BARRIERS OF NEW CONCRETE TECHNOLOGY ADOPTION IN MALAYSIAN CONSTRUCTION INDUSTRY

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A project report submitted in partial fulfillment of the requirements for the award of Bachelor of Science (Hons) Construction Management

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

I certify that this project report entitled **"BARRIERS OF NEW CONCRETE TECHNOLOGY ADOPTION IN MALAYSIAN CONSTRUCTION INDUSTRY"** was prepared by **LEE KAR CHUN** has met the required standard for submission in partial fulfillment of the requirements for the award of Bachelor of Science (Hons) Construction Management at Universiti Tunku Abdul Rahman.

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Specially dedicated to
my beloved mother, father and friends.

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ABSTRACT

Sustainable development is a popular and important concept. In construction industry, concrete plays a vital part in our daily lives and in a functioning society. Its benefits to society are immense, being used to build schools, hospitals, apartment blocks, bridges, tunnels, dams, sewerage systems, pavements, runways, roads and more. Given that cement production for construction work accounts for a significant percentage of all energy consumed nationally in developing countries, it is vitally important to develop products and systems that can be used to construct more durable, energy-efficient eco-buildings, and new concrete can be used to do just this. New concrete, with its outstanding strength, durability, excellent thermal mass and other desirable properties, should be a key component in eco-buildings of today and the future. Nevertheless, the adoption rate of new concrete technology in local Malaysian construction industry is relatively low compare to other developed countries which will directly or indirectly demotivate Research and Development of new concrete technology in future. This study identified the barriers of adopting new concrete materials in Malaysia, which are cost barrier, perception barrier, technical barrier, reliability barrier and law & policy barrier. Among all the five barriers, cost barrier was ranked as the first significant factors that prohibiting the utilization of new concrete materials.

Keywords: sustainability, new concretes, research and development, barriers

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Construction is a broad sector which covers infrastructure, buildings and the systems that make buildings useable, such as heating and ventilation. The Malaysian construction industry is set to continue expanding in 2015 as new projects, foreign investment and increased outlooks among construction firms stimulate the industry and the wider economy. After launching of 10^{th} Malaysia Plan from year 2011 to 2015, overall construction market had positively impacted. Government is expected to spend RM 67.80 billion during 2011 to 2015, involving investors and private sectors, specifically for projects such as construction of education institute, hospitals and other public infrastructure (Malaysia Infrastructure Report, 2013).

According to Aitcin (2000) and Mobasher (2008), concrete is the main construction material and commonly used in construction industry. Since concrete plays an important role in construction industry, it is hard to imagine a world that without concrete. Concrete, is a fundamental building material that will continue to be in demand far into the future. It contains four basic ingredients which are water, cement, fine aggregate (sand) and coarse aggregate. Concrete plays a vital role in construction industry. The characteristics of concrete has made it inevitably important to every construction projects.

A statistic of Department of Statistics Malaysia, (2014) which showed in Figure 1.1 below, indicating that concrete contributed 23 % of total materials used in construction sector.

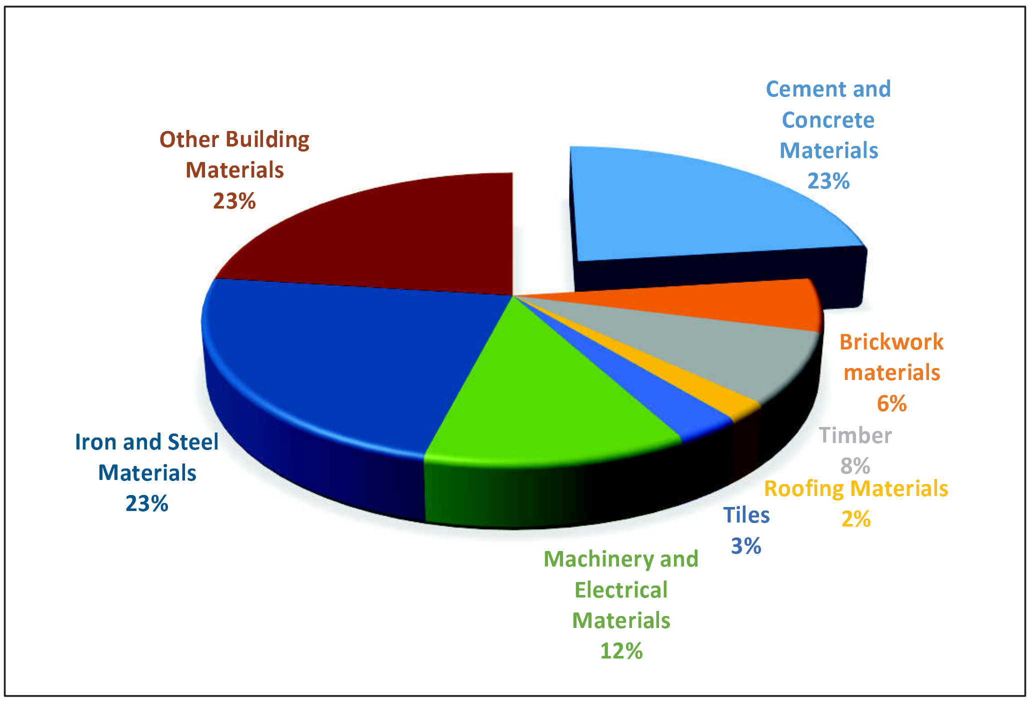


Figure 1.1 Percentage of Materials Used in Construction Sector (Department of Statistics Malaysia, 2014)

Concrete is extensively used for construction of commercial, domestic, rural and recreational purposes. Communities are rely on concrete as a safe, durable and simple building material (Cement Concrete & Aggregates Australia, 2004). Concrete basically is a composite products combining cement, sand and aggregates with water. As concrete does not undergo corrosions or deterioration, surface treatment therefore can be eliminated. Besides, concrete strength increases with time; thus, maintenance of concrete structures is not required. For less than a century, concrete technology has gone through a drastic change after the Second World War and for now, research and development of concrete technology had made modern concrete becoming a very sophisticated composite as it constitutes the marriage of ground clinker and cement, mineral or amorphous products which have yet to penetrate into the local market; organic polymers, which were engineered using highly technical processes to accommodate specific tasks, and occasionally accompanied by discrete synthetic/organic/steel fibres to exhibit properties that are too ambitious to accomplish this achievement (Voo, 2005).

Continuously efforts have been contributed in research and development of new concrete. New concrete technologies with enhanced performance have to be developed in construction industry. In this case, concrete development is critical and based on optimization of concrete mix design by concerning workability, mechanical properties, durability and reliability of the new concrete structures. Other aspects such as aesthetic of new concrete needs to be revised as well as improved of current concrete structural systems and actual building technology. New concrete offers a holistic solution to the problem of meeting the increasing demands for concrete in the future in a sustainable manner and at a reduced or no additional cost, and at the same time reducing the environmental impact of two industries that are vital to economic development namely the cement industry and the coal-fired power industry. The technology of new concrete is especially significant for countries like Malaysia, where, given the limited amount of financial and natural resources, the huge demand for concrete needed for infrastructure and housing can be easily met in a cost-effective and ecological manner.

In construction industry Research and Development is a vital and crucial component of innovation and a key factor in developing new competitive advantages especially when coming to concrete, new concrete. For decades, concrete is the fruit of a simple technology; and today it is mastered by the essence of “pure science”. Voo (2005) indicates that the emergence of scanning electron microscope (SEM) and other advanced instrumentation have progressively improved the philosophy of concrete microstructure behaviour up to the nano-scale.

As the industry moves into the era of computing technology and incorporating the essence of complex laws of physics, chemistry and thermodynamics; it will result in a rapid progression in the development of concrete technology. Malaysia is still a developing country and in order to grow and become a developed country, Malaysia must keep ahead of competitors whenever possible. In order to accomplish this, Malaysia must innovate, which often depends on R&D. Following this reasoning, investing in R&D would give Malaysia a competitive advantage, which makes new concrete technology worth to explore.

1.2 Aim and Objectives

The aim of this paper is to study the barriers of new concrete technology adoption in Malaysia. The two objectives of this study are:-

- To identify current new concrete technology.
- To determine the critical barriers of new concrete technology adoption.

1.3 Problem Statement

Environment pollution is a worldwide issue and has the tendency to influence the safety and health of human populations (Fereidoun et al, 2007). Developmental activities in construction industry not only consume the natural resources but also generate huge amount of wastes that contribute to environmental pollution. Table 1.1 shows the pollution index and expected pollution index of different countries while Malaysia is considered as comparatively high pollution index with 67.37 and expected to reach almost twice as current index to 116.37.

Table 1.1: Pollution Index and Expected Pollution Index of Different Countries (Malaysia Infrastructure Report, 2013)

Country	Pollution Index	Expected Pollution Index
China	87.89	160.87
Myanmar	84.63	155.22
Thailand	72.11	125.27
Philippines	71.92	125.65
Hong Kong	67.49	121.88
Malaysia	67.37	116.37
Singapore	37.97	64.46
Brunei	35.63	60.94
Japan	34.99	56.75
Netherlands	34.67	56.37
United Kingdom	33.81	55.09
United States	33.34	58.29
Canada	29.26	48.21
Germany	29.22	46.58
Australia	23.09	35.78

Pollution is most likely to lead to public health problems and according to Zou & Yuan (1998), the pollution index of different countries from all around the world are expected to grow exponentially. Environmental pollution is and always tangled with the unsustainable anthropogenic activities and studies have proved that buildings are responsible for the world's heaviest consumers of natural resources. Klotz et al. (2007) states that buildings occupy 36 % of the total energy used and 30 % of the raw materials consumed. This indicates that the construction, maintenance and function of buildings impacts negatively on the environment and our daily lives. Besides that, construction industry is continuosly contributing significantly to the permanent changes in the world's atmosphere, ecosystem and climate.

Concrete industry is the largest consumer of virgin materials such as sand, gravel, crushed rock, and fresh water. It is consuming portland and modified portland cements at an annual rate of about 1.6 billion metric tons (Dunn, 2001). Construction activities have the potential and tendency to generate a substantial amount of air pollution. Cement, which is the essential material in any construction project produces a large amount of carbon dioxide. The Cement Sustainability Initiative, (2012) reported that chemical process of cement emits up 50 % and 40 % from fuel burning. In this context, the environmental predicament in Malaysia cannot be overstated. The industrial development is causing substantial pollution levels, to overcome this environmental issue, requires a technological and an intellectual revolution; an alternative or new concrete that preserves and conserves resources. The indifferent attitude of the Malaysian policy makers towards a long-term development in preference to short-term fast economic gains has contributed immensely to the environmental woes of the country as one of the main reasons for societies' collapse is conscious destruction of the natural resources.

Until today, concrete technology had developed intensively, for instance, the advances in strength and mechanical properties of concrete is achieved through utilization of steel reinforcement. The reinforced cement concrete has become conventional materials. Not forgetting also the development of greener, sustainable concrete, for instance fly ash concrete. Currently, many statistics and reports had showed that lots of foreign countries started utilizing green concrete, unlike Malaysia. Table 1.2 shows annual fly ash production and utilization in different countries.

Table 1.2: Annual Fly Ash Production and Utilization in Different Countries
(Technology Information, Forecasting and Assessment Council, 2014)

Country	Annual Fly Ash Production / MT	Ash Utilization / %
China	90	38
USA	71	31
Germany	31	58
U K	12.5	49
Australia	7.9	10
Canada	2.9	45
France	2.7	57
Denmark	0.89	100
Italy	0.9	100
Netherland	0.9	100

Sustainability is very important as all the alternatives that had been track and all the decisions that made today will affect everything and everyone in the future. Through new concrete technology which is more environmental friendly, not only resource depletion of crucial resources such as raw materials, energy can be prevented, but can also avoid environmental degradation. There will be consequences if the importance of sustainability of the environment is neglected. Global warmings, heat island, rising sea level, declined in agricultural productivity are the best evidences arise from negative impact of non-sustainable environment. Therefore, Malaysia as one of the member of this planet, is obligated to contribute in sustaining our mother earth. To be able to accomplish this task, it is necessary for Research and Development to take precedence, to escalate the sustainability of constructions industry which include productivity, durability, environmental impact and architecture. It calls for the new materials development and concrete processing that the overall performance of the new concrete can be anticipated.

Figure 1.2 below shows statistic of Malaysia's Gross Expenditure on R&D invested increased every year. With Research and Development, researchers had come out with several new or alternative concretes which exhibits different properties that are capable of fulfilling different requirements in construction projects. Nevertheless, the adoption rate of new concrete is still low in Malaysia.

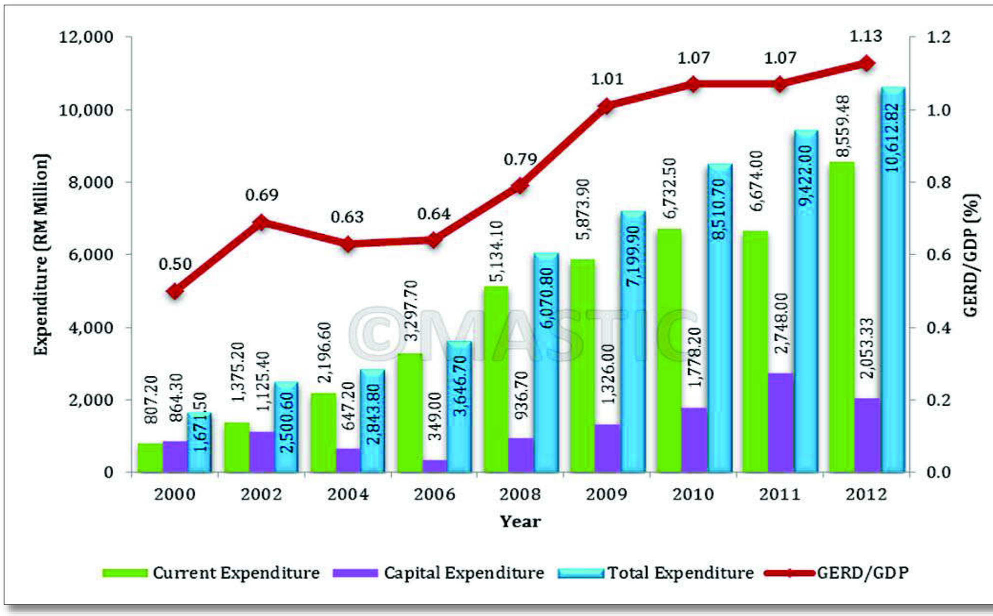


Figure 1.2 Total Expenditures in Research and Development in Malaysia (Malaysian Science and Technology Information Centre, 2014)

As a result, this situation will inevitably demotivate the research project about new concrete which is better than current traditional concrete. Researchers may not continue to develop any new materials since the rate of utilizing the new product is very low and government or other private organizations might stop funding the related research projects. Concrete development is aimed to produce cost benefits, savings and efficiencies concrete, offer faster construction and building delivery, simplify construction processes, improve control and productivity, optimise both material and human resources, and produce more improved products and efficient buildings. However, all of these advantages stated will be wasted completely without implementation of this new concrete technology and it comes back to zero, leaving this greener, better product behind.

1.4 Scope of Study

The target respondent in this study will focus on developers, contractors and consultants involving in construction project which are located in Kuala Lumpur, Penang and Johor in Malaysia because these 3 big cities are experiencing vast development and majority of REHDA registered developers established their company as well as their projects in these 3 cities of Malaysia. Furthermore, studies had showed that Malaysia is comparatively low in new concrete adoption compare to other countries like USA, UK, Japan, etc . The propective respondent will be targeted to REHDA registered developers as well as contracors and consultants with sample of 199 respondents will be choosing to answer the survey questionnaires.

