Flinders University

Adelaide Australia

College of Science and Engineering

Analysis of Alkali Silicon Reaction using Recycled Aggregate Concrete (RCA)

June 2020

Student: Yash Patel

Academic Supervisor: Dr. Aliakbar Gholampour

Topic: ENGR9700 – Master Thesis Research Report

A Master Thesis submitted to the College of Science and Engineering in partialfulfilment of the requirements for the degree of Master of Engineering (Civil) (Master’s) at Flinders University

DECLARATION OF AUTHOESHIP

I certify that this work does not incorporate, without acknowledgement, any material previously submitted for a master in any University; and that to the best of my knowledge, does not contain any material previously published or written by another person except where due reference is made in the text.

yash **8/11/2021**

Yash Patel **Date**

ABSTRACT

Ordinary concrete is very popular construction material all around the world but Failure of concrete structures cause deaths and create hazardous environmental conditions if the composition or the engineering design has not been made accordingly. The one issue that the following thesis is going to explore is the ASR reactive chemistry and the development strength of waste material based concrete structures. Concretestructures fail due to excessive deformation, chemical and hazardous gelling effects and materials reaction that is, the deformation is more than the tolerance level of the structure. The causes for failures are rarely external but mostly occur due to internal causes. One of the major causes that are being discussed here is the Alkali-Silica Reaction (ASR). It is a reaction that enables the silica crystals to form and grow into a binding structure. The crystals grow through the pores of the concrete and filters thus creating a strong interlocked structure that can support multiple floors or heavy vehicles and etcetera. The ASR can also harm the structures if not controlled well.

Over crystallization process leads to forcing the concrete structures from the inside and overcoming their compressive loading to create cracks in the lateral direction. The colliding expansive and compressive forces lead to structures getting brittle and ultimately crumbling under load. The aim of the research is supposed to be controlled by controlling the ASR and the number of other building materials used. Reducing the alkalinity can cause crystallization to slow down. The finding ASR effects on concrete waster material is challenging in this study because applied manual chemical reaction on concrete by short time. The use of Natural Aggregates or gravel with a concrete mix can strengthen the building. The higher used of waste concrete material is creating environmental improvement through sustainability and effects fewer chemical reactions. The department zero waste south Australia promote to use this material and help the atmosphere and development of concrete strength.

The performing study has been conducted to use of Recycled Aggregate Concrete (RAC) with Natural Aggregates (NA) or gravel. The various types of construction waste materials used in this study as a replacement with ordinary concrete materials such as glass sand, glass powder, fly ash, GGBS, recycled coarse aggregates. Also used the combination of different percentage of new and old materials for finding the development of strength of concrete element. The RAC is much cheaper and practically free to get if properly collected. NA are another kind of aggregate that can be mixed with the RAC or independently used to build structures. The operational and loading conditions are an important pointto consider before the use of the RAC and is an engineering problem. The research helps to get the knowledge regarding every concrete element closely with tests of particle size distribution, specific gravity classification and surface saturated dry tests of each material. The

following thesis performing tests 5 mixes of different compositions to test and analyses how ASR on RCA performs with respect to othermaterial compositions. Moreover, the thesis not only ponders over the composition but also takes into consideration the strength of concrete by used of destructive concrete tests and find the capability of waste material-based concrete.

The research aims to investigate the mechanical performance of waste material-based concrete under the threat of ASR effect, and the performance is dividing in 7 days and 28 days of manual ASR applied reaction. Throughout this research project a total of 130 liters of concrete was made, but some of failed at the initial stage, middle or hardening stage and lots of concrete cylinders used for a testing purpose. This study includes different chemical preparation methodologies and techniques such as HCL and hydro pallets formation according to Australian standards to applied ASR reaction in some period. In general, the performance of the waste material concrete mixes was equal or better than traditional natural concrete on some parameters. The GGBS (ground glass furnace slag) were also found the high compressive strength and water absorption. Furthermore, the waste glass materials that is typically unmatched at many stages of testing of ASR concrete. The primary advantages of concrete where natural materials are substituted with the waste concrete material after the ASR effects are the sustainable.

ACKNOWLEDGEMENTS

I would like to formally acknowledge my academic supervisor, Dr. Aliakbar Gholampour, for his unwavering support and invaluable guidance throughout each component of this research project. Likewise, I am grateful for the supervision and expertise of Mr. Westley Penney in assisting with the development and execution of the experimental program for this thesis. I would also like to thank Petrik and CSE store department from Bedford Park campus for supplying the HCL and Sodium pallets and related chemicals for research, as well as their enthusiastic support and assistance with organizing of site visits. Finally, I am so grateful to my family and friends for their support and understanding throughout the course of this year.

TABLE OF CONTENT

LIST OF FIGURES

List of Tables

1. INTRODUCTION

1.1 Research background

Alkali/Alkaline Silica Reaction (ASR) is a detrimental reaction that happens among the cementitious materials from the reaction of the interaction between the high silicate element with some recycled materials. It generates high alkalinity within the pore solution of the used materials. ASR is responsible for directly affecting the environment and its natural resources. The current research has been developed from the concerning situation in Australia with the increasing ASR. The current research aims to identify the ASR reaction after using different waste materials so that it will be helpful in the construction of residential, commercial, and industrial concrete structures. Figure. 1 provides brief and precise examples of 7- and 28-days ASR affective concrete columns. In the following image, there is a left-hand side image given the seven-day thermostatically hitting ASR effects columns with minor ASR damage, but on the other side provides the 28days full ASR white damaged column samples by mentioned treatment.

Figure 1. ASR Affected concrete column

The Alkali-Silica Reaction is a concerning factor within the construction industry because the aggregate cement contains the reactive silica element. The material form within the aggregate cement is that the silica will react to the alkaline hydroxide within the concrete (PCA, 2 019). The reaction between silica and alkaline hydroxide inside the concrete generates a gel element, which is responsible for absorbing water from the surrounding. The gel is a chemically reactive element generated by the reaction between the natural concrete materials combination. As a result, it provides excessive pressureto the concrete structure in facing significant damages, such as cracking. Most of the time it occursin the areas with constant contact with moisture like waterline pipes, pavements, bridge columns over a river, etcetera (PCA, 2019).

ASR occurs between unstable, reactive silica constituents that exist in some aggregates and the hydroxyl ions (OH-) and alkali ions (Na+, K+) present in the interstitial binder solution. Hydroxyl ions initially attack the silanol group (Si–OH) releasing water and attracting the alkali cations in the middle. The siloxane group (Si–O–Si) is then attacked, in a second stage, by hydroxyl ions, fragmenting the bonds of the group and replacing them with silicates. Solution silicates reacts with calcium to form calcium and aluminum silicate hydrates (C–S–H and C-A-S-H) and ASR gel.

