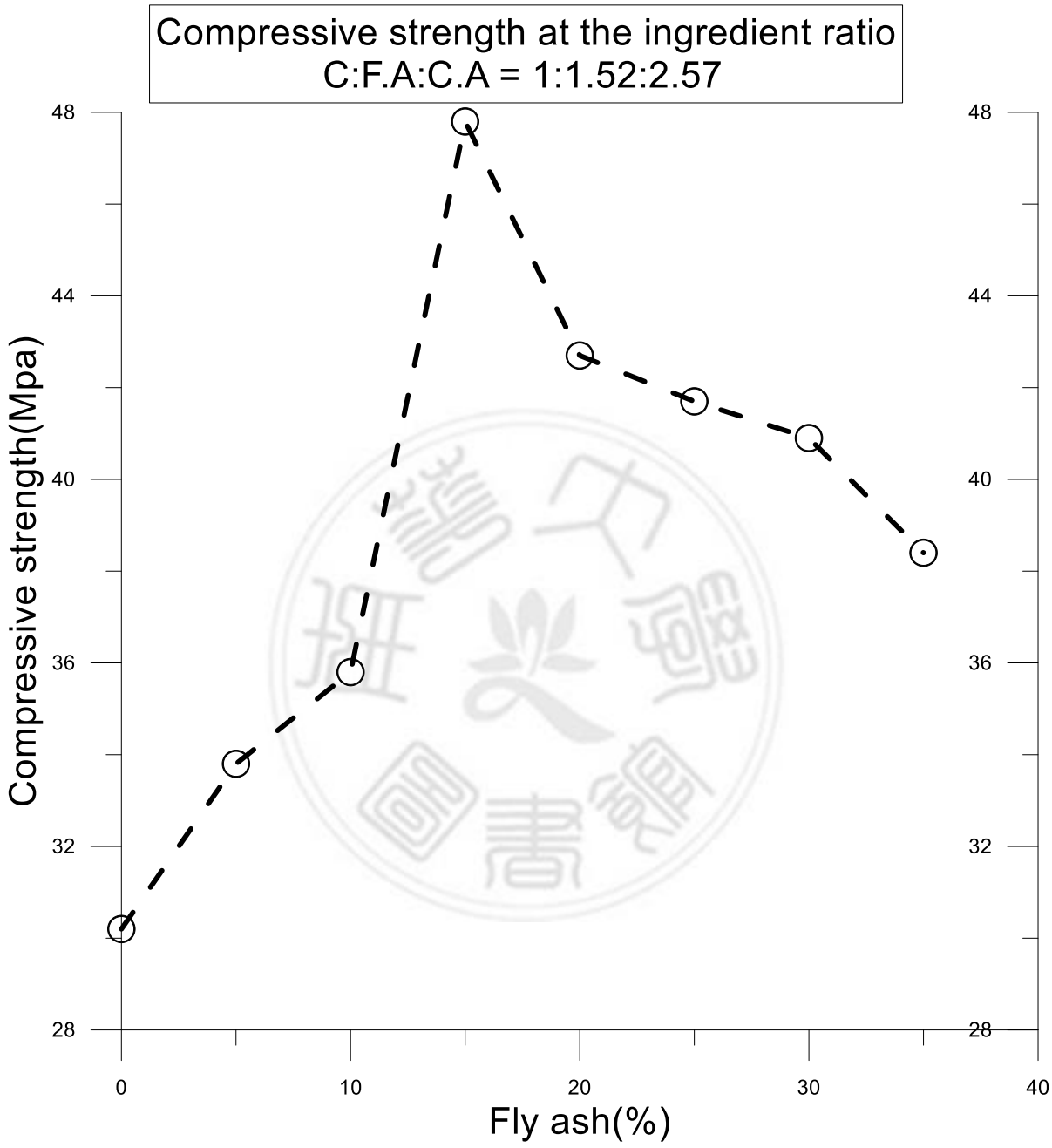
From the above table and figure 4.1.2 and 3.16, we found that the maximum compressive strength of the concrete is 40.5Mpa as the 10 to 15% of fly ash.