For this study, the technique used to gather the primary information is through questionnaire survey and interview. Questionnaires refer to a rational and non-complicated preference as a way of collecting data from individuals. A questionnaire refer to a written list of questions that requires respondent to answer. Target respondents which will be developers are given a time period to read, understand and answer the questionnaire based on their interpretations. It is important that the questions of the questionnaire are non-sensitive, clear and easy to be comprehended. Besides, the layout of the questionnaire will be neat and pleasant to the eye of respondents by arranging the questions in sequence.

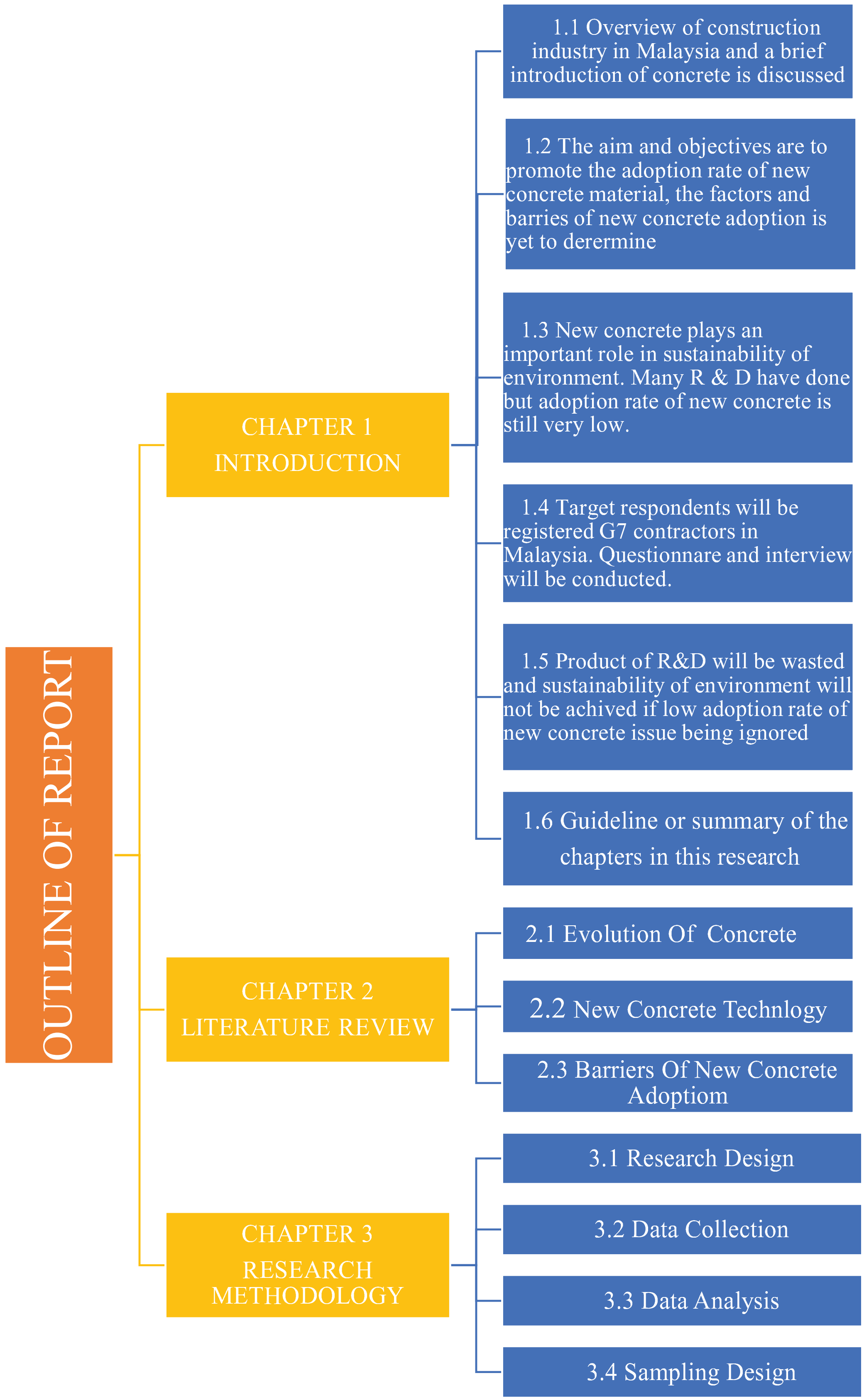
1.5 Significance of Study

Through this study, the barriers of new concrete technology adoption can be foreseen and thus will be able to tackle with. The main motivation and reason for concrete Research & Development associated to the construction industry is the rocketed requirements for durability of concrete, for instance, an elongated life cycle with low maintenance requirement. Concurrently, community is also concerned about the impact of built and environment environmental demand of society is arising as well.

Even though durability is the main stimulators and drivers for new concrete technology development, environmental issues and sustainability remain as the first priority. There are various approaches of developing concrete technology, for example improving the process of cement manufacturing, inventing more advanced equipment in cement and concrete handling, nevertheless new materials or supplementary cementitious materials in developing new concrete is focused in this study.

These new materials include, residual products for example, fly ash as partial replacement of the cement and new reinforcement materials. These new cements produced aimed to reduce environmental impact. Though there are many advantages and perks that can be benefits from new concrete technology, the adoption is still very low. All the research and development in new concrete technology will be fruitless without any implementation and execution. Therefore, in order to build a more sustainable, productive and developed country, this issue must not be ignored.

1.6 Thesis Outline



CHAPTER 2

LITERATURE REVIEW

2.1 General Introduction

This chapter is mainly discussed about the history and development of cement and concrete. Understanding the relationship between previous and current concrete technology is unconditionally a fundamental platform that allows people to construct, and, as may well be necessary, to modify and improvise existing concrete technology. None of these preferences can be undertaken well without understanding the framework and initial points of cement as well as concrete. Besides, this chapter also included the existing and latest concrete technology. Benefits and the applications of each of the new concrete is further described. Last but not least, the barriers of adoption of new concrete technology are also discussed in this chapter. Through the identification of factor barriers, methods and steps can be deployed to eliminate all the barriers and thus, increasing the adoption rate of new concrete technology.

2.2 Evolution of Concrete

Cement was being created when the earth itself was experiencing extreme geologic change, in which this natural cement was put to use by human beings. Gradually, humans learned how to create cement from other materials. Basically, concrete is an artificial building material that its appearance similar to stone, but now, cement and concrete had evolved over the millennium and becoming more and more advanced in the properties to meet the demanding requirement of different applications of concrete.

Concrete was an essential materials that used in constructing aqueducts and roadway in Rome back in 3000 BC. The Romans invented a primal mix for the concrete of their own which consists of gravel, sand mixed together with hot lime and water as well as with milk or animal blood as natural admixtures (Shaeffer, 1992). To reduce the shrinkage of concrete, horsehair were incorporated at that time. Meanshile, ancient Egyptians used lime and gypsum cement in constructing the world-acclaimed pyramids. In year 1756, John Smeaton produced the modern concrete by combining aggregate and powered brick, and mixed it with cement. Another significant development of concrete took place in the year 1824, where Joseph Aspdin successfully manufactured Portland cement. Joseph Aspdin produced concrete by incinerating clay and chalk until evaporation of carbon dioxide took place which result in strong cement. Along the years, rapid research and development of cement and concrete had been undertaken, producing more and more types of concrete, to fulfil the specific requirements of end-users For example, reinforced concrete or Ferroconcrete refer to concrete that contains imbedded metal which enhance not only the compression strength but also the tensile strength of the concrete (Shaeffer, 1992).

With the technology available, cement and concrete are able to develop continuously. Natural admixtures such as animal blood and milk are no longer been used, and substituted by more advanced artificial admixtures, for instance air entraining agents and super plasticizers which were introduced in 1930 and 1960 respectively. Besides, increased strength with reinforced materials, concrete is also developed for the high-performance characteristics. In 1950, the use of high performance concrete can be traced especially in high-rise building.

In the next two and three decades, high performance concrete is extensively used in constructing bridges such as Tsing Ma Bridge in Hong Kong and high rise buildings. One of the example in Malaysia is the Petronas Twin Tower (KLCC). In the mid-1990's, Reactive Powder Concrete (RPC) which is also known as ultra-high performance cementitious mortar was developed. Since then, RPC is widely used in construction industry and the first RPC filled steel tube composite footbridge was built in 1997 at Sherbrooke, Canada and the first fully RPC footbridge is constructed at Seoul in South Korea.

2.3 New Concrete Technology

The emerging new concrete alternatives rely on technological advances that include energy efficiency, low carbon production methods, novel cement formulations, carbon negative cements and novel concrete products. There are various types of new concrete materials which have its own special and distinct characteristics to meet special requirements of projects. Basic introduction, characteristics and application of each new concrete technology is further discussed.

2.3.1 Fibre Reinforced Concrete

Concrete is strong in compression, but weak in tension. According to Banthia, (2012), concrete is relatively brittle, and its tensile strength is typically only about one tenths of its compressive strength. The weak matrix in concrete, can be improved by the mixing certain fibres. A fibre is a small discrete reinforcing material produced from various materials like steel, glass and natural materials. The fibre reinforcement for concrete was undergo slow development before 1960's. Nevertheless, research on glass fibres had been conducted in early 1950's. Various types of Fibre Reinforced Concrete for instance Steel Fibre Reinforced Concrete and Glass Reinforced Concrete, re further discussed.

Steel Fibre Reinforced Concrete

Steel Fibre Reinforced Concrete (SFRC) is reinforced with steel fibres, normally used to overcome cracking problem of concrete due to environmental factors and the inherent weakness of concrete to withstand tensile forces. When concrete is reinforced with steel fibres, concrete gains massive strength, thus rendering the matrix to perform as a composite material with an increasing on both the compressive and tensile strength (ACI Committee 440, 1996). Steel fibres are uniformly distributed throughout a given cross section whereas reinforcing bars or wires are placed only where required. According to Priti et al, (1997) SFRC has resistance to impact, blast and shock loads. Typically it does not significantly alter free shrinkage of concrete, however at high enough dosages they can increase the resistance to cracking and decrease crack width. Generally, SFRC has a very high flexural, shear and tensile strength thus prevent erosion and abrasion resistance to splitting (Shah, Surendra and Rangan, 1994).

Besides, SFRC is able to resist high temperature and seismic hazards, hence maintaining its structures from collapsing. Steel Fibre Reinforced Concrete was traditionally used in constructing pavements, but now has gained acceptance not only in constructing aircraft parking and runways but also now used in high way kerbs, sea-defence walls, building panels and blocks, blast-resistant storage cabins, piles and prefabricated storage tanks. SFRC can be used in biological shielding purpose in atomic reactors, too. With the ability of the steel fibres to resist deformation and undergo large rotations, SFRC is used extensively in blast-resistant and seismic-resistant structures, by allowing the expansion of plastic hinges under over-load circumstances. Marine structures that built by SFRC have the ability of resistance to corrosion at the air-water interface, for example floating caissons and pontoons (ACI Committee 440, 1996). Figure 2.2 shows an example of steel-fibre reinforced building, the Library and Learning Centre at the Vienna University of Economics and Business.

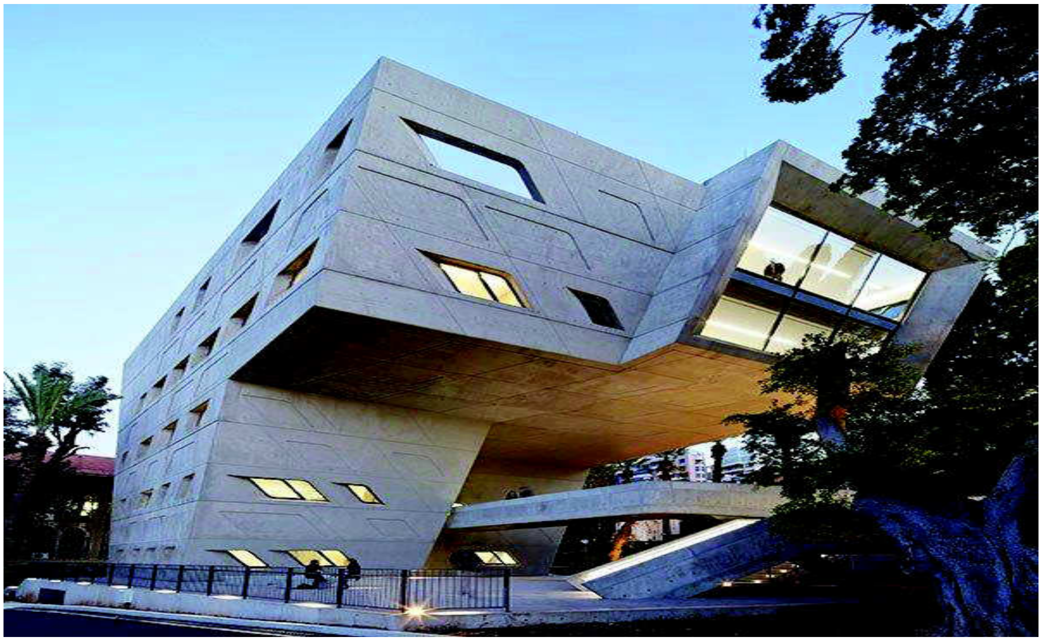


Figure 2.1: Library and Learning Centre at the Vienna University of Economics and Business (Charlotte, 2014)

Glass Fibre Reinforced Concrete

Glass Fibre Reinforced Concrete is basically concrete material that contains glass fibres as reinforcement. The glass fibres, which are resistant to alkali were used extensively since it is able to resist the harsh environmental effects. Unlike steel, glass fibres will not rust therefore concrete coating is not required. Substantial, the mass of hollow and thin products produced by GFRC is relatively lesser than the conventional concrete (PCI committee, (1981). Majumdar, et al., (1968) stated that GFRC is a good resistor of heat as it is manufactured by minerals. GFRC will not easily burn and act as a thermal regulator that protects the materials within it from the fire. Besides, GFRC is comparatively lighter than the conventional materials. Therefore, the installation of GFRC is more simple and fast. Since GFRC can be produced in thin sections, GFRC can be cast to almost any shape of mouldings, columns and beams. Moreover, GFRC are also a good weather resistant and can save repairing and maintenance costs.

As GFRC is durable and light, it has a high ratio of weight-to-strength. The transportation costs therefore are decreased significantly as GFRC is light in weight. Excessive reinforcement are not required that may be complicated for complicated moulds since GFRC is internally reinforced. GFRC has been used mainly in non-structural works, for example piping for sanitation network systems, facing panels and architectural panels, because of GFRC's light weight it can be transported easily. GFRC which are good noise and sound barriers can be used to manufacture sound walls. GFRC is widely used to reduce noise pollution in addition, various and interesting shapes and colours are available. Light and strong GFRC permit engineers to repair structures during rehabilitation of structures. Not only that, Glass Fibre Reinforced Concrete can be applied in sewer lining as its ability to resist acid, lime and water corrosion. GFRC pipes could be manufactured in various desired shapes and could be a suitable substitutes for traditional and conventional piping systems (Akihama, et al, 1987). Figure 2.3 shows the Broad Contemporary Art Museum is being enclosed with an innovative glass fibre reinforced concrete (GFRC) panel skin.