ASR has become one of the main concerns of concrete-based construction industries. Despite mentioning an extensive range of prevention methods, moreover, there is still no preventive measure that canreduce the expensive consequences. Thorough a study on the ASR in the current recycled aggregateconcrete has defined that the conditions are dependable on the - 1) exposure condition of the concrete structure, 2) age of the exposed structure, and 3) heterogeneity source that is influencing the reaction (Barreto Santos *et al.*, 2020).

The further-mentioned figure (Figure 2) has provided the real-time expansion of the Alkaline reaction with the existing moisture in turning the recycled concrete decreased over time. It has been observed that the usage of different types of waste material in the concrete manufacturing processhas become common for reducing the significant impact of climate change and achieving sustainability in the construction industry (Revilla-Cuesta *et al.*, 2020). However, the usability of recycled aggregate concrete is dependable on the durability of the used waste materials. Therefore, it has the portability in enhancing or reducing the ASR. As it is shown in the provided graph (Figure 2) how the expansion of the Alkali reaction is reacting on the different states of recycled aggregate concrete (RAC).

Image removed due to copyright restriction.

Figure 2. ASR-Expansion concrete graph (Revilla-Cuesta 2020)

The integration of ASR in using RAC within modern construction projects requires more in-depth research. It includes both discussions on the existing secondary data and conducting primary laboratory research to practically assess the element. ASR has become a global concern, especially for the regions situated at high humidity and temperature. However, ASR also is a slow process that develops over time under the influence of changing environment and durability of the concrete structure (Alnaggar*et al.*, 2017). The implementation of RAC from the easily available wattage materials can easily influence the poor performance of the concrete after the ASR. It includes swelling, expanding, and cracking on the concrete structure. It is important to analyze the durabilityof the used waste materials to determine the timeline of the ASR.

Figure 2 above shows the cumulative expansion percentage in two decimal values of different types of concrete elements such as NAC, RCA at 2 months and RCA at full and half expansion for different period. The highest expansion identified at month of 48 in RCA based concrete element with 0.24 real time ASR growing. On the other hand, NCA has been affected by only 0.10 real time expansion after 48 hrs.

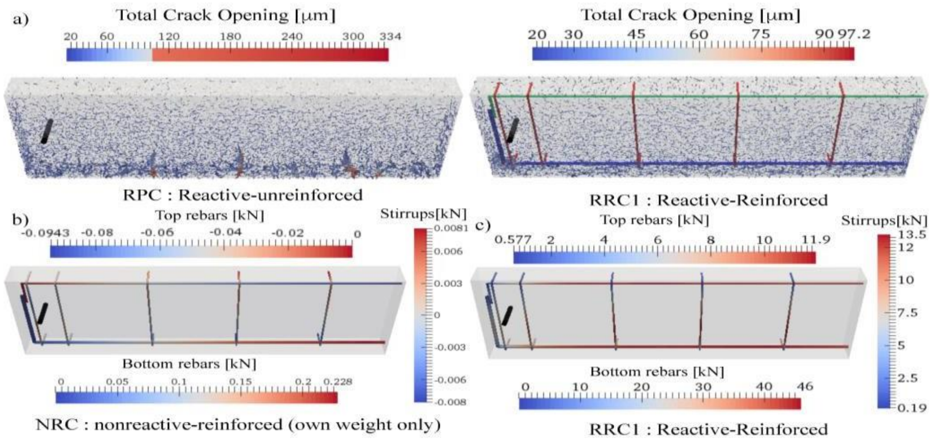


Figure 3. Simulated Crack Pattern within the Reactive Unreinforced Concrete and Reactive Reinforced

The above-mentioned figure (Figure 3) has provided a visual understanding on the crack suppression on both Reactive Unreinforced Concrete (RPC) and Reactive Reinforced Concrete (RRC1). Additionally, it showcased the impact of the beam weight and internal forces with and without ASR, shrinkage, and creep effects. Therefore, it indicates that the effect of deteriorating phenomena and ageing of the concrete structure is responsible for determining the severity of ASR. The current research paper is working on understanding the improving methods on the worst cases of ASR in reducing the annual cost and existing problems at the concrete construction.

Concrete structures around the world are experiencing ASR expansion alongside the compressive strength and transferring the strength to the unstressed directions (Gautam*et al.*, 2017). The multiaxial stress within the concrete structure most of the time faces inadequate understanding which influences the ASR expansion. The complicated ASR effect is a combination of several common factors, such as humidity, alkaline element, temperature, type of waste element within the RAC, and building stress rate (Gautam*et al.*, 2017). Therefore, the expansion of ASR requires maintaining a uniaxial compressive strength that would reduce the compressive strength impacting on the unstressed directions.

1.2 Problem statement

The impact of Alkali-Silica Reaction (ASR) on the usage of Recycled Aggregate Concrete (RAC) has become a major problem within the construction industry for reducing the structural strength associated with associated cracks and stress. The problem is with the element used in the RAC and their durability for backing up the concrete structure for a longer time. The impact of ASR is a serious threat to the construction industry with an increased amount of annual cost and lack of knowledgeon the usage value of RAC.

Continuous ASR reactive problems in natural and waste material based concrete structure are challenged to solve and develop the strength for worldwide concrete industries. The main problem of this research study is applied manual ASR effects in sort time with different chemicals combinations and their availabilities.

ASR effect is very long and periodic process in concrete elements, and that is a multiple-stage and sequential reaction, that will very hand to identifies in this study with different binder materials and aggregate reaction capacity. Some materials take long time to affected by manual method. There are number of problems faced during the generation and implementation of chemical application for short ASR effects such as heating, storage, and equipment availabilities.

1.3 AIM & objective

The current research paper aims to identify different RCA materials from available resources at the South Australian Concrete construction, then observe the alkaline silica reaction on both natural (ordinary concrete samples and another waster material-based concrete samples. Finally, applying various destructive concrete tests according to Australian standard codes (AS 1012) and all parts and calculate their strength and capacities in different periods.

The objectives of the current research are,

- To use waste elements with natural materials with different percentages and measure an Alkaline SilicaReaction on different periods.
- To identify the improving factor for the worst-performing ASR within the concrete structures.
- To use different methods and applications to be applying manual ASR effects according to Australian standards and observe the reaction on waste concrete.
- To specify different destructive Australian standards testes on ASR effective concrete and find the development strength of concrete after 7 and 28 days.

1.4 Research questions

The current study will help in evaluating the following research questions,

- What are the effective materials for RAC in resisting the ASR effect at the concrete structure?
- What are the materials functions that are responsible for worst-performing ASR within the concrete structures?
- What are the different methods and waste materials are useful to reduce the ASR rate behind the increasing safety at the construction materials?
- What are the specific different changing material techniques used at the construction processin reducing the economic impact 0f ASR?

1.5 Rationale

ASR is currently performing as a damaged source of concrete structure within the construction industry. The impact of ASR has a significant residue on the natural elements such as air, plants, land composition, etcetera. Currently, the researchers are working on understanding different methods and materialsto reduce the ASR rate to decrease the worst-case scenarios with RAC and economic impact. The current research is working on shedding light on establishing better methods to replace the worst performing RAC at the South Australian Concrete construction.