4.1.3 The ratio of ingredient (C:F.A:C.A) = 1:1.52:2.47

Place-Sustainability center lab (Nanhua university, Taiwan), Date-2020/03/27

Table 4- 3 The ratio of ingredient (C:F.A:C.A) = 1:1.52:2.47

Replacement ratio of fly ash (%)	Coarse aggregate (kg)	Recycled coarse aggregate (kg)	Cement (kg)	Sand (kg)	Fly ash (kg)	28-d Compressive strength (Mpa)
0	3.439	3.439	2.785	4.233	0	30.2
5	3.439	3.439	2.785	4.233	0.139	33.8
10	3.439	3.439	2.785	4.233	0.278	35.8
15	3.439	3.439	2.785	4.233	0.417	47.8
20	3.439	3.439	2.785	4.233	0.557	42.7
25	3.439	3.439	2.785	4.233	0.696	41.7
30	3.439	3.439	2.785	4.233	0.835	40.9
35	3.439	3.439	2.785	4.233	0.974	38.4



C- Cement; F.A. - Fine aggregate; C.A. - Coarse aggregate

Figure 4. 3 Compressive strength Vs fly ash

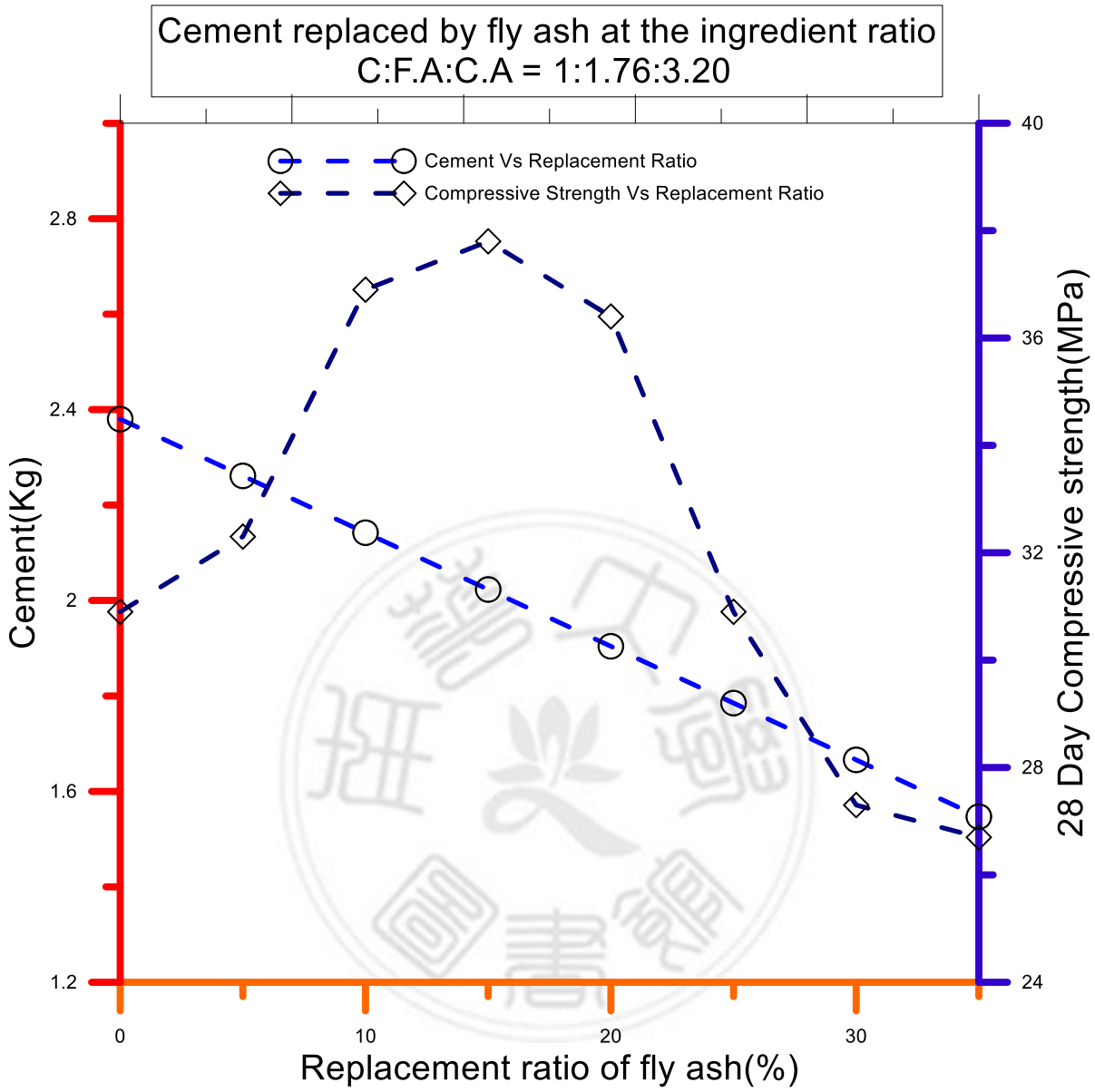
From the above table and figure 4.1.3 and 3.17, we found that the maximum compressive strength of the concrete is 47.8Mpa as the15% of fly ash.