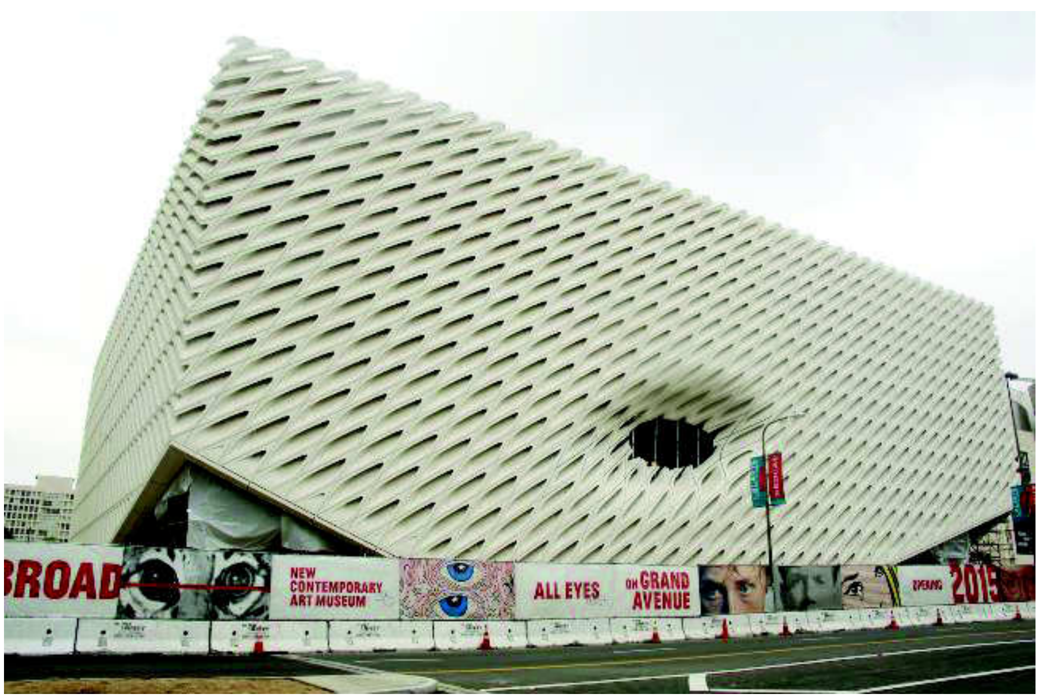


Figure 2.2: The Broad Contemporary Art Museum (Hopkins, 1966)

2.3.2 Self-Compacting Concrete

Self-compacting concrete was first developed in 1988. According to IUREŞ, et al., (2010), Self-compacting concrete (SCC) is a concrete that utilize superplasticiser and a stabiliser to the concrete mix aimed to increase the ease and rate of flow. SCC does not require any vibration by its nature. SCC can achieve compaction into every part of the formwork or mould by its own weight without resulting in any segregation of the coarse aggregate. To be considered as a self-compacting or self-consolidating concrete, the concrete must have a fluidity and ability that permits self-compaction without external force exerted on it, and flow easily through reinforcement (Ouchi, 2001). As a high-performance concrete, SCC delivers these attractive benefits while maintaining all of concrete's customary mechanical and durability characteristics. Adjustments to traditional mix designs and the use of superplasticizers creates flowing concrete that meets tough performance requirements. SCC creates the level of reliability and durability of the structure from the existing on-site conditions independently relate to the quality of casting, labour and compacting systems available.

The self-compacting ability and high resistance to external segregation allow the elimination of air bubbles, and honey combs which responsible for penalizing structure durability and mechanical performance. The development of high performance polycarboxylate polymers and viscosity modifiers have made it possible to create "flowing" concrete without compromising durability, cohesiveness, or compressive strength. Moreover, Self-Compacting Concrete aids the introduction of automation of construction works into concrete construction instead of man-power in which the safety and health can be accomplished through elimination of handling of vibrators (Okamura & Ouchi, 2003). Self-Compacting Concrete has a wide applications, from bridge components construction such as anchorage, arch, pier, and joint to box culvert, and diaphragm wall. According to Ouchi, (2001), Self-compacting concrete was used for the construction of wall of a large LNG tank as shown in Figure 2.3, belonging to the Osaka Gas Company as well as the anchorages of Akashi-Kaikyo (Straits) Bridge in Japan as shown in Figure 2.4.

Figure 2.3: LNG Tank of Osaka Gas Company (Ouchi, 2001)

Figure 2.4: Akashi-Kaikyo Bridge (Ouchi, 2001)

2.3.3 Bendable Concrete

Engineered Cementitious Composites or known as Bendable Concrete that overcomes the brittleness of conventional concrete with its ductile properties. Dhawale, et al., (2013) stated that bendable concrete had developed in 1900's. Bendable concrete in direct tension, is three hundred times more flexible and deformable than normal concrete with tensile strain capacity of 3 %. Conventional concretes are almost unbendable and have a strain capacity of only 0.1 % making them highly brittle and rigid. This lack of bendability is a major cause of failure under strain and has been a pushing factor in the development of an elegant material namely, bendable concrete also known as Engineered Cementitious Composites abbreviated as ECC. Bendable Concrete (ECC) is much more flexible and deformable compared to traditional concrete. While traditional concrete is considered brittle and rigid which can suffer from concrete fractures in an earthquake or by routine overuse, Bendable Concrete remains intact and safe to use at tensile strains up to 5 %, as traditional concrete cannot endure load at 0.01 % tensile strain (Dhawale, et al., 2013).

Bendable Concrete consumes only 2 % of short fibre reinforcement to attain cost effectiveness and easy implementation in construction field. (Gadhiya et al, 2015). ECC incorporates super fine silica sand and tiny Polyvinyl Alcohol-fibres covered with a very thin (nanometer thick), slick coating. This surface coating allows the fibre to begin slipping when they are over loaded so they are not fracturing. Wide applications of Bendable Concrete which include construction of bridge decks, concrete pipes, roads and structures that are subjected to seismic and non-seismic loads, where a tough, lightweight, and durable building material is desired. Bendable Concrete has been under development and was used in the construction of the 27-story Glorio Roppongi High Rise in 2006 as shown in Figure 2.5. Besides, Figure 2.6 shows the 41 story Nabeaure Tower in Yohohoma also constructed using bendable concrete in coupling beams in the building core (Li, 2006).

Figure 2.5: The Glorio Roppongi High Rise Residential Building (Li, 2006)

Figure 2.6: The Nabeaure Tower (Li, 2006)

2.3.4 Pervious Concrete

Pervious concrete is an approach designed mainly for monitoring, regulating, and handling storm-water runoff. Pervious concrete allows the water to flow through the concrete into the sub-base and restore the underground water level. Pervious concrete also referred to as gap-graded, enhanced porosity, or permeable concrete. Typically, there is no sand and the air void content differs between 15 % and 30 % in Pervious Concrete. Pervious concrete was first invented in the 1800s in Europe in constructing load bearing walls and pavement surfacing (Chopra et al, 2006). Tennis et al, (2004) indicated that with high levels of permeability, storm-water runoff and contaminants in waterways can be reduced with pervious concrete by allowing it to flow and percolate into the sub-base and underground where it is filtered via biology and soil chemistry. Pervious concrete is able to eliminate heat island effects by percolating water throughout the pavement. Cooling effect can be exerted through water evaporation and convective airflow with utilisation of Pervious Concrete. The voids within Pervious Concrete that contribute to noise absorption at the tire–pavement interface is able to diminish tire–pavement noise emissions (ACI 2010). Pervious concrete has been used in construction of pavements, from parking areas and driveways to residential roads, alleyways, and other low-volume roads (Tennis et al. 2004). Figure 2.7 shows about 2.7 million square feet of pervious concrete was placed in Beijing, China, for the 2008 Summer Olympics.

Figure 2.7: Pervious Concrete in Beijing, China (Liu, Ji, & Jin, 2010)

2.3.5 Lightweight Concrete

Lightweight concrete can be referred as a type of concrete that it increases the volume of the mixture while giving additional qualities and reduced the dead load. Lightweight concrete upholds the large cavities and not creating cement films or laitance layers during concrete placement. Lightweight Concrete was first introduced and used by the Romans in the eighteen centuries (Chandra, 2003). Typically, the main properties of lightweight concrete are its low thermal conductivity and low density. Because of these properties, lightweight concrete is used to decrease the dead weight and static load of a building which eventually allows the reduction in the size of the footings, columns and other loadbearing structures which eventually leads to cost savings. Though the size of elements are decreased, the strength does not reduced. Lightweight concrete creates an extra efficient strength-to-weight ratio in building structures and can attain still the similar strengths as standard concrete. Replacement is not required in maintenance process since the lightweight construction becomes part of the building and structures (Mohd et al., 2003). Lightweight concrete has been extensively used as insulation in masonry construction in which it eliminates noise pollution, resistance to termite and fire. It is also used in construct vessels or roof decks applications (Mohd et al, 2003). Figure 2.8 shows the Marina City Tower in Chicago which constructed using lightweight concrete.

Figure 2.8: The Marina City Tower (Marjanovic & Ruedi, 2010)

2.3.6 Geopolymer Concrete

Geopolymer is considered as one of the family of inorganic polymers and was first introduced in 1978 by Davidovits. The implementation of Geopolymer concrete is able to minimize the emission of carbon dioxide (Geopolymer Institute, 2010). Geopolymer attain its structural strength by poly-condensation of alumina and silica. The specialties of Geopolymer concrete are high resistance to heat, sets at room temperature, low heat of hydration and the drying shrinkage is comparatively lower. The permeability of Geopolymer is very low thus protecting internal steel reinforcement from deteriorations. Nowadays, Geopolymer is widely used in applications for bridges and precast structural items, decks and structural retrofits. Due to the ease in handling sensitive materials such as high-alkali activating solutions, Geopolymer technology had become the most advanced in precast applications. Up to the present time, none of these potential applications has improved beyond the development phase, however the durability features of Geopolymers make them attractive for use in harsh environment and high cost applications such as precast pavers and slabs for paving. Figure 2.9 shows The University of Queensland's Global Change Institute (GCI) which constructed with the use of Geopolymer concrete.

Figure 2.9: University of Queensland's Global Change Institute (Peter, 2013)

2.3.7 Self-Healing Concrete

Self-Healing Concrete has been undergo development since 2006 under Civil Engineering and Geosciences Faculty in Delft. Limestone is produced biologically to heal cracks on surface of concrete through conversion of nutrients with Genus bacteria. The process of this autogenous healing is mainly due to secondary hydration of partially reacted cement particles exist in the concrete (Jonkers, 2011). The healing mechanism takes place when water is constantly sipped through the cracks of concrete due to capillary movements. This result in formation of which eventually cause the expansion of hydrated cement particles. The layer of calcium hydroxide and calcium silicate hydrates (Portlandite) will then allow to dry when exposed in the air which will be able to seal the cracks completely provided that cracks are small. Not only that, the feasting of oxygen during the conversion process of calcium lactate to limestone has an extra benefits. During the process of corrosion of steel, oxygen is an essential element. When the bacterial activity has used up all the oxygen, it therefore intensifies the durability of steel reinforced concrete constructions. Basically, Self-Healing Concrete is limited to maintenance and repairing applications only, for instance roads, bridges and other infrastructure applications. One of the example is the Irrigation canals in Ecuador as shown in Figure 2.10.

Figure 2.10: Irrigation canals in Ecuador (Sierra-Beltran, et al., 2015)

2.3.8 Supplementary Cementious Materials (SCM) Concrete

Supplementary cementitious materials are mixed together with concrete as part of the total cementitious system. The development and practise of adopting Supplementary Cementitous Materials in concrete has been introduced since 1970. SCM concrete is preferable not only for the technical benefits of concrete but also for the environmental and energy conservation purposes. Depends on the desired requirements and effect of concrete, SCM can be added or partially replaced the Portland cement.

Fly Ash Concrete

Fly ash is used as a supplementary cementitious material (SCM) in the production of portland cement concrete since 1937. Fly ash, a by-product of the combustion of pulverized coal in electric power generating plants has been commonly used in concrete. Fly ash is basically silicate glass containing alumina, calcium and iron whereas minor constituents include sulphur, magnesium, potassium, sodium, and carbon. Small amount has a beneficial effect on the workability of concrete however it may not be sufficient to improve the durability and resistance of sulphate deterioration, alkali-silica expansion, and thermal cracking. Thus, the amount of fly ash added depends on the desired applications of Fly Ash Concrete (Prabakar et al, 2011). Fly Ash Concrete contains a siliceous or alumina-siliceous material, known as pozzolan, reacts chemically with the calcium hydroxide that released during the hydration process of Portland Cement to form additional calcium silicate hydrate and other cementitious compounds that making tougher, denser and more durable as compared to traditional Portland Cement concrete mixtures. Secondly, Fly Ash Concrete has greater workability and thus lowering of water demand for the same concrete consistency. Fly Ash Concrete has a lower heat of hydration compare to Portland Cement Concrete that releases considerable heat upon hydration. During mass concrete placements in construction works, the amount of excess internal heat generated can lead to thermal cracking.

With utilisation of fly ash, may significantly reduce this heat accumulated and avoid external cracking. Besides, Fly Ash Concrete is able to reduce the adsorption and permeability of concrete. Through reducing the permeability of concrete, oxidation of embedded steel is critically decreased (Ash Grove Resources, 2006). From residential foundations to marine structures and high-rise construction, footprints of Fly Ash Concrete can be observed. Mega structures require higher percentage of fly ash (30 % to 50 %) for example, foundations and dams. Some examples of constructions that utilized fly ash concrete are the new St. Clair River Tunnel in Michigan as shown in Figure 2.11 and the Lower Notch Dam in Canada as shown in Figure 2.12.

Figure 2.11: The Lower Notch Dam (Thomas, 1996)

Figure 2.12: The St. Clair River Tunnel (Finch, 1996)

Silica Fume Concrete

Silica fume, is a by-product material which formed in manufacturing process of silicon. It is used as a pozzolan and was introduced in 1985. Silica fume exists in extremely fine powder form or as a water-slurry form, which is 100 times smaller compare to average cement particles. The physical and chemical properties of silica fume result in highly reactive pozzolona and when these small, fine pozzolona grains distributed in the concrete paste, a huge number of nucleation sites are generated for the precipitation of the hydration yields, which makes the concrete paste denser and more homogeneous for the fine pores' distribution. This is because of the amorphous silica of the pozzolanic reacts chemically with the calcium hydroxide by the cement hydration process (Morsy & Shebl, 2007). Silica fume concrete exhibits characteristics such as high tensile, elasticity and flexural strength, early compressive strength, high durability, low permeability to water movement and high abrasion resistance on structures. Silica fume as SCM is used widely for its applications, for instance, Silica-fume Shotcrete which used in mine tunnel linings, and restoration of damaged bridge, marine piles and columns.

Besides, silica fume also used in grouting of oil well, whether for primary or secondary applications. The former application include grout placement in well-bore as a hydraulic seal whereas the secondary applications involve remedial operations for example leak repairing. Silica fume has the ability to provide blocking effect that stops gas movement for better control of gas leakage as well as improve flow for more effective and easier applications. Besides, silica fume also used in various cementitious repair products. Silica fume modified mortars or grouts can be designed to accomplish in many different applications, for example vertical and overhead mortars has better surface adhesion with silica fume which intensively improves cohesiveness. This properties is ideal for use in underwater grouts, reduce permeability in grouts for post-tensioning applications and amplify the resistance to destructive chemicals (Siddique, & Khan, 2011). Example of applications of silica fume are the Burj Khalifa in Dubai as shown in Figure 2.13 and the One Island East Tower in Hong Kong as shown in Figure 2.14.

Figure 2.13: Burj Khalifa, Dubai (Aldred, 2010)

Figure 2.14: One Island East Tower, Hong Kong (Riese, 2008)

Rice Husk Ash Concrete

Metha & Folliard (1992) investigated the effect of pozzolanic reactivity of rice husk ash in 1973. Rice Husk Ash (RHA) Concrete is a carbon neutral products as well as a good super-pozzolan. The pozzolanic activity if mostly depends on the silica content, silica crystallization stage and the size or surface area of rice hush ash particles. RHA establish properties like better workability with small amounts of rice husk ash, decreased segregation and bleeding, lower creep and prevent shrinkage, greater resistance to chemical attack, less heat of hydration and low transmission rate of chloride ions which provide a higher resistance to corrosion of steel in concrete (Krishna, 2008). Studies by Gambhir (2006) and Hwang & Chandra (1997) had indicated the extraordinary technical benefit of integrating RHA that comparatively increases the durability properties of concrete. Rice Husk Ash is used to decrease temperature in high strength mass concrete. Mehta and Pirtz (2000) later stated that greater substitution amounts results in lesser water absorption amounts and the addition of RHA increased the compressive strength of concrete. This product can be used in a variety of applications like refractory, flame retardants, ceramic glaze, insulator and roofing shingles. Rice Husk Ash Concrete also widely used as an effective repair mortar without the use of SBR latex or Acrylic polymer bonding agents. Figure 2.15 shows the German School in Chiang Mai, Thailand that was constructed with loading bearing interlocking RHA concrete blocks.