1.6 Significance of research

The impact of ASR has become an undeniable factor in the global construction industry. It is linked with the safety measures at the commercial, industrial, and residential buildings. The current research paper has discussed the impact of recycled aggregate concrete as an alternative option for the sustainable construction process. However, the poor composition of RAC is from the weak composition of waste materials. A study by Tiarella et al. (2018) has explained how the industry is trying to recycle waste material, such as waste glass as an architectural mortar material. The authors have also pointed out the usage of hydrophobic admixture for mitigating the ASR rate. It can be an effective method for the current study to propose to the modern construction industry in reducingthe impact of ASR.

The motive of the current study is to define the appropriate construction method to work with the worst performing RAC in reducing the ASR rate. Wright (2021) has explained how the degradation model of concrete reduces the durability of concrete structures with common signs such as physical and chemical reactions, and cracking's. The knowledge behind understanding the impact of ASR on the RAC is related to identifying the reason behind early-age cracking. The presence of moisture elements and consistency of the ongoing chemical reactions provide mitigating methods in reducing future cracklings. The methods proposed by the current study will help the construction industry to work with the RAC without influencing the ASR rate and sustain the usage of waste materials.

1.7 Probable research output

The current research has undertaken a set of tasks that has been followed with project planning, laboratory tests, material selection, economic examination of RAC and mitigation methods of ASR rate. The current research is expected to identify the impact of ASR on the ordinary and recycled aggregate concrete specimen to identify the rate differences. The result is expected to analyze the RAC saturation and durability of the mortar materials. The calculation of the different ASR rates will define the new appropriate aggregate concrete material to use in the concrete column to reduce the reaction rate.

2. LITRATURE REVIEW

2.1 ASR & Durability of RCA

According to El-Harari *et al.* (2019), the performance and durability of the different RCA mixtures incorporate at least 25% of the ground-granulated blast-furnace slag in replacing the normal cement. The incorporation of RCA as an alternative to traditional cement is being taken after examining its influence on the water penetration, shrinkage, compressive strength, ASR effect and water absorption situation. The result has defined the implementation of mineral material at the RAC for enhancing its mechanical and durability properties. The 25% additional slag at the place of cement has also resulted in reduced water absorption. The study has also tested the effect of ASR after one year and it shows that the additional slag provided prevention to the excessive compression. The examination of the chemical composition of Ordinary Portland Cement (OPC) andGround-granulated Blast-furnace Slag (GGBS) has generated a different reaction rate. The different reaction rate is helpful in making effective decisions on the material choice.

Ingredients	Percentage	
	PC	GGBS
Silicon oxide: %	20·83	33·60
Aluminium oxide: %	4·44	12·50
Ferric oxide: %	3·53	0·52
Calcium oxide: %	64·55	42·50
Magnesium oxide: %	1·45	7·52
Sulfur trioxide	2·52	1·68
C_3S	62·30	—
C_2S	12·70	1·26
C_3A	5·80	—
Alkalis	0·65	0·48
Chlorides	0·01	0·01
Loss of ignition	1·41	0·02
Density: g/cm^3	—	2·98
Specific surface: m^2/kg	322	542·5

Figure 4. Different percentages of the Reactive Ingredients within OPC and GGBS

The noticeable trend was that the silicon, aluminum oxide and calcium oxide percentages has been the highest amount of ingredients percentage found after compared between Ordinary Portland cement GGBS binder and The C_3S and C_3A had zero percentage of Chemical proportion in GGBS due to their ingredient properties, which was sources by Hawary et al (2019). the researchers are determined to investigate the appropriate construction material that will reduce the impact of ASR. As per a study by Mariaková *et al.* (2021), the contribution of the probable Alkaline Silica Reaction can be prevented by using silica flour and fine sand with waste glass. The authors have verified the potential risk from the future reaction with the mentioned waste material under the influence of a moisture environment. The authors have proposed the usage of waste glassto reduce the risk of experiencing ASR. The authors have used a laboratory test with ASR on different specimens with several day gaps to generate effective results. Another study by Ramjan*et al.* (2018)explained the implementation of bagasse ash (BGA) in preventing the ASR rate on the mortar reactions. The authors have used BGA in replacing the OPC at the rate of 10%, 20%, 30% and 40% inaccordance with the cast mortar binder. The investigation was based on the ASR rate and its compressive strengths on the mortar materials. The result shows the high fineness of BGA- containing mortar has a higher compressive strength with lower ASR expansion.

According to Kazmi *et al.* (2020), nowadays, at the novel construction process, the usage of waste material has become an integral part. The authors from the selected research paper have focused on studying the post-cracking and mechanical characteristics of recycled aggregate concrete. The study has used a twenty-seven notched beam specimen to replace three different levels at the RCA.The study has used synthetic fiber to enhance the flexural tensile strength. The result showed that the implementation of synthetic fiber within RAC helps it to be more energy absorbing sustainable concrete material. On the other hand, Gupta *et al.* (2020) have explained that there is a lack of recycling processes as per the environmental requirement. In recent years, construction waste has become a major problem in disposing of waste materials. The authors have mainly examined the intensity of the absorption rate among various waste materials to expand the range of construction materials.

2.2 Structural effects of RCA

According to Wang *et al.* (2018), it has been concluded that the main aim of the pyramiding is the structure of the recycled aggregate which is used in the alkali-silica reaction. The use of recycled aggregates from construction helps in the demolition of the waste that can help in the perseveranceof the natural aggregate which thus helps in the reduction of the landfill and hence, as a result, contributes to the sustainable form of the environment to be built. The use of the recycled aggregate (RA) and that of the Recycled Aggregate of Concrete (RAC) regarding the history of recycling and manufacture and other processes which help in the inherent defect of the additional zone of the interface of that of the RAC structure helps in the interfacial transition of that of the material property attributes. The properties of RAC which include fresh concrete workability helps in the physical and chemical properties (identified to be density, carbonation, depth, and chloride and iron penetration). There are other factors of mechanical aspects like compressive flexural and splitting the tensile strength and finally the elastic modulus. This helps in catering the ways to long-term performance like that of the freezing and thawing resistance, the alkali-silica reaction itself, and thecreep and dry shrinkage of the property as well. Thus, t is to be put into the view that RAC has improved properties of mechanical way which helps in the summarizing and thus categorizing it intothree specific groups:

- The reduction of the recycled aggregate of porosity
- The reduction of the old mortar layer on the recycled surface of aggregation.
- The improvement of property without the recycled aggregate modification (in technical terms, mixing different concrete designs and giving a tinge of fiber reinforcement)

The current regressive models and artificial models are based on the prediction of the compressive strength added to it and different modulus and compressive strength curves of modulus and RAC which are then finally reviewed and further the limitations of these models are further discussed. The scarcity of landfill space could result in consequences such as the sharp rise of the cost of various forms of waste disposal which thus further raises severe environmental concerns. The CDW caneven contain hazardous materials such as examples of varnish, adhesive, seals, lead-based productssuch as paints of mercury which are specifically used in fluorescent lamps. This however might bean effective way of living, but further leads to the contamination of earth and groundwater.