4.1.4 The ratio of ingredient (C:F.A:C.A) = 1:1.76:3.20

Place-Sustainability center lab (Nanhua university, Taiwan), Date-2020/03/27

Table 4- 4 The ratio of ingredient (C:F.A:C.A) = 1:1.76:3.20

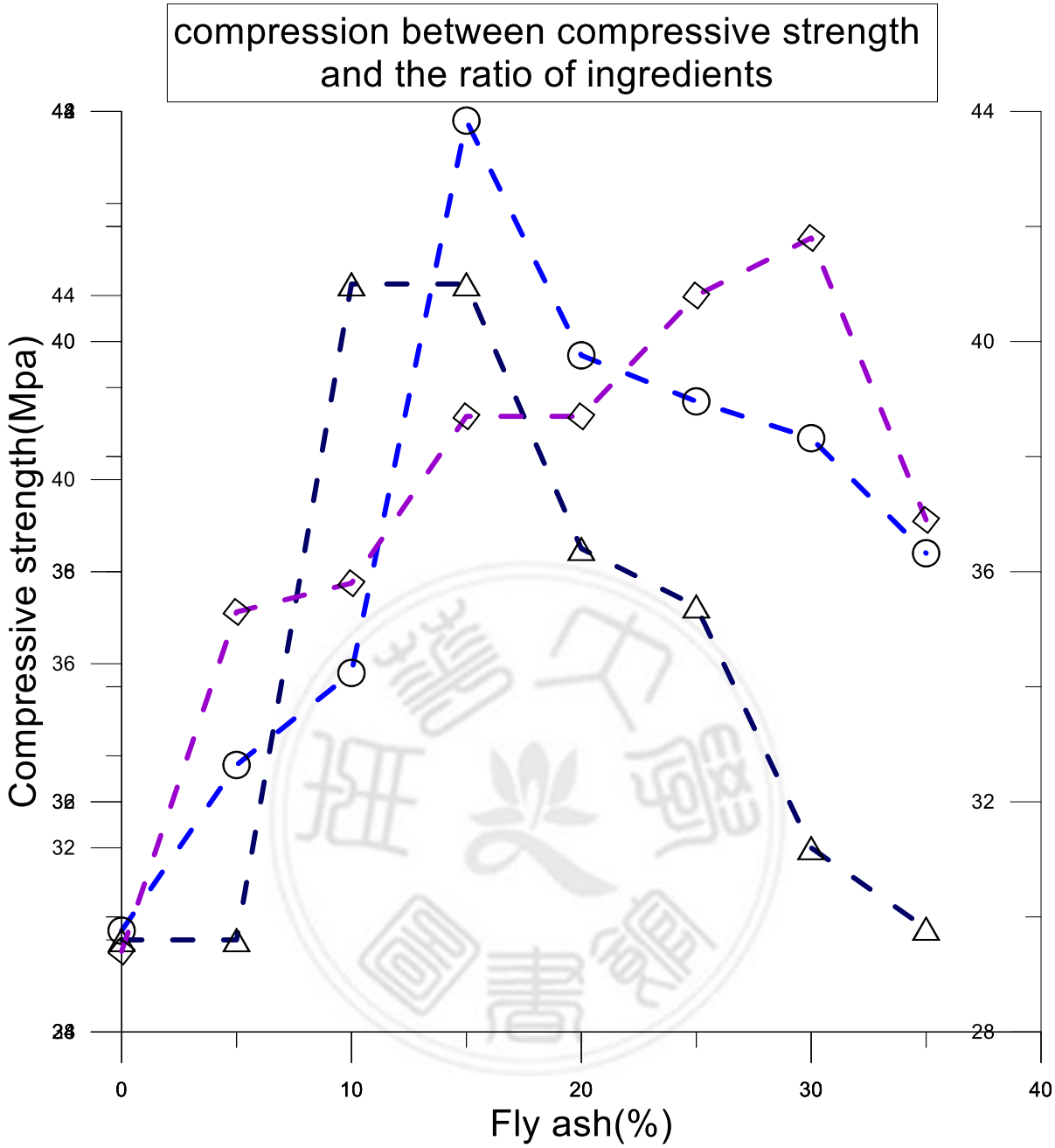
Replacement ratio of fly ash (%)	Coarse aggregate (kg)	Recycled coarse aggregate (kg)	Cement (kg)	Sand (kg)	Fly ash (kg)	28-d Compressive strength (Mpa)
0	3.840	3.840	2.38	4.190	0	30.9
5	3.840	3.840	2.261	4.190	0.125	32.3
10	3.840	3.840	2.142	4.190	0.250	36.9
15	3.840	3.840	2.023	4.190	0.375	37.8
20	3.840	3.840	1.904	4.190	0.50	36.4
25	3.840	3.840	1.785	4.190	0.625	30.9
30	3.840	3.840	1.666	4.190	0.75	27.3
35	3.840	3.840	1.547	4.190	0.875	26.7