Figure 2.15: The German School in Chiang Mai, Thailand (Karl, 1995)

2.4 Barriers of Adopting New Concrete Technology

As mentioned earlier, construction process involves usage of natural resources and creation of greenhouse gas emissions. As awareness of resource depletion and climate change, construction industry need to adopt more sustainable technologies through material selection (Heidrich, et al., 2015). Besides, it is not sufficient if only the concrete technology or level of the knowledge be improved and advanced, but in addition, the knowledge is essential to be conveyed and transferred to those who are doing the work, in order to allow the improvement and advancement turn into state of execution. However, this adoption of the new research into routine practise in structural design or concrete mixtures is a challenge that has often left substantially behind. In this scenario, Vanikar, (2004) suggested that research projects not only need to be developed but is crucial to established with implementation of the results as well. Despite the potential benefits from using new materials in concrete production, majority of these concrete innovations are still remain outside routine practise. In this subtopic, different barriers to the wide application of potential new concrete technologies are further discussed. Figure 2.16 below shows the 5 major barriers in new concrete technology adoption.

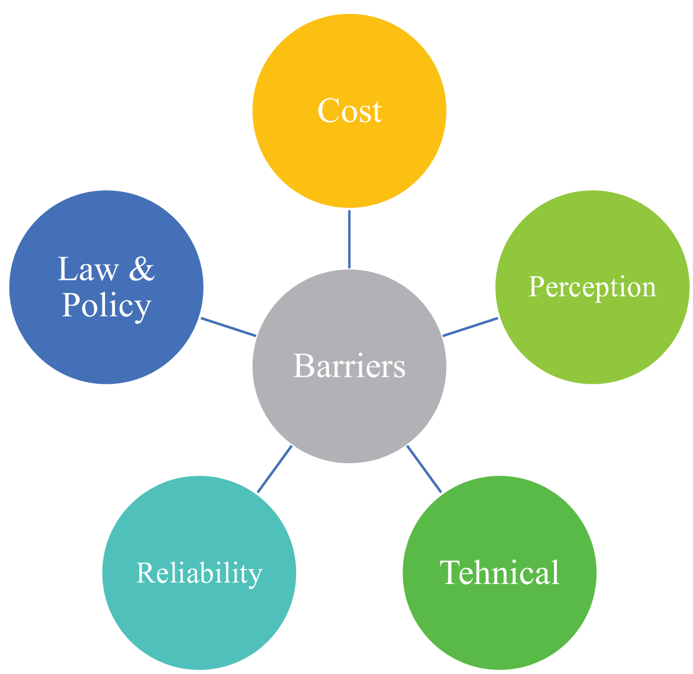


Figure 2.16: Barriers of New Concrete Technology Adoption

2.4.1 Cost Barriers

In adopting new concrete technologies, under cost perspective, acquisition of the material is the primary determinant cost. Acquisition cost include sum of total costs associated with receiving and using of a product or service, including ordering administration costs, ordering size costs, product costs, inbound shipping costs, assembling or conversion costs, quality costs and maintenance costs.

Moreover, it is often problematic to evaluate the cost effectiveness of new concrete technology. Subsequently, evaluation of capital expenditure for new concrete technology may be hard to acquire. Pflughoeft-Hassett, et al., (1993) stated that the market price of new concrete varied significantly, ranging from $4 to $25 per tonne, depending on the material and the transportation expenditures. In certain circumstances, transportation costs may discourage new concrete adoption because of the distance from the source of the materials. Availability of new concrete is an issue in this situation. Consumers may need to transport the new concrete from other states or import from other countries if there is no desired new concrete available in markets nearby. New concretes are supposed to aim for the lower the cost of a construction project, therefore if transportation cost is comparatively high, consumer will definitely not taking into considerations.

In order to adopt new concrete technology, the execution cost can be over-priced. Since implementation of new concrete technology differs from conventional concrete, a new system or protocol is required to be introduced in which the cost of execution can be rocketed to certain amount. In this situation, small or medium sized company will not be able to sustain due to the budgetary issue. Only large company can afford the high execution cost in adopting new concrete technologies. Not only that, capital cost must be considered as well. Initial costs and maintenance costs can be extortionate. For example, The Sydney Opera House spent maintenance expenditure totalled $32.0m in 2012/13 (Colbert, 2012). Moreover, it is problematic to evaluate the cost effectiveness of new concrete technology. Subsequently, evaluation of capital expenditure for new concrete technology may be hard to acquire.

Besides, unpredictable cost is also one of the barrier that prohibits the adoption of new concrete technologies. Traditional concrete has a far history which can be traced back, and is been used for over ten decades, traditional concrete is proven can be implemented in constructing buildings. Due to the low adoption rate of new concrete technology in Malaysia, there is less success example of building construction that used new concrete material. The uncertainties and the unforeseen risk in new concrete adoption which may incur extra cost thus creating the barriers. Cost savings is one of the key importance, and anything that would reducing the cost while maintaining the quality would be favourably considered (Batayneh et al., 2007). Cost effectiveness would be the driving force for the industry to implement new concrete.

2.4.2 Perception Barriers

Duxson, et al., (2007) stated that construction industry is conservative in nature, mainly is because consumers afraid and worried about product failure. Besides, the existing negative perceptions of the construction industry on non-conventional practice for example utilization of new concrete in construction projects, which may not be always accurate also contribute to the perception barriers. For instance, fly ash concrete was perceived to have low freeze-thaw resistance. Rogers (1962) pointed that lack of credible information happened in two phases over a technology's development, the first phase is demonstration whereas the second phase refers to adoption. Demonstration is a process verifying that the concrete technology is valid in various applications while adoption phase is about sharing the information of new concrete technology throughout the construction industry in order to take full advantage of the benefits of the new concrete technology. The incapability to verify and validate performance of the new concrete is prohibiting consumers from utilizing efficiency new concrete technologies.

New concretes are frequently thought to be low quality as there is insufficient familiarity with established applications and that this absurd perception has result in slow commercialization of new concrete in construction industries. In some cases, consumers claimed that some of the new concrete materials are hazardous wastes. This perception may derive from an association of the term solid waste with that of hazardous solid wastes. Therefore, even when consumers ready to consider a new concrete, any uncertainty about its performance, value or other characteristics can contribute to barriers of adopting the new concrete. Moreover, consumers who learn about new concrete technologies only from seminar, journals or advertisements may not have sufficient data to evaluate the potential value of these new concrete technologies. Not only that, consumers tends to think that the researchers are biased sources of information, and, indeed, manufacturers and suppliers are sometimes unable to deliver comprehensive and precise information on new concrete technologies.

On the other hand, there is a low level of awareness about the remunerations of new concrete technology is one of the barriers that emerged in the construction industry (Heidrich, et al., 2015). New concrete technologies are viewed more as a time-consuming distraction from the construction routines rather than a way of improving and facilitating construction processes. The benefits of utilizing new concrete are not recognized and some construction company owners are more concerned about the dynamic nature of new concrete technology than the awareness of using new concrete. Company owners are worried that the characteristics and properties of the new concrete may suddenly become obsolete too soon and therefore not worth the investment. In addition, lack of awareness in sustaining the environment contributes to the barriers of adopting new concrete technology as well. Sustainability in construction as a holistic concept which targets to integrate social, economic and cultural policies to ensure high quality of construction growth has been ignored. Some construction companies are not really concern about the sustainability of environment as there is lack of awareness of the correlation between sustainability and the importance of adoption of new concrete technology.

2.4.3 Technical Barriers

New concrete production, product commercialization and demonstration, standards and specifications, and user-related factors are included in technical barriers. As new concrete production, commercialization and specifications varies with traditional concrete, modifications in manufacturing processes or machineries may be essential for new concrete production, cement manufacturing, and other applications. Although consumers may be willing to attempt replacing conventional concrete with new concrete, consumers may not have suitable facilities and equipment to follow through. For example, a small ready-mix supplier might not own facilities to store both coal fly ash and cement. As the cost of constructing extra storage is relatively high, it may not be beneficial or economically practicable for a small ready-mix supplier, which eventually become one of technical barrier of new concrete adoption. (Pflughoeft-Hassett, 1993).

Furthermore, special skill or professional knowledge are required to manufacture or handle new concrete materials. Different types of new concrete technology demand specific handling techniques before implementing it. Not any contractor or other stakeholders can perform this process arbitrary. Since the process of manufacturing new concrete technology is comparatively complicated and troublesome, developers, contactors or consultant may not prefer new concrete technology in their construction projects. Besides, new concrete technology cannot be solely adopted without deliberate education and knowledge in adoption of new concrete. Ignorance toward new concrete utilization was cited by end users, such as architects, engineers, contractors, state and local personnel. Although efforts were made for educational opportunities, there is less support provided to increase educational opportunities that emphasizing new concrete adoption at the high school, university and even professional levels (Pflughoeft-Hassett, 1993). Education of engineers, architects, and other professionals at the university and college level was most greatly recommended to deliver a baseline level of comfort in utilizing new concrete technology since the university and college students are the future decision makers or stakeholders in construction industry.

2.4.4 Reliability barriers

High reliability is a crucial factor for stakeholders in construction such as engineers, architects, contractors, and especially client to adopt new concrete technology. Early adopter fleets recognise that new concrete always seek for improvements and developments in later generations. However, poor reliability with several new concrete introductions has caused scepticism and concern that mostly suspending or removing adoption decisions and demonstration project.

Under this circumstances, without verification of new concrete technology by the supplier might prohibits the adoption of new concretes. Verify product verification examines purchased products at the supplier facility to validate conformance to all customer requirement and meet a set of design specifications. Product verification minimizes risk, especially when suppliers have a history of performance issues or when products are critical, complex or expensive. In the development phase, verification procedures involve performing special tests to model or simulate a portion, or the entirety, of new concretes, then performing a review or analysis of the modelling results.

In fact, stakeholders tend to resist to change as changing may cause countless of uncertainty, which eventually becomes one of the barrier to the adoption of new concrete. Lack of confidence towards the new concrete technology as there is doubt about construction practicability and constructability in construction project. Normally, stakeholders will not run toward risks and remain ‘status quo’ attitude. Therefore, without calculated risk taking, no progress is made. Since stakeholders know that innovation is risky, they prefer to remain mired in misery than to head toward an unknown. However, most of the time when the risks are identified, innovation is often stopped. Andrews (2006) stated that with a clear-eyed view of risks balanced against benefits, manage to create an environment where innovation is nurtured rather than killed.

Additionally, government or industry's organization play a vital part under this picture. New concrete technology will be more difficult to penetrate and diffuse into construction. Product certification or product qualification is the process of certifying that a certain product has passed performance tests and quality assurance tests, and meets qualification criteria stipulated in contracts, regulations, or specifications. Most product certification bodies (or product certifiers) are accredited to ISO/IEC Guide 65:1996, an international standard for ensuring competence in those organizations performing product certifications. The organizations that perform this accreditation are called Accreditation Bodies, and they themselves are assessed by international peers against the ISO 17011 standard. Therefore, without the verification of government or accreditation bodies will inevitably discourage the adoption rate of new concrete technology.

2.4.5 Policy and Law Enforcement Barriers

Straits Settlement Ordinance No.3 of 1894 was the initial formal response to environmental issues arising from development especially those relating to the exhaustion of natural resources. It is unquestionable that the objective of a system of comprehensive environmental regulation in Malaysia is to protect the environment in the interest of the community.

The Department of Environment (DOE), is mainly in charge for pollution control. However, enforcement of policies and laws are not strong enough to give sufficient attention to construction stakeholders regarding sustainability of environment. Traditional cement which produces more carbon emission to the atmosphere is still widely used in construction projects and leaving a cleaner concrete technologies behind. Nevertheless, no efforts had been done to encourage the adoption of new concrete technologies in policy and law enforcement, for instance, there is no credits available for client or developer who adopt new concrete technologies.

Furthermore, a code is a law or regulation that sets forth minimum requirements and, in particular, a building code is a law or regulation that sets forth minimum requirements for the design and construction of buildings and structures. These minimum requirements, established to protect the health and safety of society, attempt to represent society's compromise between optimum safety and economic feasibility (Gross, 1996). Therefore, in the event where absence of codes and standards, consumers or end-users will be having difficulties in adopting new concretes as there is no direction to guide or follow them. Although builders and building owners often establish their own requirements, the minimum code requirements of a jurisdiction must be met.

2.5 Concluding Remark

A total of 11 types of new concrete technologies had been reviewed in this chapter:- steel-fibre reinforced concrete, glass-fibre reinforced concrete, fly ash concrete, silica fume concrete, rice husk ash concrete, pervious concrete, geopolymer concrete, bendable concrete, self-healing concrete, self-compacting concrete, and lightweight concrete. There are many other new concrete technologies available worldwide, different types of new concrete exhibit different features in which are capable of meeting different requirements according to project demands. Nevertheless, the adoption rate of new concrete technologies in Malaysia are still very low compared to other developed countries.

In addition, less study on barriers of new concrete technology adoption was undertaken to mitigate and tackle this issue, which creating a research gap in this study. A research Gap is the missing element in the existing research literature, and this study minimizes this gap as much as possible until no further distinctions exist.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 General Introduction

In this chapter, the methodology used in carrying out in this study is described to achieve the aim and objectives of this study. Redman & Mory, (1933) stated that research methodology is a systematized effort to gain new knowledge. Research consist of defining and redefining problems, forming hypothesis or recommended solutions; gathering, analyzing and evaluating data; making assumptions and reaching conclusions. Besides, the aim and objective of this study are planned to achieve through the data collection in questionnaire referring to the literature review.. For this study, questionnaire and interview are used to obtain data.

3.2 Research Design

Research design is a overall layout that gives a direction and indicates the different methods to be used in solving the research problem. The research design will help performing the chosen task easily and in a systematic way. Particularly, theoretical methods, numerical techniques, experimental techniques and other relevant data and tools necessary for the present study have to be collected and learnt (Rajasekar, Philominathan, & Chinnathambi, 2006).

3.3 Data Collection

Generally, the sources of data employed during the course of this study were:

- Secondary Data
- Primary Data

3.3.1 Primary Data

Primary data is data obtained from sources for example questionnaires, interviews, observation and discussion by the researcher, which information is then evaluated by that person. Process of collecting primary data can be lengthy but it does provide first-hand information. In this study , techniques used to collect the primary data is through questionnaire survey and interview.

3.3.2 Secondary Data

Secondary data is information that is already obtainable and accessible somewhere, whether it be, on the internet, in journals and in a company's records or archives. Secondary data permits for comparison of statistical information relating to, where the information may be used to evaluate whatever it is that is being researched. In this study , techniques used to collect the secondary data is through literature review.

3.4 Research Instrument

3.4.1 Questionnaire Design

A questionnaire is used for obtaining and recording information about a specific issue of interest. It is mainly consists of a list of questions for respondents to answer. Close-ended questions are preferable. Questionnaires are a cost effective method when comes into large sample size and large geographic areas (Statpac, 2014). In this context, questionnaires can be used in various types of survey situations, for example telephone, postal, face-to-face and electronic. There are 3 sections, Section A, Section B and Section C in the survey questionnaire. The overall layout and structures are as follows:

<u>Section A</u>

This section requires respondents to fill in the general personal information such as job position, age, qualification and working experience as well as company's information.

<u>Section B</u>

Under this section, the general knowledge in new concrete material of respondents are determined. Respondents are demanded to choose types of new concrete that are aware of. The motivations of respondents in adopting new concrete technology in the respect of clients, consultants and governments are going to be determined as well.