2.2.1 RCA effects in civil industries

According to Abbas *et al.* (2020), the reaction of the alkali and silica is one of the most well-known reactions in the civil engineering industry. It is also used for the recycling of the coal bottom ash that is used with a value that is added in the process. The coal bottom ash is known to be used for research purposes in the construction industry. The local untreated coal bottom ash in the concretefor the ash is also known for its usage in the construction industry. The local untreated coal bottomash in the concrete is being used as the partial replacement for the cement, especially the Portlandcement. The toxicity characteristics of the coal bottom ash were taken under consideration and were used for the determination of the presence of the heavy metals that have been considered forevaluation purposes. With the use of the local untreated coal bottom ashes in the treatment of thealkali-silica reaction.

According to Adams & Dekker (2020), recycled concrete aggregate is one of the most critical tools being used in the civil engineering industry for construction and demolition businesses. The use of the aggregate in the newly formed concrete is being held up due to the less amount of research in the domain of recycled aggregate systems. The results in the research pursued indicate that a largeramount of mitigation effects need to be required for the Recycled concrete aggregates. A higher amount of mitigation might be felt to be necessary for some of the recycled concrete aggregates. The levels necessary are researched into the mitigation of the prevention of the Alkali silicate reactions that are conducted for the reaction processes for the research purposes. The results deduced from the modified accelerated mortar bar tests are also presented from two completely different for their ability deduced for the mitigation with the aggregate concrete.

2.3 Chemical and gel consideration in ASR

According to Sun *et al.* (2020), a model is being developed for the chemical damage that is being considered for evaluation purposes through the alkali-silica models of the reactions. The capacity for the swelling of the alkali-silica reaction needs to be considered for the gel reactions of the gel for the quantification by the element of sodium to the ratio of the calcium in the solution being considered for the pore. The alkali that is bound in the gel is also recycled in the concerned model. As per the consideration of the research being considered for reaction purposes, the alkali bound inthe reaction can be the bound alkali in the reaction and the gel recycled by the calcium. Both the capacity for the swelling needs to be considered in the case of the alkali-silica reactions and it is alsoquantified for the ratios generated for the sodium and the calcium ratios in the pore solutions.

Image removed due to copyright restriction.

Figure 5. Reaction front of the reaction of the alkali-silica reaction and the alkali recycling front seen in a representative reactive aggregate Sun et al., (2020)

Interestingly, formation of basic ASR (alkali-silica reactive) gel is higher in aggregate at different stages of times, which are denoted with $t=t_0$ While more research in this area is required on the gelling formation of CSH and ASR, it is speculated that free alkalinity stages depends from the reaction proportion and gelling formation with different phases of time period, which is explained in the following image different phases at time Sun et al. (2020) and can therefore see the representative reactive aggregates in (sun et al 2020).

Image removed due to copyright restriction.

Figure 6. The progress of the phase distribution; A. Free alkali B. reactive silica, C. ASR reaction gel, D. free calcium, E. CSH gel by alkali recycling, F. the distribution of the different phases at time Sun et al. (2020)

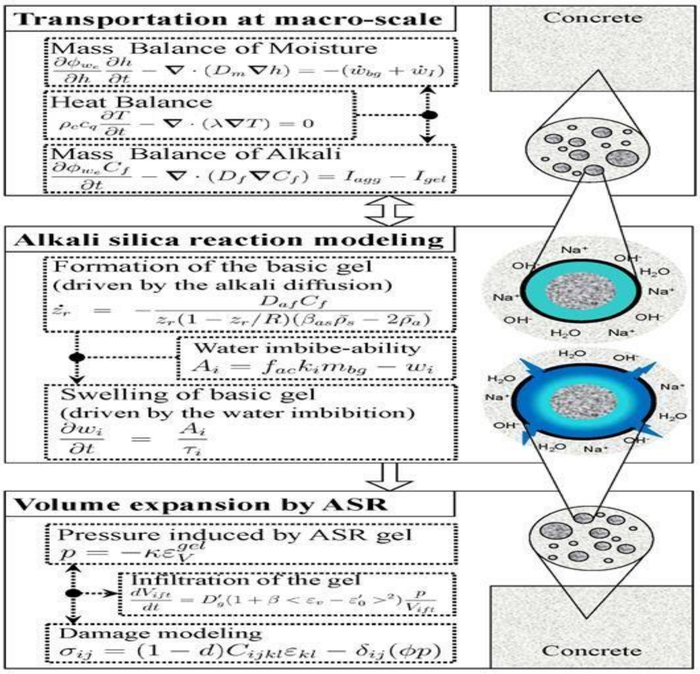


Figure 7. Schematic description of the model proposed by the researchers

2.3.1 Temperature consideration while ASR effects

According to Shi *et al.*, (2020), there are three types of the al; kali silica reactions products that arebeing considered as the product, for instance, crystalline products. These products have been generated at a temperature of around 89 degrees Celsius. It has become of utmost importance forthe verification and formation of the alkali-silica reactions for the development of the concrete for the formation of the products that are related to the field concrete. The results are between the temperatures of 60 and 80 degrees Celsius. The first two products have been seen not to precipitatein the following reaction procedures. The products of the alkali-silica reaction are seen to be formedin the concrete that is exposed to the potassium hydroxide reaction and the sodium hydroxide reactions and the mixture of the potassium hydroxide reactions. The product is exposed to the hydroxides of the potassium and the sodium are seen to behave differently as per the reactions considered.

Image removed due to copyright restriction.

Figure 8. The comparison between the ASR expansions namely, the measured one and the simulated one, the effect of temperature Source: Sun et al. (2020)

By comparison, the results from these literatures show that models of concrete columns as a providing the expansion% during the heating process in different period. However, most of the study shown in Figure 8 added model 1 at temperature (38 degree) and model 2 (-80 degree) and find the expansion at 7, 14, 21 and 28 days. After 28 days of process the expansion percentage were 1.4% of -80-degree concrete and 0.7% of -38 degree respectively. (The comparison between the ASR expansions sun et al 2020).

2.4 ASR behaviour based on waste concrete materials

According to AL Naggar *et al.* (2017), it has been concluded by the author about the behavior of concretes which are affected by the alkali-silica reaction depending on the environmental conditions. Alkali-silica is a major problem of concrete worldwide especially affecting places with high humidity conditions and high-temperature conditions. ASR is a slow process that develops at a preferable period from years to decades which is majorly influenced by the changes in the environment. The problem is much more effective if it happens with a more complicated recognitionthan of another phenomenon like creep and shrinkage which is also coupled with ASR. The results due to which the mechanisms are synergized but cannot be properly deciphered and understood without a proper comprehensive viewpoint of the computational model. To achieve this model, themulti-physics formulation is used to compute the evolution of the temperature, humidity, and methods of cement hydration.