C- Cement; F.A. - Fine aggregate; C.A. - Coarse aggregate

Figure 4. 4 Compressive strength Vs fly ash

From the above table and figure 4.1.4 and 3.18, we found that the maximum compressive strength of concrete is 37.8Mpa at the Cement replaced by 15% of fly ash at the ingredient ratio of C:F.A:C.A = 1:1.76:3.20.



C- Cement; F.A. - Fine aggregate; C.A. - Coarse aggregate

Figure 4. 5 Compressive strength Vs fly ash

From table and figure 4.1.3 and 3.17, it can be considered that the concrete combine with 15% fly ash alternative of cement has the very best compressive strength amongst all the fly ash mixes at all ages. It is additionally clear that as the share of fly ash in a concrete combine goes over 10% the

compressive strength decreases. In general, for up to 40% fly ash alternative the concrete has greater compressive strength than the normal concrete at fifty six days. However, at 35% replacement, the compressive strength used to be decrease than finally; the compressive strength of pervious concrete will amplify with the increments of fly ash due to the pozzolanic reactivity of the fly ash and the fineness of the particles which prolonged the microstructure of the hardened concrete due to packing and filling effect. In this blended concrete, 15% of fly ash is considered to be the pleasant ratio of cement replacement. Regular concrete.

4.4 Permeability of the fresh and recycled coarse aggregate

Permeability is the property of the pervious concrete that allows water passing through it. Generally, the permeability we can measure by two method, constant head and falling head methods permeability test. In our assignment work, we have taken a constant head permeability test and it fits satisfactory for the pervious concrete.

To determine the permeability of pervious concrete as shown in table 4.6, we used mold having dimensions with height 20cm and diameter 10cm. The permeability test is conducted for the standard pervious concrete (0 % fines), pervious concrete with 50% of recycled coarse aggregates, pervious concrete with 15% fly ash as a cement replacement, tested after 28 days from preparation.

Coefficient of permeability (K) of Recycled coarse aggregate and fresh coarse aggregate

Place-Sustainability center lab (Nanhua university, Taiwan), Date-2020/03/27

Table 4- 5 Coefficient of permeability (K) of Recycled coarse aggregate and fresh coarse aggregate

Discharge (cm3)	Time (sec)	Length (cm)	Head difference (cm)	Cross-section area (Cm2)	Coefficient of permeability(K) (cm/sec)
1000	45.2	11.8	117	78.5	0.028
1000	44.4	11.8	117	78.5	0.027
1000	45.8	11.8	117	78.5	0.028
1050	48.8	11.8	117	78.5	0.029
1000	45.3	11.8	117	78.5	0.028

The coefficient of permeability is a maximum of 0.028 cm/sec for standard pervious concrete with 50% of recycled coarse aggregates. The reason for the largest values of permeability is due to the natural and recycled coarse aggregates.

Chapter-5 Conclusion and scope for the future work

Pervious pavements can be a principal contributor to the advantageous administration of storm water. They grant the probability of remodelling a standard supply of storm water runoff into a satisfactory administration exercise for capturing, storing and infiltrating storm water into the herbal surroundings.

This pavement allows water to pass through them and can prevent excessive storm water from running over and off these areas. Instead, the water infiltrates through or between the material components. More storm water stays within the soils or water collection systems, less soil erodes and less sediment washes downstream.