Section C

The questions are designed with 5-point Likert Scale that requires respondents to select a degree of agreement or disagreement based on the statements of low adoption rate situation of new concrete in Malaysia.

3.5 Sampling Design

3.5.1 Target Respondent

The target respondent in this study is focused on the REHDA registered developers, contractrors and consultants in Kuala Lumpur, Penang and Johor, Malaysia.

3.5.2 Sampling Technique

Random sampling technique is used to distribute the questionnaire. The questionnaire is delivered to the respondents with questionnaire survey either by hand or online survey.

3.5.3 Sample Size

The sample size of the questionnaire is calculated based on the Slovin's formula given below:

$$\text{Sample Size} = \frac{N}{1+Ne^2}$$

Ellen, (2012)

A population size of 396 requires 199 sample size with 95 % confidence level and 5 % of limit of error, where N= Population Size and e = limit of error.

3.6 Data Analysis

3.6.1 Analysis Method

Data analysis is carried out after collection of the data from respondent. The data is then analysed and tabulated in tables, bar charts or pie charts forms. Quantitative data obtained from questionnaire can be analysed by Factor Analysis, Reliability Analysis, Validity Analysis and Descriptive Analysis with Statistical Package for Social Science (SPSS).

3.6.2 Factor Analysis

Factor Analysis can be used to reveal the magnitudes or dimensions of a group of variables. Attribute space from a greater number of variables is able to decrease to a smaller number. According to which original variables have the highest relationships with the principal component factors, this approach can be also used to choose a sub-section of variables from a bigger category. Beside, Factor Analysis is one method to handle multi-collinearity in such procedures as multiple regression. Moreover, index or scale can be validated by demonstrating that its integral items which categorise under the same factor, and to drop suggested scale items that cross-load on more than one factor. Clusters or outliers of cases can be identified, too.

3.6.3 Reliability Analysis

Reliable Analysis is used to measure the overall consistency of the items that are used to define a scale. As a result, sample size, number of items and reliability coefficients are provided. This analysis can be used in determining whether the items in the questionnaire is related to each other or not. Cronbach's alpha reliability coefficient normally ranges between 0 and 1. However, there is actually no lower limit to the coefficient. The closer Cronbach's alpha coefficient is to 1.0 the greater the internal consistency of the items in the scale.

Table 3.1: Cronbach's Alpha Reliability Coefficient (George and Mallery, 2003)

Cronbach's alpha	Internal consistency
$\alpha \geq 0.9$	Excellent (High-Stakes testing)
$0.7 \leq \alpha < 0.9$	Good (Low-Stakes testing)
$0.6 \leq \alpha < 0.7$	Acceptable
$0.5 \leq \alpha < 0.6$	Poor
$\alpha < 0.5$	Unacceptable

3.6.4 Kaiser-Meyer-Olkin (KMO) and Bartlett's test of Sphericity

Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity is conducted in this study to exploratory factor analysis. The value of KMO ranges from 1 to 0, in which the acceptable index for KMO value is above 0.6. If the value of KMO exceed the threshold value of 0.6, in other words the test is said to be significant (Tabachnick & Fidell, 1989). However if the outcome of KMO value turned out to be less than 0.6 or below, this test is then consider as not desirable which will be eliminated from the study. Furthermore, the Bartlett's test of Sphericity is used to determine the correlation matrix in the factor analysis.

3.6.5 Descriptive Analysis

Descriptive analysis is mainly used for data summarizing and presenting. This approach can be used to measure central tendency, dispersion and variability. Mode, mean and median of data are being measured and to determine the central tendency of data. Variability is to summarize the spread or dispersion of a distribution. In this case, low variability indicates the scores of data are similar, while high variability refers to difference in data scores. Range, Interquartile range, standard deviation and variance calculations are then being calculated.

3.7 Concluding Remark

Questionnaire will be used in this study as survey method. Random sampling technique is used to distribute the questionnaire. A total of 199 sets of questionnaires will be distributed to the target respondents, in which consists of developers, contractors as well as construction consultants. The scope of research area is limited to only 3 states of Malaysia, which are Kuala, Lumpur, Penang and Johor. This is mainly because these 3 big cities experienced vast development and majority of REHDA registered developers established their company as well as their projects in these 3 cities of Malaysia. Subsequently, the data collected will be analysed using Factor Analysis, Reliability Analysis, Validity Analysis and Descriptive Analysis with Statistical Package for Social Science (SPSS).

CHAPTER 4

RESULTS AND DISCUSSION

4.1 General Introduction

This chapter shows the results from data collection and analyse the findings of the study. Information gathered include preliminary analysis of data collected, background of the respondents, reliability test and validity test of the measurement and ranking of barrier factors of new concrete technologies adoption in construction industry.

4.2 Preliminary Analysis

The survey questionnaire of this study is distributed to 300 respondents based on calculated sample size (approximately 199 sets) as per Chapter 3. The data collected through face-to-face and online survey questionnaire. Table 4.1 shows the preliminary analysis pf this study. From data screening, only 40 sets (40 %) are useable survey questionnaires from the overall of 43 returned sets.

Table 4.1 Preliminary Analysis

Description	Quantity	Percentage (%)
Questionnaire was distributed	199	100 %
Questionnaire was returned	43	21.60 %
Useable questionnaire	40	20.10 %
Incomplete questionnaire	3	1.51 %

From data screening, only 40 sets (20.10 %) are useable survey questionnaires from the overall of 43 returned sets. According to Nulty, (2008), response rate of 20 % considered acceptable for research external study. Poll, Krosnick, Marquette & Curtin, (1996) showed that surveys with lower response rates (near 20 %) yielded more accurate measurements than did surveys with higher response rates (near 60 or 70 %).

4.3 Respondent Demographics

The targeted respondents for this study was REHDA registered developers and engineering consultants in construction industry in Kuala Lumpur, Penang and Johor. Random sampling technique is using to distribute the questionnaire. The following section A of the questionnaire discuss about the respondents' gender, age, years of working experience, degree of qualification, profession in construction industry, service sector, common type of project and types of new concrete materials that potentially used in Malaysian construction industry.

4.3 Gender of Respondent

Table 4.2 indicates the frequency of gender of respondent. There are 29 of male and 11 female responded to the questionnaire.

Table 4.2 Frequency Table for Gender of Respondent

No.	Gender	Frequency	Percentage (%)	Cumulative Percentage (%)
1	Male	29	72	72
2	Female	11	28	100.00
Total	**-**	**40**	**100.00**	-

Based on the Figure 4.1, there is a huge gap between male and female respondent that participate themselves in construction industry.

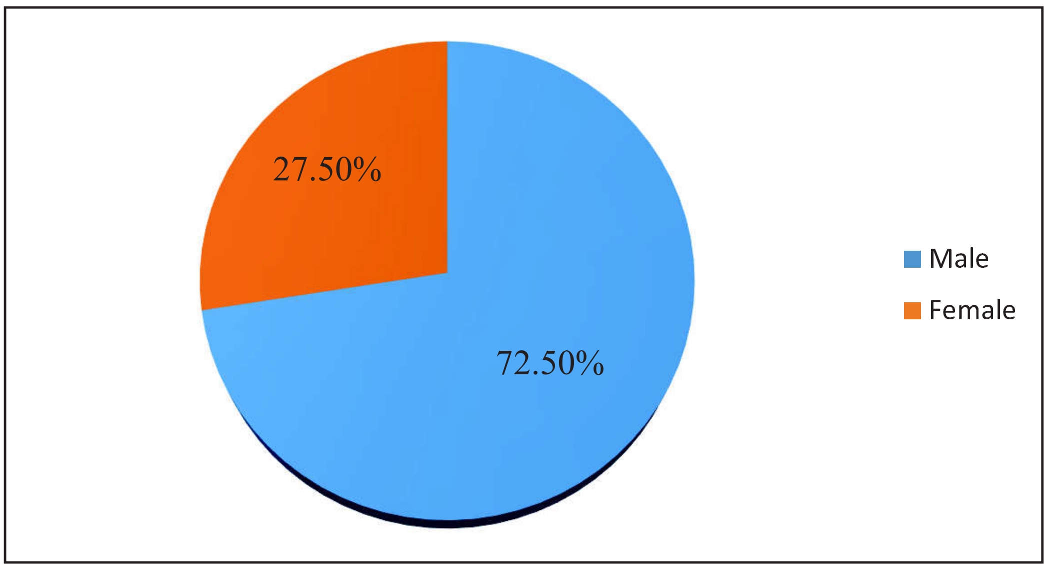


Figure 4.1: Gender of Respondents

The male respondent occupied a majority of 72 % whereas only 28 % of female were indicated. This shows a norm whereby more female respondent are more willing to commit themselves in other industry instead of construction.

4.3.2 Age of Respondent

Table 4.3 below indicates the frequency of respondents' gender. There are 29 of male and 11 female responded to the questionnaire.

Table 4.3 Frequency Table for Age of Respondent

No.	Age	Frequency	Percentage (%)	Cumulative Percentage (%)
1	21-30	12	30	30
2	31-40	18	45	75
3	41-50	9	22	97
4	50 and above	1	3	100.00
Total	**-**	**40**	**100.00**	-

According to Figure 4.2, most of the respondents are in the range of 31-40 years old which contain 45 % from the overall samples. This is followed by the age 21-30 years old with total of 30 %. Respondents with age of "41-50 years old" constitutes of 22 % whereas the respondents with age of "50 years old and above" are only 3 % from the overall samples.

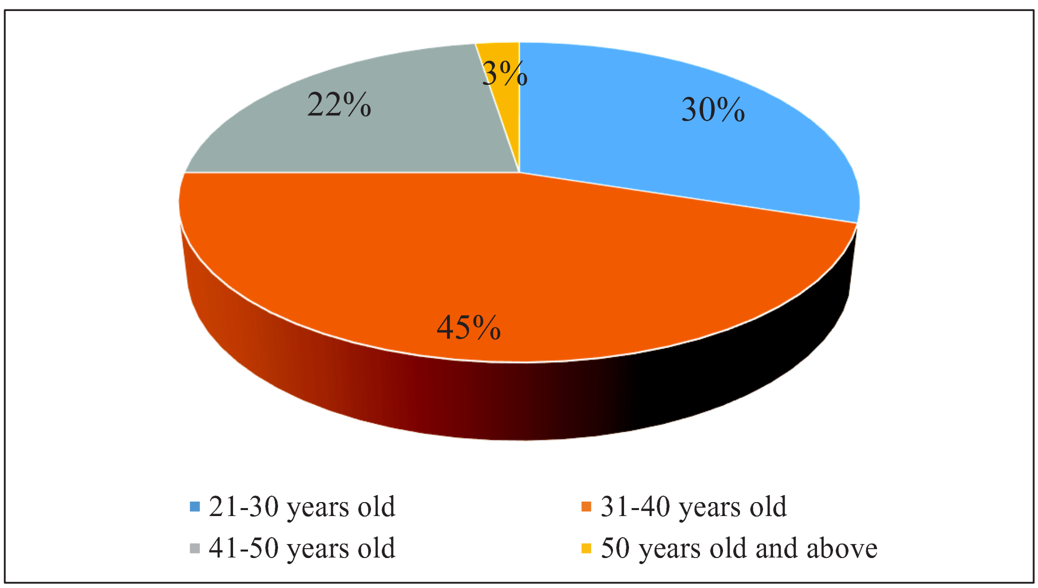


Figure 4.2: Age of Respondents

4.3.3 Working Experience

Table 4.4 below indicates the frequency of respondents' working experience.

Table 4.4 Frequency Table for Working Experience of Respondent

No.	Working Experience	Frequency	Percentage (%)	Cumulative Percentage (%)
1	≤ 5 years	12	30	30
2	6-15 years	16	40	70
3	16-25 years	8	20	90
4	≥ 25 years	4	10	100.00
Total	**-**	**40**	**100.00**	-

Based on Figure 4.3 there are 30 % of respondents with "less than or equal to 5 years" working experience whereas respondents with ' 6 to 15 years' working experience consists of 40 % and it ranked as highest from the overall respondents. This is followed by the "16-25 years" working experience with 20 %. Besides, there are only 10 % of respondent have 'more than 25 years' working experience in construction industry.

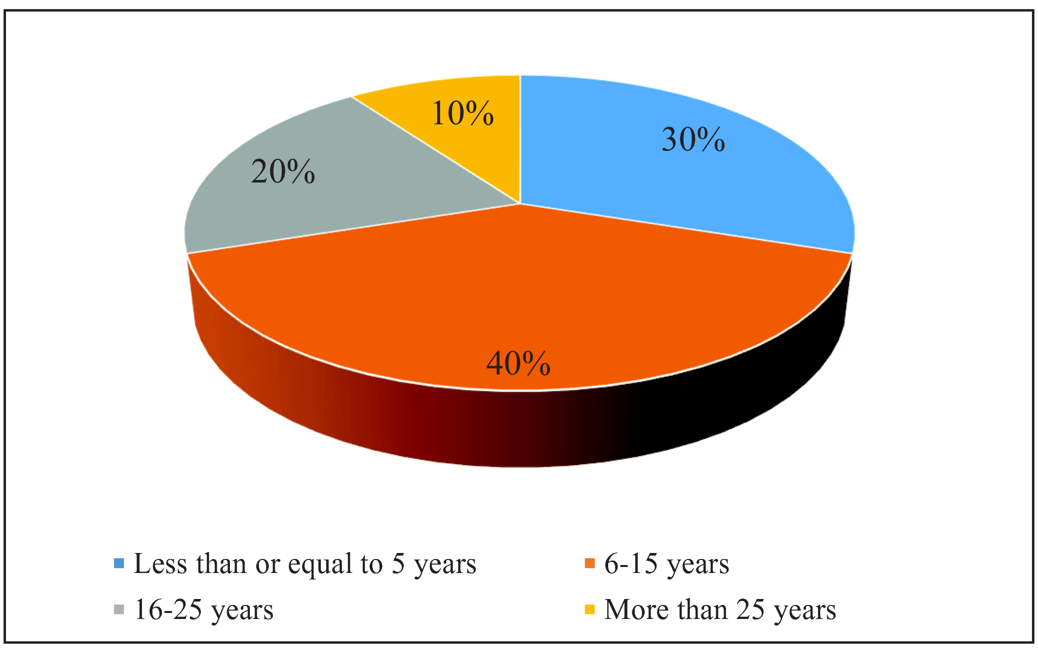


Figure 4.3: Working Experience of Respondents

4.3.4 Degree of Qualification

Table 4.5 below indicates the frequency of respondents' qualification.

Table 4.5 Frequency Table for Qualification of Respondent

No.	Degree of Qualification	Frequency	Percentage (%)	Cumulative Percentage (%)
1	Technical Certificate	12	16	16
2	Diploma	10	26	42
3	Degree	6	55	97
4	Master and above	1	3	100.00
Total	**-**	**40**	**100.00**	-

According to Figure 4.4, there are 55 % of the respondents with bachelor degree while only 3 % of respondents owned master degree and above. Besides, there are 26 % of respondents with diploma education level and 16 % for Technical Certificate Level.