2.4.1 ASR plastic-based formulation system

ASR, both in space and time, when it is further used in the physics-based formulation systems of cracking, creep, and shrinkage. The overall model is further calibrated and validated thus based on the experimental data which is available in the literature. Results have preferably shown the fact that during the free expansions methods (with zero macroscopic stress) it has been hypothesized that a significant degree of coupling exists because ASR induced expansions are likely to be caused by relaxed mesoscale creep driven by the self-equated form of stress

According to Khan *et al.* (2020), the author has concluded that the reuse of the waste glass as a supplementary binder and aggregate for sustainable cement-based construction materials. It is well known that the utilization of various by-product materials like fly-ash (FA), ground granulated blast furnace slag (GGBFS), rice husk ash (RHA), and silica fume (SF) in concrete provides for environmental economic and above all, engineering benefits. The research talks about the various usage of waste materials and thus the further in the application of construction materials in different aspects of bringing environmental technical and economic benefits. Although the research on waste glass as construction was started in the year 1960s, it later acquired its prevalence in further studies.

where it has been hypothesized that waste glass is suitable because of its flexibility, size, shape chemical composition, and many other widespread prospects which makes it one of a kind.\

But, on the other hand, it can be found that hundreds and thousands and tons of glass are hence getting stockpiled and landfilled globally every year which has posed a grave danger to the environment. Since glass in general is a non-biodegradable material, it almost takes one million years to break down naturally. Therefore, recycling waste glass has become a major alarming threatto the scientific community in the present day.

2.4.2 ASR physics-based formulation system

According to AL Naggar *et al.* (2017), it has been concluded by the author about the behavior of concretes which are affected by the alkali-silica reaction depending on the environmental conditions. Alkali-silica is a major problem of concrete worldwide especially affecting places with high humidity conditions and high-temperature conditions. ASR is a slow process that develops at apreferable period from years to decades which is majorly influenced by the changes in the environment. The problem is much more effective if it happens with a more complicated recognitionthan of another phenomenon like creep and shrinkage which is also coupled with ASR. The results due to which the mechanisms are synergized but cannot be properly deciphered and understood without a proper comprehensive viewpoint of the computational model. To achieve this model, themulti-physics formulation is used to compute the evolution of the temperature, humidity, and methods of cement hydration.

ASR, both in space and time, when it is further used in the physics-based formulation systems of cracking, creep, and shrinkage. The overall model is further calibrated and validated thus based on the experimental data which is available in the literature. Results have preferably shown the fact that during the free expansions methods (with zero macroscopic stress) it has been hypothesized that a significant degree of coupling exists because ASR induced expansions are likely to be caused by relaxed mesoscale creep driven by the self-equated form of stress.

According to, Maejir *et al.* (2020), the author connotes the fact of the effect of fly-ash on concrete performance and durability. In modern-day technology, ultra-fine ash is a novel by-product that hasbeen obtained by a dry and close separation process that was invented in the initial cement replacement in concrete. The impact of the ultra-fine fly ash on material purposes was further investigated on the upscaling and the basis of the approach used in paste, mortar, and other concrete properties. Concrete itself has an extremely dominating property in the modern method of civil engineering. It is the second most useful ingredient used in the world after water which is a major and critical component in the construction of infrastructure energy for the sake of social andeconomic development.

The production of concrete is further characterized by the considerable demand for energy and rawmaterials which further results in the significant emission of greenhouse gases which causes extreme harm to our environment. In present-day modern construction ideology, sand and cementare the two major components which are incorporated in the construction procedure. Current policies for sustainable usage of materials that aren't harmful to the environment are used which support recycling of materials, using non-renewable natural resources, and more efficient.

2.5 Use of RCA in Morden construction

According to Ke *et al.* (2018), in recent times the waste glass has a high contribution of increase of total solid waste in today's modern waste and pollution management problems. It has been seen invarious studies regarding the effects of solid waste to create serious environmental pollution, that these solid wastes are growing at a very accelerated rate proposing a big threat to the environment.The glass items produced in any form have a very short life and that's why they need to be reused or recycled very carefully so that they don't get chances to create pollution. Here in this study, it hasbeen focused to find the ways in which these solid wastes can be recycled and reused as the aggregate in the concrete mixture that can be used in the construction industry.

For this purpose, the investigation was run on the effects of various particle sizes and content of the alkali-silica reaction and their level and rate of expansion in various cementitious composite bars.

According to Rashidian-dezfouli *et al.* (2018), every year around the globe millions of tons of wastes generated from glass materials are produced. Other than doing harm to the environment by polluting in any possible way these wastes also get disposed of in landfills. In this study, the following figure 9 has been demonstrated how these so-called wastes can be utilized to find out the cure of one of the prime problems in concrete constructions by mixing them as the aggregate. It has been evident in this wayalong with reducing pollution these waste glass materials can also be used as a pozzolanic additive in concrete if used in very fine powder form it can potentially be used as supplementary cementitious material (SCM).

Image removed due to copyright restriction.

Figure 9. Effect of the content of waste glass powder on ASR expansion of cement mortar bars at different curing ages. a Curing age of 14 days, b curing age of 28 days, c curing age of 35 days Ke et al. (2018)

The earlier research has proved that a concrete mixture that contains SCM then the mechanical property of the concrete structure increases so as the durability of that structure. In this study alsowith the help of various tests such as accelerated mortar bar tests (ASTM C1260-ASTM C1567) andthe miniature concrete prism tests (AASHTO TP110) was done on the concrete structure made withGround Glass Fiber (GGF) and the results showed that the structures made of concrete mixtures containing GGF were proved much effective in the mitigation of ASR. In these experiments along with the GGF the finely ground soda-lime glass (GLP) and metakaolin and the various types of cement replacements were used to find the most suitable composition to fight against the ASR build-up. From the analysis of the results and data obtained from these investigations and tests conducted and performed, it has been clear that the best performance against the ASR problem canbe given using GGF among the three taken alternatives. The main reason behind this supreme performance of GGF are said to be its high aluminum contains and its high specific surface area.

Image removed due to copyright restriction.