Benefits accomplished encompass decreased storm water discharges as properly as upgrades to water best inclusive of decreased suspended solids and discount of chemical contaminants. While they can be an advantageous tool, their layout and development need to cautiously think about structural and hydrological issues to make sure that they grant competitively priced options over their diagram life.

Fly ash is one of the deposits made at some stage in the burning of coal. Around 40% of this fly ash is utilized in a variety of engineering applications, even though the relaxation is disposed of as waste. The use of fly ash in concrete as an alternative of cement or nice mixture is growing the workability of concrete as it improves the long-tern compressive strength. Result shown:

- Regardless of the substitution stage for all the mixture, the consideration of fly ash has improved the overall performance of concrete due to the fineness and spherical shape of its particles.
- The dimension of coarse aggregates, water to cement ratio, and combination to cement ratio performs a fundamental characteristic in the compressive strength of the pervious concrete.
- 15% fly ash as substitute of cement has carried out the most compressive strength of pervious concrete pavement.
- 50% recycled coarse mixture as alternative of path mixture has completed the most compressive strength.
- 35% fly ash as substitute of cement has performed much less compressive strength than normal concrete after fifty six days.
- The compressive strength and co-efficient of permeability of pervious concrete are inversely proportional to each other up to the addition of 8% of fines.
- The addition of fines and choice of Cementitious will minimize the coefficient permeability (k) of pervious concrete.
- Hence it is influenced that the addition of 15% fly ash and 50% of recycled coarse aggregate to the pervious concrete will fulfill every the compressive strength and permeability of the pervious concrete pavement.

References

1. S. Deepika, “Experimental investigation of pervious concrete using single size aggregate (course aggregate) without fine aggregates and as an admixture”, volume 4, issue 1, 2014-2015.
2. Ketan Brijesh Jibenkar, V.D vindya, S.S Waghamareet, “Experimental Investigation of pervious concrete using Titanium Dioxide”, volume 1, issue 1, 2015.
3. Mohiuddin Abdul Kader, “Experimental study on pervious concrete using brick chips as coarse aggregate” ,volume 2, 2013.
4. Rashmi J John, “Experimental investigation on environmental friendly concrete for sustainable concrete”, 2015.
5. R. S Ravindraraj, “Experimental investigation on environmental friendly concrete for sustainable concrete”, volume 3, 2010.
6. Brattebo, B. and Booth, B. Long-term stormwater quantity and quality performance of permeable pavement systems, Journal of Water Research, 37(18), 2003, 4369–4376.
7. Sansalone, J., Kuang, X., Ranieri, V. Permeable pavement as a hydraulic and filtration interface for urban drainage. J. Irrig. Drain. Eng. 134(5), 2008, 666-674.

8. Mullaney, J., Lucke, T. and Trueman, S.J. A review of benefits and challenges in growing street trees in paved urban environments, Landscape & Urban Plan., 134, 2015a, 157– 166.
9. Morgenroth, J., Buchan, G. and Scharenbroch, B.C Belowground Effects of Porous Pavements – Soil Moisture and Chemical Properties, Journal of Ecological Eng., 51, 2013, 221–228.
10. Borgwardt, S. Long-term in-situ infiltration performance of permeable concrete block pavement, in Proceedings of 8th ICBP, San Francisco, 2006, USA.
11. Colandini, V., Legret, M., Brosseaud, Y. and Baládes, J.D. Metallic pollution in clogging materials of urban porous pavements, Journal of Water Sci. and Technology, 32(1), 1995, 57- 62.
12. Z. Chen, H. Li and T. C. Wong, "An application of bar-code system for reducing construction wastes", Automation in Construction, vol. 11, no. 5, pp. 521-533, 2002.
13. M. M. M. Teo and M. Loose more, "A theory of waste behavior in the construction industry", Journal of Construction Management and Economics, vol. 19, no. 7, pp. 741-751, 2001.
14. R. M. Gavilan and L. E. Bernold, "Source evaluation of solid waste in building construction", Journal of Construction Engineering and Management, vol. 120, no. 3, pp. 536-555, 1994.

15. C. McGrath, "Waste minimization in practice", Resources, Conservation and Recycling, vol. 32 pp. 227-238, 2001.

16. Marthong, C & Agrawal, T 2012,' Effect of Fly ash Addititve on concrete Properties', International Journal of Engineering Research and Applications, 2(4), pp. 1986-1991.