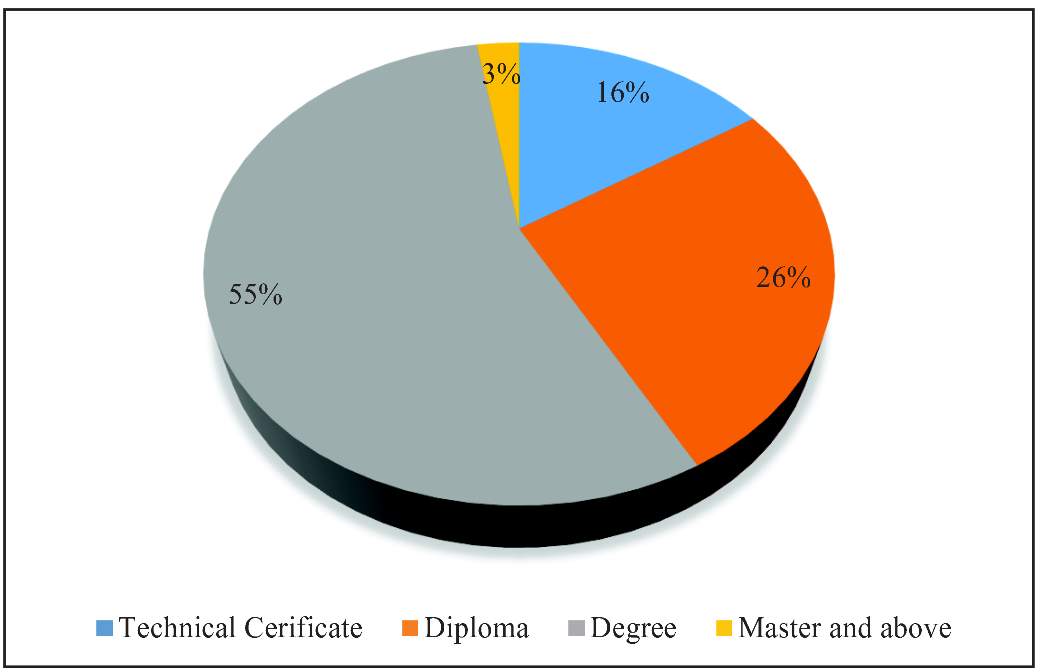


Figure 4.4: Degree of Qualification of Respondents

4.3.5 Profession

Table 4.6 below indicates the frequency of respondents' profession. Based on Figure 4.5, there are total of 35 % of respondent play as client/ client representative in the industry. In addition, 33 % and 32 % acts as consultant engineer and contractor respectively.

Table 4.6 Frequency Table for Profession of Respondent

No.	Profession	Frequency	Percentage (%)	Cumulative Percentage (%)
1	Client	15	35	35
2	Contractor	12	32	67
3	Consultant	13	33	100.00
Total	**-**	**40**	**100.00**	-

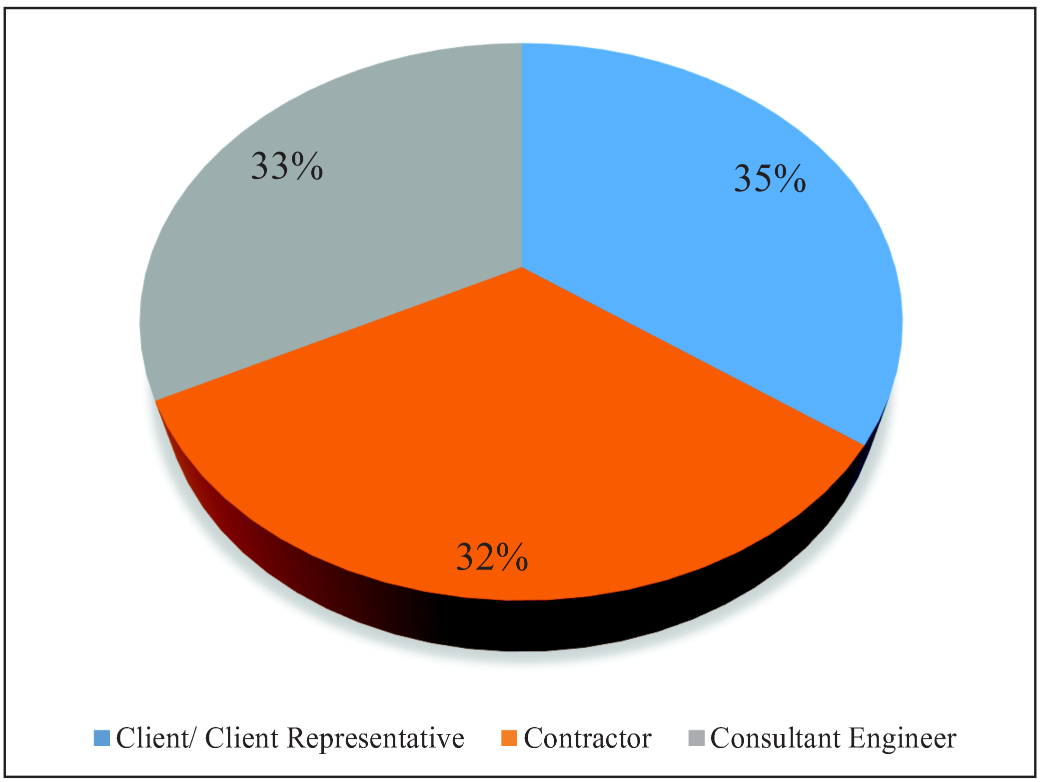


Figure 4.5: Profession of Respondents

4.3.6 Service Sector

Table 4.7 below indicates the frequency of respondents' service sector. In the samples based on Figure 4.6, respondents involved in private sector is almost half of the data, which reached 48 %. Next, only 12 % of respondents expose themselves in public sector and 40 % of respondent participate themselves in both private and public sectors. This number shows that private investment in Malaysian construction industry is still very active apart of government-leaded construction project.

Table 4.7 Frequency Table for Service Sector of Respondent

No.	Profession	Frequency	Percentage (%)	Cumulative Percentage (%)
1	Public Sector	5	12	12
2	Private Sector	19	48	60
3	Both	16	40	100.00
Total	**-**	**40**	**100.00**	-

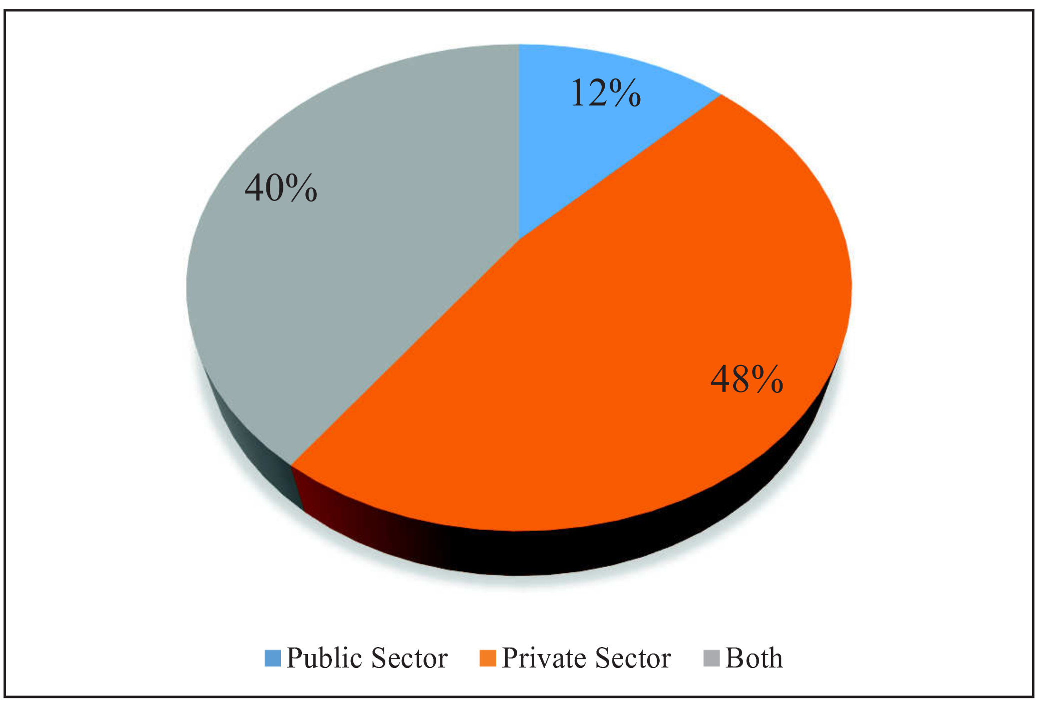


Figure 4.6: Service Sector of Respondents

4.3.7 Common Type of Project

Table 4.8 below indicates the frequency of respondents' project types. According to Figure 4.7, in terms of project types, majority of respondents involved themselves mainly in building projects. In the contrast, only 18 % of respondents are interested in executing engineering projects. 25 % of respondents are participating in both building projects as well as engineering projects.

Table 4.8 Frequency Table for Project Types of Respondent

No.	Type of Project	Frequency	Percentage (%)	Cumulative Percentage (%)
1	Building Project	23	58	58
2	Engineering Project	7	17	76
3	Both	10	25	100.00
Total	**-**	**40**	**100.00**	-

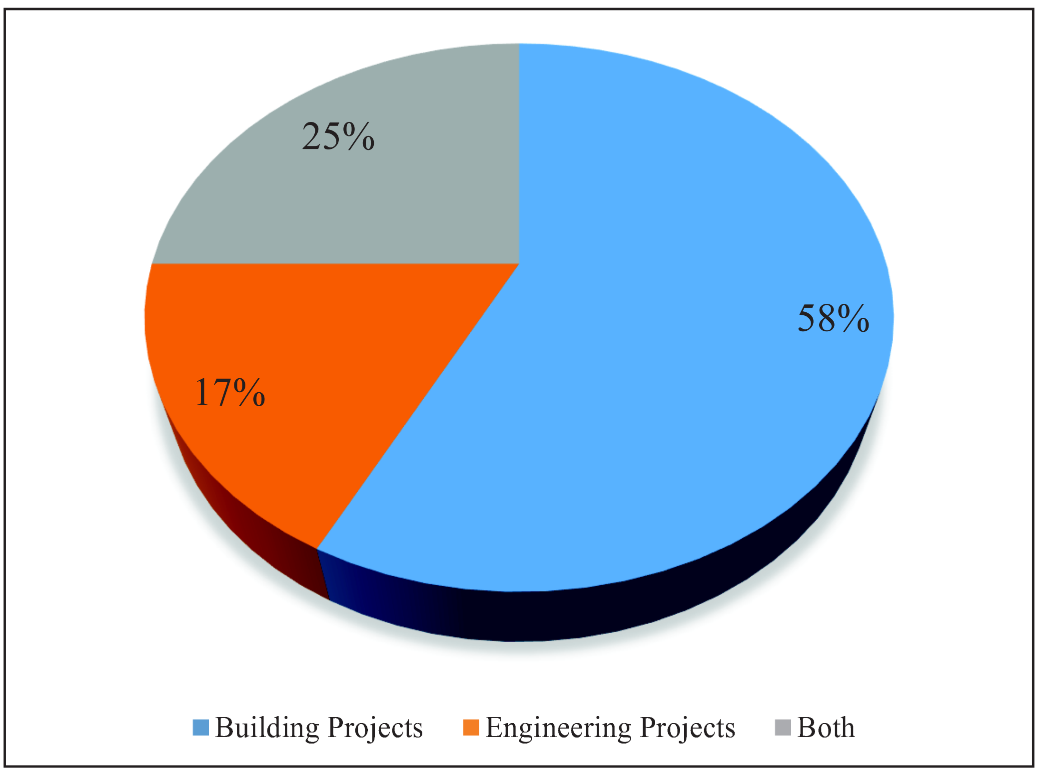


Figure 4.7: Common Type of Project

4.4 General Knowledge of New Concrete Material

4.4.1 Recommendation of New Concretes

Based on Figure 4.8, 100 % of respondents are well-aware of all stated new concretes in questionnaire as they are able to recognize all the new concretes

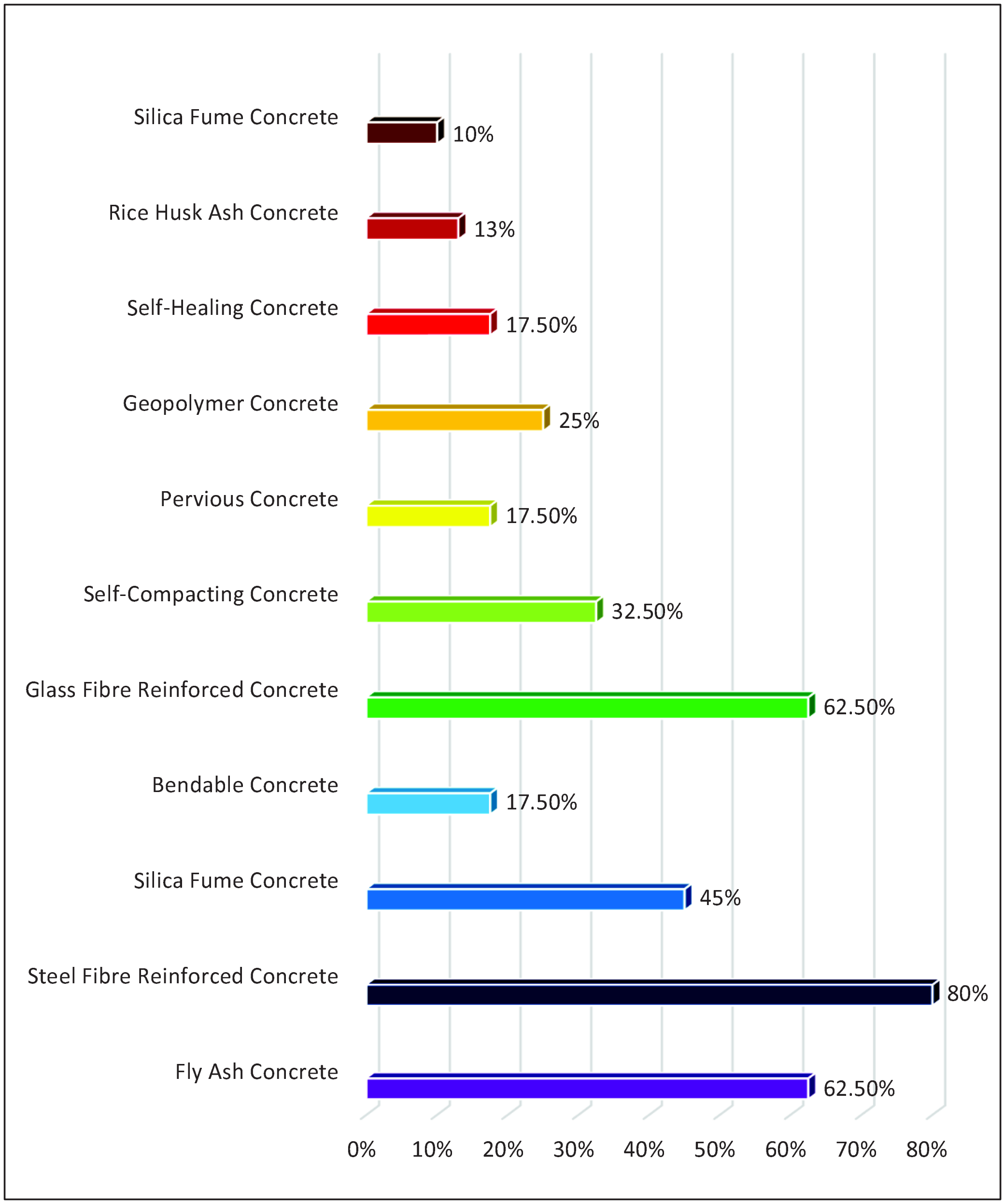


Figure 4.8: Types of New Concrete Material that Potentially Used in Construction Industry

The most popular new concrete that most respondents recognized is Steel Fibre Reinforced Concrete, which consist of 80 % of respondent. This may due to the aforementioned standards cover a new range of applications, for example foundation slabs of multi-storey buildings, clad rack buildings, structural floors, fluid tight floors and many more slab types subject to high structural and serviceability requirements. Based on the study, there are 58 % of respondent involved in engineering projects in which steel-fibre reinforced concrete is commonly used for the structural elements of the buildings.

Whereas Silica Fume Concrete had the least percentage, which consists only 10 % as most of the respondents did not familiar with the function and benefits of this new concrete. There are total of 3 types of new concrete that shared the percentage of 17.5 %, which include Self-healing Concrete, Pervious Concrete and Bendable Concrete. Both Glass Fibre Reinforced Concrete and Fly Ash Concrete occupied 62.5 % which ranked as the second popular new concrete. Followed by Silica Fume Concrete, Self-Compacting Concrete, Geopolymer Concrete and Rice Husk Ash Concrete which consists of 45 %, 32.5 % 25% and 13 % respectively.