Figure 10. Scanning electron microscopy (SEM) of concrete samples a. 100% Portland cement b. 30% GLP c. 10% metakaolin d. 30% GGF Source: Rashidian-dezfouli et al. (2016)

2.6 Construction domestic waste (CDW)

According to Zhu (2020), it is quite common to see various highways and hydraulic structures that are affected by alkali-silica reaction (ASR) be demolished every year as they have reached the end of their service life. By using these recycled demolished parts of the various old constructions not just reduces the construction cost and use of natural aggregates also remarkably reduces both the rate and amount of deposition of construction demolition waste (CDW) in the landfills. The process of recycling also reduces environmental pollution this way. But without proper and detailed research it is not recommended to use all these recycled concrete aggregate (RCA) in new constructions as there are chances of compromise in the durability of that structure if those RACs are previously affected by ASR. In this research work, various types of RACs that have been collected and processed from nearly 50 years old foundation blocks, bridge deck and columns etcetera have been put under test to see their efficiency by using them as coarse aggregate. To testing the efficiency and mitigation property two types of concrete mixtures were one with 50% and the other with 100% replacement prepared to build concrete structures from them and they were put under suitable conditions to build ASR in them. After a series of mechanical (i.e., Stiffness Damage Test - SDT) and microscopic (Damage Rating Index - DRI) tests and the analyses of the obtained results show that the performance of the concrete constructions depends on the degree of previous ASR build-up conditions.

According to Verian *et al.*, 2018, in this selected research the comparison of advantages and disadvantages of using recycled concrete aggregate (RCA) as the substitute for natural aggregate (NA) in concrete mixtures has been discussed with the help of the results obtained from the various tests to do that. The use of RCA in concrete mixtures for construction purposes reduces the generation of solid waste that goes to the landfill, as well as reduces the pollution that happens due to the mining in search of new natural aggregates. The quality and durability of the newly prepared structure depend on the specific gravity, adsorption power and the previous ASR contamination of that specific RCA that has been used as the aggregate. Along with the effect of the degree of ASR contamination in the RAC that degrades the performance of the concrete structure built using that RAC, other various facts, and methods to improve the performance of RAC have been discussed in this paper.

The literature has examined the addition of number of studies related with concrete technology elements such as fracture energy, permeability, creep, drying shrinkage and modular of elasticity ext….. However, there is a gap in research around the differences between the increases and decreases number of studies on RCA by concrete properties. Verian *et al.*, 2018 used the process of classification, the following figure 11 is indicating the number of studies affected by the compressive strength by used of 20 experiments. On the other hand, drying shrinkage properties increased during the studies and it shows 10 around experiments.

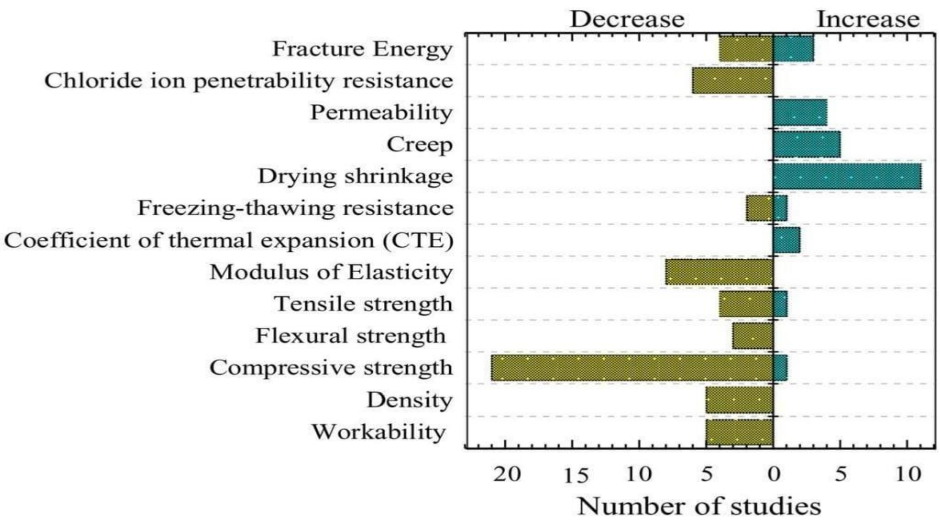


Figure 11. RCA impact on concrete properties summary

2.7 Appropriate standards

To ensure that the test methods used for this project are of academic value and reflect industry practice, research has been conducted to select relevant standards governing mixing and testing. concrete test. AS 1012 was found to contain methods for mixing, curing, and testing concrete samples. A list of relevant sections is provided in Table 1 below. All standards listed are 2014 versions, unless otherwise noted. For different ASR based tests and their methodology related standards also mentioned in the following table.

Table 1. ASTM concrete design and construction material standards

AS 1012.1	Method for sampling fresh concrete
AS 1012.2	Preparing concrete mixes in the laboratory
AS 1012.3.1	Methods for the determination of properties related to the consistency of concrete — Slump test
AS 1012.8.1	Method for making and curing concrete — Compression and indirect tensile test specimens
AS 1012.9	Compressive strength tests — Concrete, mortar, and grout specimens
AS 1012.10:2000 (R2014)	Determination of indirect tensile strength of concrete cylinders (‘Brazil’ or splitting test) [2000 Edition, reconfirmed in 2014]
AS 1012.12.1:1998 (R2014)	Method for determination of mass per unit volume of hardened concrete [1998 Edition, reconfirmed in 2014]
AS1012.13	Determination of the drying shrinkage of concrete for samples prepared in the field or in the laboratory

2.8 Literature questions???

1. The replacement of RCA with Natural concrete elements could lead to changes and problems in the natural concrete. First, however, the literature information was found that some are the materials are responsible for alkaline silica reaction in waste concrete structure or not?

2. Moreover, dependence on individual characteristics and ratios of replacements, the RA utilization in concrete would demand increased attention to obtain the required feature or not?

3. In the present context, the performance of the concrete is inferior in the process of RAC compared to the standard aggregate concrete or NAC. However, the existing variation of the properties is like that of the NAC. Thus, the process is feasible enough to maintain and suggest the utilization with proper terms and conditions?

4. Why did every research have goon through the process under the use of waste construction materials as a different element for the concrete, But No one couldn’t use those materials for the strengthening process?

2.9 Research Gaps

The relevant literatures reviewed on the topic of waste materials based concrete structure and ASR effects by used of RCA indicates the variations between natural and construction waste materials used with formation of percentage. The existing ASR studies and durability of RCA were Given that the different binder and fine materials are responsible for durability of concrete after ASR. major research objective is investigating the gelling and temperature are playing crucial roles during the ASR effects on RCA based concrete. The basically the stages were mentioned in the literature studies of ASR effects in gel and temperature consideration. In the literature papers included the information that the ASR is very slowing processes in the concrete construction and their behaviors, could be defined by the ASR affective concrete waste materials. However, an evident gap in current research is the influence of waste construction-based materials behavior, temperature effects, gelling structure and strengths in civil industries which will result in the inaccuracy of measuring data. The creeping, shrinkage, and cracking process in RCA based concrete structures are affected by ASR.