17. Nath, P & Sarke, P 2011, 'Effect of Fly Ash on the Durability Properties of High Strength Concrete',Procedia Engineering , Issue 14, p. 1149–1156.

18. Nawy, E. G 2009, Reinforced Concrete A fundamental Approch, Sixth ed, New Jersey : Prentice Hall International S.

19. Ramezanianpour, A, 2014, Cement Replacement Materials, Properties, Durablility, susutainablity, 2nd ed. s.l.:Heidelberg Springer.

20. Chindaprasirt, P, Jaturapitakkul, C & Sinsiri, T 2005,' Effect of fly ash fineness on compressive strength and pore size of blended cement paste', Cement & Concrete Composites , Volume 27, p. 425–428.

21. J.T. Kerven, V.R. Schaefer, Mixture proportioning considerations for improved freeze-thaw durability of pervious concrete, J Mater Civil Eng (2013) 25:886–892.

Appendix

Table 6.1 the design mixed ratio of (cement: fine aggregate: coarse aggregate =1:1.76:3.20)

Replacement ratio of fly ash (%)	Coarse aggrega te(kg)	Recycled coarse aggregate(kg)	Cement (kg)	Sand (kg)	Fly ash (kg)	28-d Compressive strength (Mpa)
0	3.840	3.840	2.400	4.224	0	29.4
5	3,840	3,840	2.400	4.224	0.120	35.3
10	3.840	3.840	2.400	4.224	0.240	35.8
15	3.840	3.840	2.400	4.224	0.360	38.7
20	3.840	3.840	2.400	4.224	0.480	38.7
25	3.840	3.840	2.400	4.224	0.680	40.8
30	3.840	3.840	2.400	4.224	0.720	41.8
35	3.840	3.840	2.400	4.224	0.840	36.9

Table 6.2 the design mixed ratio of (cement: fine aggregate: coarse aggregate =1:2.0:2.65)

Replacement ratio of fly ash (%)	Coarse aggrega te(kg)	Recycled coarse aggregate(kg)	Cement (kg)	Sand (kg)	Fly ash (kg)	28-d Compressiv e strength (Mpa)
0	3.350	3.350	2.5	5	0	34.8
5	3.350	3.350	2.5	5	0.125	34.8
10	3.350	3.350	2.5	5	0.250	40.5
15	3.350	3.350	2.5	5	0.375	40.5
20	3.350	3.350	2.5	5	0.50	38.2
25	3.350	3.350	2.5	5	0.625	37.7
30	3.350	3.350	2.5	5	0.75	35.6
35	3.350	3.350	2.5	5	0.875	34.9

Table 6.3 the design mixed ratio of (cement: fine aggregate: coarse aggregate =1:1.52:2.47)

Replacement ratio of fly ash (%)	Coarse aggregate (kg)	Recycled coarse aggregate (kg)	Cement (kg)	Sand (kg)	Fly ash (kg)	28-d Compressive strength (Mpa)
0	3.439	3.439	2.785	4.233	0	30.2
5	3.439	3.439	2.785	4.233	0.139	33.8
10	3.439	3.439	2.785	4.233	0.278	35.8
15	3.439	3.439	2.785	4.233	0.417	47.8
20	3.439	3.439	2.785	4.233	0.557	42.7
25	3.439	3.439	2.785	4.233	0.696	41.7
30	3.439	3.439	2.785	4.233	0.835	40.9
35	3.439	3.439	2.785	4.233	0.974	38.4

Table 6.4 the design mixed ratio of (cement: fine aggregate: coarse aggregate =1:1.76:3.20)

Replacement ratio of fly ash (%)	Coarse aggregate (kg)	Recycled coarse aggregate (kg)	Cement (kg)	San d(kg)	Fly ash (kg)	28-d Compressive strength (Mpa)
0	3.840	3.840	2.38	4.190	0	30.9
5	3.840	3.840	2.261	4.190	0.125	32.3
10	3.840	3.840	2.142	4.190	0.250	36.9
15	3.840	3.840	2.023	4.190	0.375	37.8
20	3.840	3.840	1.904	4.190	0.50	36.4
25	3.840	3.840	1.785	4.190	0.625	30.9
30	3.840	3.840	1.666	4.190	0.75	27.3
35	3.840	3.840	1.547	4.190	0.875	26.7