4.4.2 Motivation of Using New Concrete Material

Figure 4.9 below shows the motivation of using new concrete technologies. Based on the combinations of multiple charts, majority of respondents are still motivated in new concrete technology adoption. Although not many respondents were “strongly agree”, the charts still show a positive trend whereby respondents were “agree” to the 8 items listed in the questionnaire.

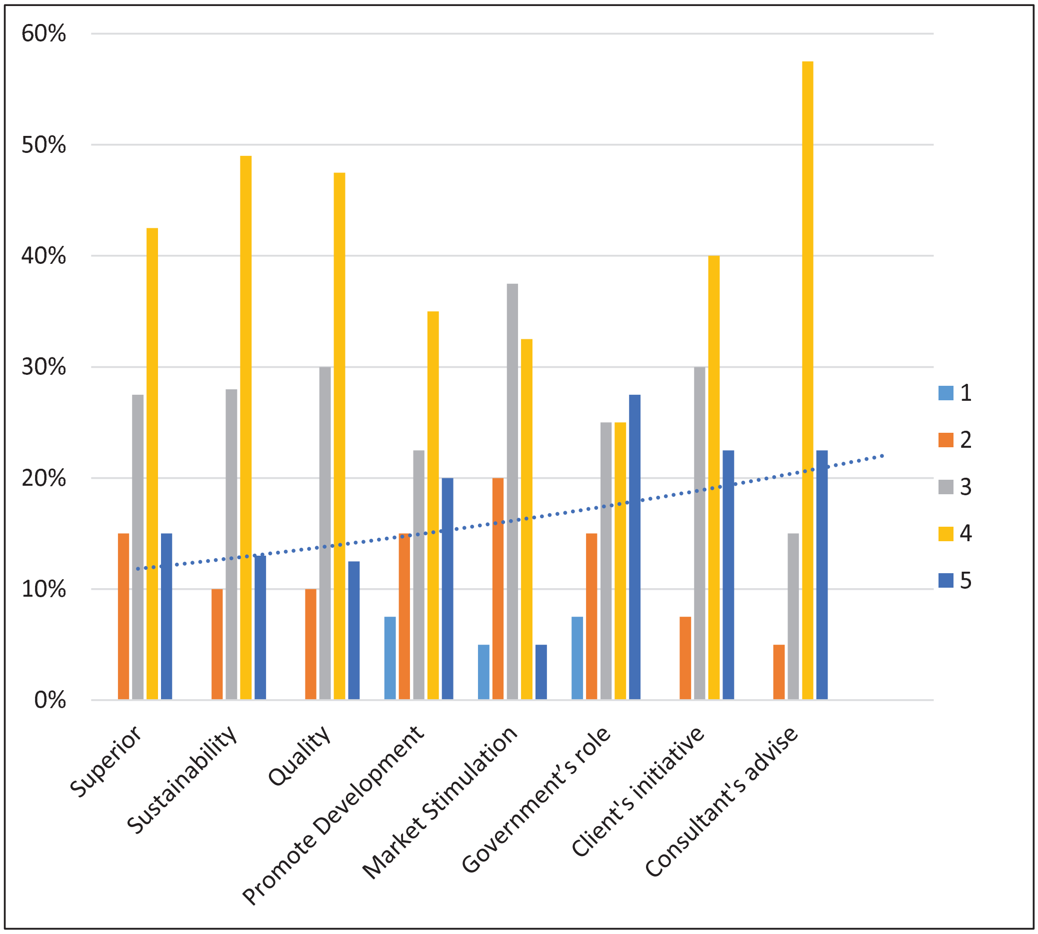


Figure 4.9 Motivations of Using New Concrete Material

Table 4.9 shows the Likert scale indicator, in which '1' represents strongly disagree, '2' refers as disagree, '3', '4' and '5' indicate slightly agree, agree and strongly agree respectively.

Table 4.9 Likert Scale Indicators

1		strongly disagree
2		disagree
3		slightly agree
4		agree
5		strongly agree

Table 4.10 below indicates the items that represents each element in motivations of respondents in adopting new concrete materials. Most of the respondents were agree that 'new concrete material is better than conventional concrete technology', 'new concrete material can maintain the sustainability of environment', 'new concrete material can enhance the quality of construction works' and 'new concrete material can promote the development of construction industry in Malaysia' whereas respondents only slightly agree that 'new concrete material can stimulate the construction market in Malaysia'.

Into the bargain, majority of the respondents agree that 'government, client as well as consultant should play their respective roles in increasing and promoting the implementation of new concrete materials'.

Table 4.10 Items Indicators

Superior	New concrete material is better than conventional concrete technology.
Sustainability	New concrete material can maintain the sustainability of environment.
Quality	New concrete material can enhance the quality of construction works.
Promote Development	New concrete material can promote the development of construction industry in Malaysia.
Market Stimulation	New concrete material can stimulate the construction market in Malaysia.
Government's role	New concrete material should be promoted or mandated by Malaysian government in the industry.
Client's initiative	Clients should consider the implementation of new concrete material in the project development.
Consultant's advise	Consultants should play their professional roles to advise clients about the implementation of new concrete material.

4.5 Validity and Reliability Test of Barrier

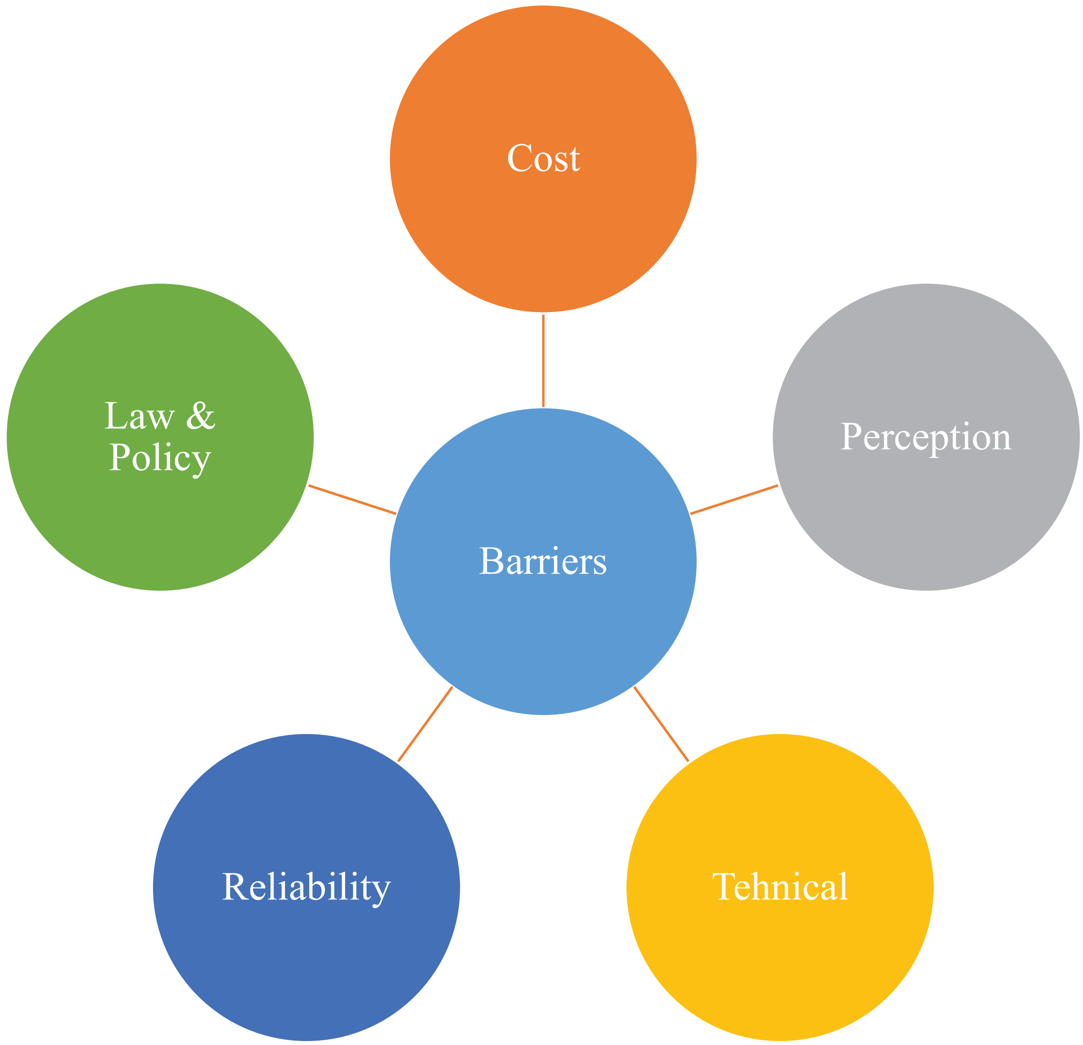


Figure 4.10: Barriers of New Concrete Technology Adoption

The reliability and validity tests are conducted for each barriers and only the sub-factors passed with the two tests will be considered for the computation of average composite score of the barriers' factor. The findings just then considered as reliable and valid for ranking objective of this study.

4.5.1 Reliability Test Result

According to Table 4.11, all of the barrier factors passed with threshold value of 0.6. The section 1 and 3 passed with 'acceptable' level, whereby the section 2, 4 and 5 passed with 'good' internal consistency. Policy & Law Barriers has the highest Cronbach Alpha value which up to 0.848. Followed by Reliability Barriers, Perception Barriers, Cost Barriers and Technical Barriers which values are 0.733, 0.705, 0.644 and 0.605 respectively.

There is no analysis of "Cronbach's Alpha if Item Deleted" is necessarily as all the value of Cronbach alpha were exceed 0.6.

Table 4.11 Analysis of Reliability Test Result for Barriers Factors

No	Barriers Factor	Cronbach Alpha	Internal Consistency	Number of Items
1	Cost	0.644	Acceptable	5
2	Perception	0.705	Good	5
3	Technical	0.605	Acceptable	4
4	Reliability	0.733	Good	4
5	Policy and Law	0.848	Good	3

4.5.2 KMO Test Result

For the validity analysis, the cut-off value for communalities is 0.5 and principal component loading is 0.6. According to Table 4.12, all items passed the threshold value. The item deletion of each section will be elaborated in detail.

Table 4.12 Analysis of Kaiser-Meyer-Olkin Measure of Sampling Adequacy and Bartlett's Test of Sphericity

	Stress Factors	KMO	Bartlett's Test of Sphericity		
			Approx. Chi-Square	Sig.	df
1	Cost	.638	26.189	.003	10
2	Perception	.678	52.482	.000	10
3	Technical	.674	20.151	.003	6
4	Reliability	.709	36.854	.000	6
5	Policy and Law	.730	48.273	.000	3

Table 4.13 below indicates the communalities and principal component loading of the 21 items under the 5 major barriers in new concrete adoption.

Table 4.13 Communalities and Principal Component Loading

	Items	Description	Communalities	Component Matrix
1	Cost Barrier 1	High material acquisition cost	.630	.777
	Cost Barrier 2	High execution cost for the new concrete materials	.159	.396
	Cost Barrier 3	High capital cost to facilitate the new concrete materials	.868	.792
	Cost Barrier 4	High transportation cost due to lack of suppliers	.357	.571
	Cost Barrier 5	Unpredictable cost for a project if adopted new materials	.925	.579

2	Perception Barrier 1	Afraid to change	.733	.846
	Perception Barrier 2	Lack of neutral perception towards something new	.590	.659
	Perception Barrier 3	Insufficient knowledge on the current best practice of concrete materials	.828	.891
	Perception Barrier 4	Negative mindset on the researchers' data as they may bias	.654	.805
	Perception Barrier 5	Majority of end users' perception on new concrete materials are hazardous	.824	.838

3	Technical Barrier 1	Lack of plants, machineries or any facilities required	.737	.786
	Technical Barrier 2	Special skill or professional knowledge are required to manufacture or handle new concrete materials	.464	.653
	Technical Barrier 3	Limited knowledge and information in adopting new concrete materials.	.636	.784
	Technical Barrier 4	Education of new concrete materials is not provided	.991	.872

4	Reliability Barrier 1	Uncertainty in the performance of new concrete materials.	.741	.861
	Reliability Barrier 2	Lack of product verification by the supplier	.482	.694
	Reliability Barrier 3	Unpredictable risk in adopting new concrete materials	.758	.871
	Reliability Barrier 4	New concrete materials lack of certification by the industry's organization or government bodies	.255	.505

5	Policy and Law Barrier 1	Lack of codes and standards on the new concrete materials	.774	.880
	Policy and Law Barrier 2	Weak enforcement of law on maintaining sustainability of environment	.743	.862
	Policy and Law Barrier 3	Limited encouragement by government and incentives are not provided for construction projects that adopting new concrete technologies	.787	.887

In validity test, all 5 barriers factor were examined. Under cost barrier factor, there are 2 items in which the communalities and component matrix did not pass threshold value of 0.6. "High Execution Cost" has communalities and component matrix of 0.159 and 0.396 respectively. This is maybe due to the ambiguous definition of the 'execution'. Different individual interpret differently the word 'execution'. Execution might refer as methods of adopting the new concrete in the construction projects or this term might also means methods of manufacturing the new concrete in order to utilize the new concretes. Translation ambiguity occurs when a word in one language can be translated in more than one way into another language. This cross-language phenomenon comes from several sources of within-language ambiguity including lexical ambiguity, polysemy, and near-synonymy. The lexical ambiguity of a word or phrase pertains to its having more than one meaning in the language to which the word belongs while polysemy refers to the coexistence of many possible meanings for a word or phrase. These ambiguities will eventually affect the decision making of developer or client in adopting the new concrete technology.

"High Transportation Cost" has communalities of 0.357 and component matrix of 0.571. Both elements did not pass the minimum value of 0.6. This could be estimated that the respondents misunderstood that the transportation cost of the new concrete material is included in the total project cost. In their wrongly perspective, the incurred transportation cost of the new concrete material will be insignificant, since only overall construction project cost is concerned.

Meanwhile, under Policy and Law Barrier, "Lack of certification by the industry's organization or government bodies" factor consists of communalities and component matrix value with 0.255 and 0.505 respectively. This can be due to the common perception of respondents that lack of certification by authorities. In their opinions, this phenomenon becomes a norm or already 'commonly accepted' by respondents. Those respondents did not consider that 'Lack of certification' is a factor that prohibiting the adoption of new concrete technology in Malaysia.

On the contrary, three items which have the highest communalities value are "Education of new concrete materials is not provided" under technical barrier, "Unpredictable cost for a project if adopted new materials" and "High capital cost to facilitate the new concrete materials" under cost barrier with communalities of 0.991, 0.925 and 0.868 respectively. Under technical barrier, "Education of new concrete materials is not provided" contains the highest communalities value, which means most of the respondents agreed that they are not exposed to the details or information of any new concrete technology. Functions, benefits and basic knowledge of new concretes technology were not explained to the respondents, not to mention that the approaches and methods to manufacture or handle the new concrete technology. No matter how good is the new concrete is, it still cease to exist if the education of new concrete technology does not provided to the users.

Next, "Unpredictable cost for a project if adopted new materials" under cost barrier has high communalities value as well, which up to 0.925. In other words, it is the nature of individual as a human to hold themselves in front of risks and uncertainties. People tend to stay in comfort zone and remain status quo especially in construction industry. A normal project in construction industry cost at least hundred thousand and above, not to speak of high-rise building or heavy infrastructure projects. In addition, the adoption rate of new concrete technology in Malaysia still very low which means there is no records or success example of projects which utilized new concrete technology for respondents to refer to, results in refusal of respondents to adopt new concrete in their construction projects.