The process of ASR infective concretes required specific time by environmental effects. Therefore, another research gap will be the applying manual ASR effects by manual chemical mixing process in the laboratory. This research can provide data and information to relevant Australian concrete industries for identifying the construction waste materials that are useful after the effecting of ASR. Currently, there is no specific Australian Standard regarding the measurement method of strength identification under training condition of chemical reactions. and this project may provide some material to provide research outcomes to assist with future investigations. This research Performing and finding the best suitable concrete waste materials to help mitigate ASR conditions using destructive concrete tests. One of the significant aspects of concrete degradation is to use different materials without finding their internal and external strength and chemical structure. Therefore, the research gapis to identify the concrete waste materials combinations with concrete structures.

3. EXPERIEMENTAL METHODOLOGY

3.1 Research design

The alkali-silica reaction also generally known as the ‘concrete cancer’ appears in any concrete construction over a certain period, due to the reaction of highly alkaline paste of cement and amorphous silica provided in the various aggregates. The cement pastes generally contain alkalis such as Na_2O and K_2O which makes it highly alkaline, and these highly reactive compounds react with silica minerals available in the coarse or fine aggregates. The reaction of the mentioned alkaline substances and the available silica has been proved to be harmful and damaging as it results in the expansion of the altered aggregate and creates characteristic crack patterns in the concrete structure.

The below-mentioned crack appears due to the formation of sodium silicate ($Na_2SiO_3 \bullet nH_2O$) in a vicious and soluble gel form. As this gel is a hygroscopic one so it attracts and holds water from the environment and increases the volume and as a result pressure in the structure increases and cracks appear in them. The equation of the reactions $SiO_2 + 2NaOH - Na_2SiO_3 + H_2O$. The further investigation done by scanning the affected part under an electronic microscope shows there are different types of rock materials that are responsible for this incident namely shale or sandstones etcetera that helps to develop ASR in concrete and takesyears to develop it.

Image removed due to copyright restriction.

Figure 12. Schematic representation of alkali-silica reaction and cracking of concrete Source: Laudat et al. (2020)

Recycled aggregate concrete or RAC is the concrete with 100% recycled aggregates tomaintain the durability and strength of the prepared concrete structure that can be used for various applications. Nowadays RAC is used in concrete production as an alternative to the Natural aggregate (NA). The production of recycled aggregate concrete (RAC) is done by recycling the waste of concrete with very low margin other building waste. The collected andbroken up concrete as the coarse or aggregate in the concrete mix instead of the previously used NA may decrease the compressive strength of the construct a bit but splitting tensile strength becomes higher. The studies also show that in comparison to the conventional concrete made with NA the modulus of rupture is slightly higher than the concrete made with

RAC. It was also noticed that the modulus of elasticity of the beams made with RAC was also lower than expectation experiencing smaller cracking moments under a service load. Thoughit is quite a new technique, it can be assumed that it will help to shape the future to fight against the ASR problem. – Preliminary Work.

3.2 Research Approach

In this research, the necessary research has been done in the primary research method in the laboratory. For this purpose, the quantitative material knowledge and research has been adopted. The main topic of research, that is the analysis of the alkaline silicon reaction using recycled aggregate concrete, has been analyzed thoroughly using the data accumulated from the laboratory research that was earlier proposed in the research proposal. Alkaline Silicon Reaction (ASR) on concrete is one of the most growing topics in Australia and has beena highly discussed and evaluated topic within the past several times in Australian states and all around the world to improve the safety of their Residential, Commercial and Industrial Constructions of concrete materials. As this project aims to ensure the safety of the concretestructure from ASR so in the laboratory research has been done using various mixtures with concrete to find out the most appropriate mixture combination that will help to attain the aim of this project.

From the various studies that were done in the project proposal part, it was quite clear that most of the studies mentioned in that part have not used different concrete alternative materials such as fly ash, glass powder, GGBS, glass powder, recycled course construction-based aggregates to replace the previously used materials that cause ASR in the concrete structure. The proposed research has tried to collect data from the arranged research work that can fillthis gap by using recycled aggregate concrete as one of the useful replacements. To produce a consistent and sound result from the research work, a proper set of tasks was developed toaccomplish the thesis investigation. The set of tasks that has been maintained throughout this whole research followed by the respective calculations done in the laboratory are as below.

- Prepare the fool proof plan of the project.
- Do research on the topic and choose the methods of concrete materials and concrete tests.
- Perform those selected tests in the laboratory.
- Analysis of the data collected from materials tests and prepare concrete formation.
- Selection of the construction waste materials.
- Economic acceptability analysis of the application of RAC and lastly.
- The delivery of the result.

Apart from the laboratory research, the current research paper has also conducted surveys as a part of its primary analysis. The participants were related to the construction industry toprovide additional information on the ASR and the preventive measures they take to combatthe reaction. The survey has also provided information regarding the usage of RAC in the modern construction process. It will help in understanding how the construction is thinking of using RAC and the materials that are durable for resisting the ASR.

The current study has also conducted secondary research with the existing research journalsand articles. The secondary data has helped in forming the research background and differentmethods related to the mixing process while constructing a concrete structure. The secondary data has also helped in providing information on the usability of RAC and the impact of ASR on the construction industry. The methods used by other researchers have helped in optimizing the current study with appropriate laboratory examination with the concrete mixtures.

3.3 Data collections and analysis

Data collection for any research to prepare a thesis paper is one of the most important steps.Data collection in this case has been done with the help of laboratory methods taking various samples and alternatives to get very precise and useful findings that can surely be helpful to find a cure to one of the biggest problems of concrete construction weathering. In this research, the main comparison has been drawn between the generally used old-style naturalaggregates with the implementation of newly invented different RAC concrete material fromdomestic wastes and other alternatives. For the comparison between the two types of aggregates various tests have been done on both concrete constructions to test their compressive strengths, density, and durability, splitting tensile strength, modulus of rigidity and modulus of elasticity etcetera.

As stated in the earlier sections, for this research necessary and required data has been collected through the pre-decided set of laboratories research maintaining the following phases of data collection and analysis. The mentioned phases of data collection are as follows:

- **Analysis of the concrete material:** In this phase of data collection data has been collected focusing on the fact to find out the main possible causes of the appearance of ASR in the concrete structures over the period. In this segment also, the nature and the componentsof the used aggregates of the ordinary concrete has been analyzed through various tests showing that the main source of silica in the concrete mix comes from sandstone, shells, or glass stones etcetera.
- **Calculation of alkaline silicon reaction on ordinary concrete specimen:** Now in this phaseof data collection and analysis first the amount of development of ASR in any ordinary concrete construction over any certain period is calculated. For this purpose, to test the build-up of ASR that is the formation of $Na_2SiO_3 \cdot nH_2O$ the sample is let to react with sodium hydroxide and hydrochloric acid of selected concentration. The results obtained from the tests are gathered for further use.
- **Finding alkaline silicon reaction and its effects through suitable tests:** in this segment of

data collection and analysis tests are conducted and performed to find out the degree ofreactions and their future effects on the selected concrete structures both made of ordinary aggregates and various RAC collected and gathered from various sources. The main tests that have been performed are namely, Accelerator mortar bar test, Concrete prism test etcetera.