Last but not least, under same cost barrier, "High capital cost to facilitate the new concrete materials" occupies a considerable high communalities value of 0.868. Cost is always an important consideration that every client concerns. To switch from conventional concrete to new concrete, high capital cost is required to facilitate the new concrete materials. Different system is demanded to integrate new concrete materials with original existing current system together. In this contest, the small and medium construction companies will not be able to afford due to the additional cost incurred, where only the large construction companies have the expenditure for these efforts.

4.6 Ranking of Barriers Factor in New Concrete Adoption

Figure 4.11 indicates the ranking sequence of each items under the 5 major barriers, which include cost barriers, technical barriers, reliability barriers, perception barriers as well as policy and law barriers.

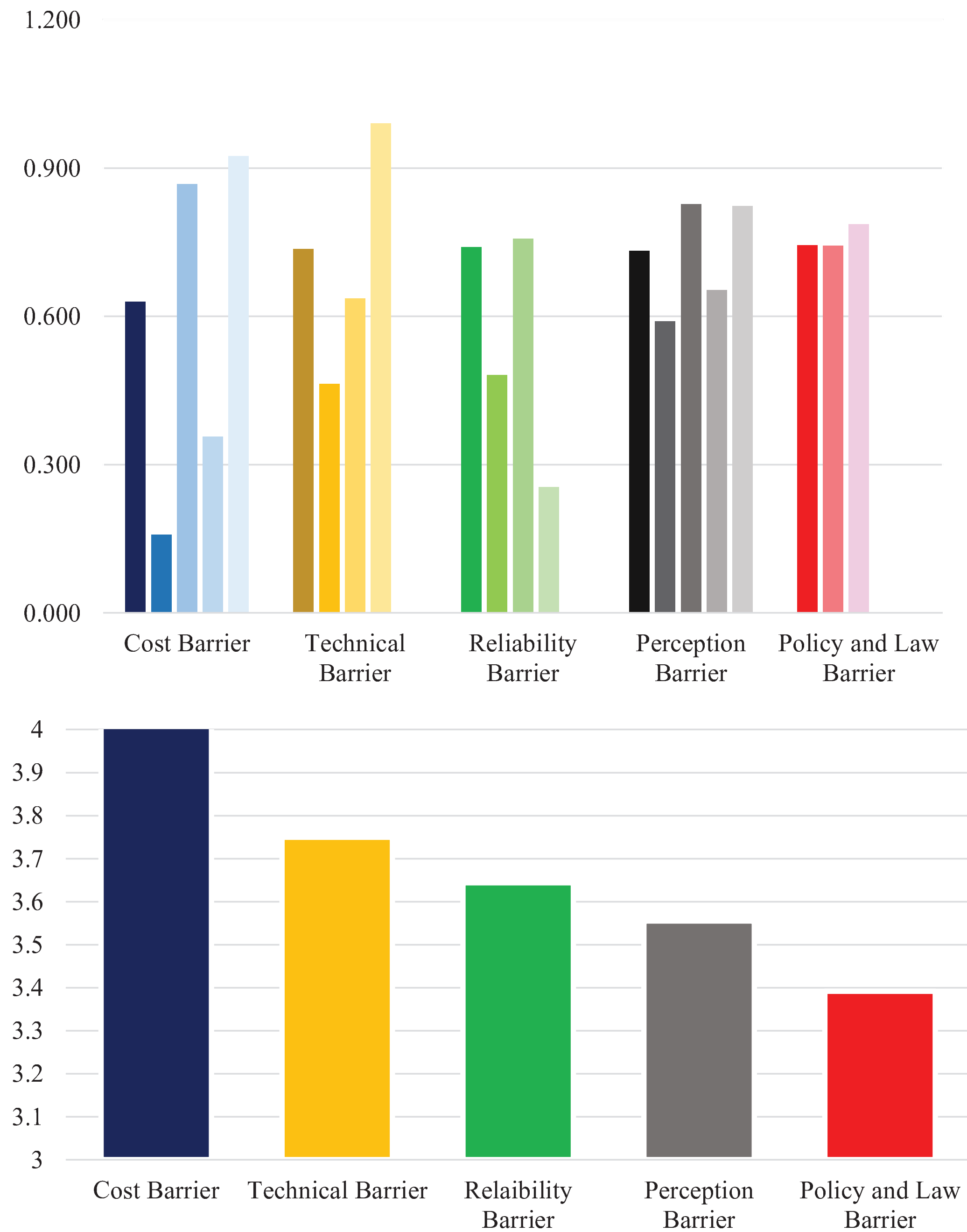


Figure 4.11: Ranking Sequence of Barrier Factors

Table 4.14 below shows the colour indicators of the 21 sub-factors under the 5 major barriers.

Table 4.14: Indicators of Barriers

	High material acquisition cost
	High execution cost for the new concrete materials
	High capital cost (supporting) to facilitate the new concrete materials
	High transportation cost due to lack of suppliers
	Unpredictable cost for a project if adopted new concrete materials
	Lack of plants, machineries or any facilities required
	Special skill or professional knowledge are required to manufacture or handle new concrete materials
	Limited knowledge and information in adopting new concrete materials
	Education of new concrete materials adoption is not provided
	Uncertainty in the performance of new concrete materials
	Lack of product verification by the supplier
	Unpredictable risk in adopting new concrete materials
	New concrete materials lack of certification by the industry's organization or government bodies
	Afraid to change
	Lack of neutral perception towards something new
	Insufficient knowledge on the current best practice of concrete materials
	Negative mind-set on the researchers' data as they may bias
	Majority of end user's perception on new concrete materials are hazardous
	Lack of codes or standards on the new concrete materials
	Weak enforcement of law on maintaining sustainability of environment
	Limited encouragement by government and incentives are not provided for construction projects that adopting new concrete technologies

The barrier that ranked as the first significant by the respondents is cost barrier. Among the 5 items under cost barrier, '**capital cost'** factor contributed the most value within the category. For an investment to be worthwhile, the expected return on capital must be greater than the capital cost. Respondents are concerned about the return of adopting new concrete material. Although new concretes are sustainable and environmental-friendly, the price and the cost is and always the priority of respondents. The conventional concrete is comparatively cheaper than the new concrete in which respondents more prefer to be used in their construction projects.

Barrier that allocated as second place is technical barrier. Within the 4 items of technical barrier, '**special skill or professional knowledge are required to manufacture or handle new concrete materials'** factor has the highest mean up to 4.2, which makes technical barrier allocate as second ranking. Unlike traditional concrete, new concrete materials require extraordinary set of protocols in order to be produced. Extra professions and machineries are needed to be introduced in to ensure the quality and functions of new concrete technology.

Next, the third barrier that has third ranking is reliability barrier. '**Unpredictable risk in adopting new concrete materials'** factor occupied the most mean value. It is a normal phenomenon whereby respondents are not willing to take any risk regarding new concrete technology. As there are many risks and uncertainties, many respondents prefer staying in the comfort zone, satisfying their own desires, rather than taking any risk that concerns about the consequences. Majority of the respondents prefer collecting and gathering all data and information before making a decision, rather than trust own instinct and take a leap of faith, despite the uncertainty.

Perception barrier ranked as the fourth place among the 5 barriers. Under perception barrier, **'afraid to change'** contributed the most to the average mean value. Respondents tend to have negative perception towards new technologies, including new concrete technology. In most situation, technical change is not neutral which means new concrete technology might benefits some factors of construction, while directly or indirectly reducing the compensation of other elements. This fear inevitably prohibits the adoption of new concrete technology.

Lastly, the least significant barrier that rank as fifth position is policy and law barrier. Among the three items under policy and law barrier, **'Limited encouragement by government and incentives are not provided for construction projects that adopting new concrete technologies'** factor contains the highest mean value. If government itself does not encourage the adoption of new concrete materials or creating awareness in environment sustainability, developers are then more difficult to be motivated in this case. For those construction projects that utilized any type of new concrete materials, incentives should be rewarded or subsidise the particular construction projects.

4.7 Concluding Remark

This chapter presents the data analysis. 40 sets of valid questionnaire survey are collected, with developers, contractors and consultants as respondents. All the factor barriers are going through the reliability and validity analysis, included Cronbach Alpha, KMO and Bartlett's Test of Sphericity, Communalities and Component Matrix Analysis. For the reliability test, it used to measure the internal consistency of each sub-factors to ensure each of them are interrelated. After go through the reliability, each factor value must be 0.6 or above to justify the consistency of each items. Cronbach alpha value less than 0.6 should be omitted in this study. KMO and Bartlett's Test of Sphericity are a pre-analysed procedure where the KMO value must be more than 0.5. All the sub-factors have passed the KMO and Bartlett's Test of Sphericity. Besides, the cut-off value for communalities is 0.5 and principal component loading is 0.6. There are total 3 sub-factors were omitted due to failing to exceed the threshold of the cut-off value

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 General Introduction

This chapter shows the recommendations and make conclusion based on discussion through the data analysis. Recommendations will be proposed under this study aimed to resolve the critical barriers of new concrete adoption. Recommendation will be released or resolve of factor barriers for future study. In the conclusion, there will be summarized findings under this study to determine the objective outline had been established.

5.2 Conclusion

A research on the barriers of new concrete technology adoption was conducted to study the critical barrier of adopting new concrete technology in Malaysian construction industry. The results getting from this study were analysed and several conclusions can be make:

1. A total of 11 new concrete technologies were studied which are commonly utilized in construction project. They are steel-fibre reinforced concrete, glass-fibre reinforced concrete, fly ash concrete, pervious concrete, geopolymer concrete, self-healing concrete, self-compacting concrete, bendable concrete, lightweight concrete, rice husk ash concrete and silica fume concrete.

2. 100 % of respondents were well-aware about all the new concrete technologies that stated in the questionnaire. Among the 11 new concrete technologies, Steel fibre reinforced concrete occupied the most percentage which up to 80 % in which respondents recognized and utilized.

3. The barriers were grouped and categorized into 5 main items, which are cost barriers, perception barriers, reliability barriers, technical barriers and last but not least, policy and law barriers. Based on the result and analysis, the most critical factor barrier is cost barrier, followed by technical barriers, reliability barriers, perception barriers and policy & law barriers.

5.3 Limitation of Study

In this study, though there is much remains to be done, this paper generates important findings in the field of adoption rate of new concrete technologies in Malaysian construction industry. In other words, having acknowledged the limitations of data processing and analysing, there are some limitation of this study. Although the present study has yielded some preliminary findings, the design is not without flaws. Several caveats need to be noted regarding this study.

The main limitation of this study concerns the barriers of new concrete technology adoption. To put it in another way, there might be some relevant factors, which significantly influence on the adoption rate of new concrete technologies. Nevertheless, the discussion of other relevant factors or barriers is beyond the scope of this paper. Barriers of adopting new concrete technologies in Malaysian construction industry are still tentative, subject to confirmation and modification through further investigation and examination.

Besides that, due to the time constraint, only certain amount of respondents' feedback were obtained. Out of the 199 sets of questionnaires distributed, there were only 21.60 % (40 sets) of questionnaires returned. In addition, there is also access limitations. The target respondents of this study are selected in Penang, Kuala Lumpur and Johor only because these 3 big cities experienced vast development and majority of REHDA registered developers established their company as well as their projects in these 3 cities of Malaysia. Thus, the data collected from this study cannot represent whole Malaysia.

This study emphasized on barriers which affecting developers, main contractors and consultants in adopting new concrete technologies as these three stakeholders are often the decision maker in a construction projects. Therefore, this study is not suitable for other stakeholders in construction industry.

5.4 Recommendation for Future Study

New concretes are being ignored and left in the cold due to the low adoption rate. There are a lot of scope in barrier factors and the mitigation steps which can be conducted. Thus, the future recommendation in this study can be undertaken as below:

- To evaluate critical success factors of adopting new concrete technologies

  Various approaches in promoting the utilization of new concrete technology have been introduced. To successfully adopting new concrete technology in Malaysian construction industry, critical success factors that can motivate and stimulate the adoption of new concrete technology need to be discovered.

- To study barriers of new concrete of other stakeholders like suppliers, sub-contractors, etc

  We purchase raw materials, fabricated and other components and energy supplies from a variety of suppliers. Key materials include stainless steel, organic chemicals, fuel, and plastic components. The availability and prices of raw materials and energy supplies are subject to volatility and are influenced by worldwide economic conditions, speculative action, world supply and demand balances, inventory levels, availability of substitute materials, currency exchange rates, anticipated or perceived shortages, and other factors.

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APPENDICES

A Study of New Concrete Material in Malaysian Construction Industry

All information to be given will remain confidential and use for study purpose only.

Company Name

Your answer

Company Address:

Your answer

Gender of Respondent:

- ○ Male
- ○ Female

Age of Respondent:

- ○ 21 - 30 years old
- ○ 31 - 40 years old
- ○ 41 - 50 years old
- ○ 50 years old and above

Years of Working Experience:

- Less than or equal to 5 years
- 6 - 15 years
- 16 - 25 years
- More than 25 years

Degree of Qualification:

- Technical Certificate
- Diploma
- Degree
- Master above
- Other:

Profession in Construction Industry:

- Client/ Client's representative
- Contractor
- Engineering Consultant

Service Sector:

- More in Public Sector
- More in Private Sector
- Equal in Both Sectors

Common Type of Project:

- More in Building Projects
- More in Engineering Projects
- Equal in Both Types

Section B: General Knowledge of New Concrete Material

Which of the following new concrete materials are potentially used in Malaysian construction industry?

- [ ] Fly Ash Concrete
- [ ] Steel Fibre Reinforced Concrete
- [ ] Silica Fume Concrete
- [ ] Bendable Concrete
- [ ] Glass Fibre Reinforced Concrete
- [ ] Self-Compacting Concrete
- [ ] Pervious Concrete
- [ ] Geopolymer Concrete
- [ ] Self-Healing Concrete
- [ ] Other: ____________

Motivation of Using New Concrete Material

Please rank the level of agreement for statements below:
Strongly disagree = 1 , Disagree = 2 , Less agree = 3 , Agree = 4 , Strongly agree = 5

New concrete material is better than conventional concrete technology.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

New concrete material can maintain the sustainability of environment.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

New concrete material can enhance the quality of construction works.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

New concrete material can promote the development of construction industry in Malaysia.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

New concrete material can stimulate the construction market in Malaysia.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

New concrete material should be promoted or mandated by Malaysian government in the industry.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Clients should consider the implementation of new concrete material in the project development.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Consultants should play their professional roles to advise clients about the implementation of new concrete material.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Section C: Barrier Factors of Implementing New Concrete Material

Please rank the level of agreement for statements below:
Strongly disagree = 1 , Disagree = 2 , Less agree = 3 , Agree = 4 , Strongly agree = 5

Cost Barrier Factor

High material acquisition cost.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

High execution cost for the new concrete materials.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

High capital cost (supporting) to facilitate the new concrete materials

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

High transportation cost due to lack of suppliers.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Unpredictable cost for a project if adopted new concrete materials.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Perception Barrier Factor

Afraid to change.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Lack of neutral perception towards something new.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Insufficient knowledge on the current best practice of concrete materials.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Negative mindset on the researchers' data as they may bias.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Majority of end user's perception on new concrete materials are hazardous.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Technical Barrier Factor

Lack of plants, machineries or any facilities required.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Special skill or professional knowledge are required to manufacture or handle new concrete materials.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Limited knowledge and information in adopting new concrete materials.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Education of new concrete materials adoption is not provided.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Reliability Barrier Factor

Uncertainty in the performance of new concrete materials.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Lack of product verification by the supplier.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Unpredictable risk in adopting new concrete materials.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

New concrete materials lack of certification by the industry's organization or government bodies.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Policy and Law Barrier Factor

Lack of codes or standards on the new concrete materials.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Weak enforcement of law on maintaining sustainability of environment.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Limited encouragement by government and incentives are not provided for construction projects that adopting new concrete technologies.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Concrete Timeline