- **Use of various specimens of RAC gathered from various sources:** Use of RAC in construction as aggregate has started from the second world war as the war has demolished a lot of buildings during that time span. The residue of those demolished buildings was then used as fine and coarse aggregate in the new construction. Though those practices were very limited at that time, in recent times the use of these remnantsas aggregates have shown a path of success to fight against ASR in concrete constructions. In this research, the focus was on using RAC from various sources and finding out their level of usefulness against ASR build-up in concrete.
- **Comparison of data collected from both specimen tests:** After the completion of tests mentioned in the earlier sections on both types of samples the collected data has been compared. The process of comparing the results obtained creates the difference betweenthe ordinary and the RAC concrete construction. In this segment the comparison was done on various samples that contained either with the conventional that is with 100% naturalsand and 100% natural graves as fine and coarse aggregates or other various compositionswith parts of or cent per cent grave sand, or recycled aggregates as fine or coarse aggregate respectively.
- **Data Collection from Survey:** The survey process has generated information on the current practices in the construction industry and how they are preventing the risks fromASR. They have also established various facts regarding the implementation of RAC in achieving sustainability.
- **Secondary Data:** The literature review on the relevant articles and journals helped in providing background of the research and other important elements in continuing the progress of the current research paper.

3.3.1 Primary laboratory work

Earlier to conducting work in the concrete, materials related laboratories and on site, there were some preliminary works might be required to protect that all laboratory and working areas of the laboratory equipment were to be performed in a proper manner that was secureand concluded in precious and qualified data. Lots of inquire helped to involved with the primary study and could contradict and compare multiple resources that could representing different points of view in this research study.

Visiting tensely campus geotechnical and concrete technology laboratory and need an excess permission of laboratory entrance.

3.4 Concrete materials

- **Glass Powder**

Fly ash is a very important binding agent made from the pulverized coal and is in the form ofa very fine powder. Due to their small size, the particles are excellent bonding agents that help absorb water into the concrete and keep them there for the crystals to grow. The new mix includes 30-35 % fly ash along with other mixtures to form a concrete mix.

- **G - Ground Granulated Blast Furnace Slag (GGBS)**

It is a by-product that is generated from iron manufacturing and is extremely useful to increase the durability of the concrete mix. The GGBS reduces the problem of thermal expansion in concrete that causes cracks in the concrete structures. It helps reduce the effect of alkali-silica reaction (ASR), chlorides and sulphates that are constant sediment on the surface and internals of the concrete structures. It is used in a fixed amount of 35% in the whole experiment and has helped in inducing flexibility into the concrete. The Figure 13 provides brief view of ground granulated blast furnace slag materials, which is useful as a binder element in concrete mix.

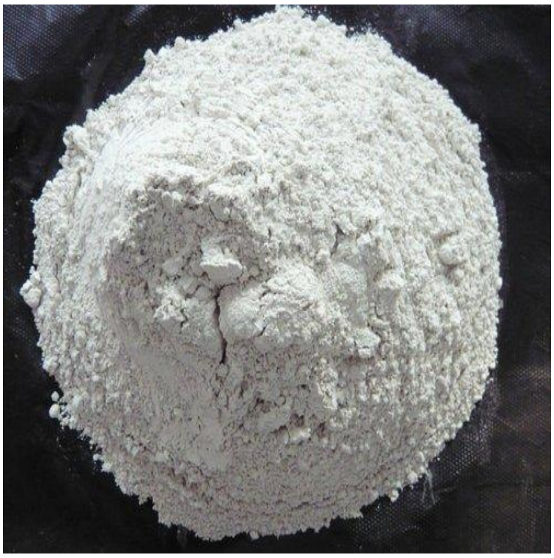


Figure 13. Ground granulated blast furnace slag

- **Natural Sand**

Natural sand is an excellent naturally rounded fine aggregate that can be used for the concrete mixes for increasing the bonding nature of the mix. The particles are rounded to near-spherical shapes that are ideal for the construction mix as it reduces free space in the mixture. It is highly workable and thus requires very less water to be used as a functional component. Among the two options of glass sand and natural sand few of the mixes are utilized for 100% natural sand and the other samples with 100% glass sand and checked for strength.

- **GS - Glass Sand**

Glass sand is another aggregate that is made of silica and is used for glass making. It melts to fuse together and form glass. The glass sand is a fine aggregate that can be used in the concrete mix, and it acts like the natural sand. The figure 14 on the right-hand side gives the view of waste material-based glass powder materials, which is used as a fine aggregate.

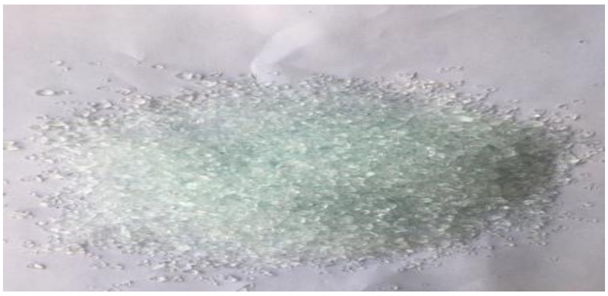


Figure 14. Glass Sand

- **NA - Natural Aggregate**

Natural gravel or crushed stone are broken down rocks that are formed by years of sedimentsand under pressure. Different rocks have different properties, and a mix of these rocks are used to create coarse aggregates as a filler in the concrete mix various proportions of the aggregates are utilized to find the best possible strength of the mix.

- **RA - Recycles Aggregate**

These are generated from broken building concrete parts and are used as a filler as a replacement for the natural aggregate like gravel. They too have been used in multiple variations and in mixes of both aggregates to find the best possible mix.

Figure 15. Recycled Coarse Aggregate

3.6 ASR mechanical properties on concrete

Alkali-silica reaction (ASR) in concrete can degrade its mechanical properties, leading to compromised serviceability and even loss in the load-carrying capacity of concrete structures. Considering the importance of the problem, extensive studies, primarily employing experimental investigations, have been carried out to understand the impacts of ASR on the mechanical properties of both natural concrete and recycled concrete elements.

- Finding the mechanical properties ASR plain affected concrete under different testing process.
- Mechanical property used by different construction waste material.

4. DATA COLLECTIONS AND ANALYSIS

4.1 Laboratory experiment and material measures

For the current research project, the analyses need to be done for the concrete cubes. Thereare several data collections that are divided into stages. The laboratory experiments and thematerial measures that have been undertaken for the research project are given below. The factors that are known to affect the alkali-silica reaction on the recycled aggregate concrete can be considered as:

1. The reactivity on the OA and the extent of the reaction on the recent concrete.
2. The mortar materials of three domains considering the residential, the commercialand the industrial engineering domains.
3. The size, the density and the durability of the mortar materials being considered forthe research project.
4. The crushing and the recycled aggregate concrete of the content stages.
5. The saturation of the recycled aggregate concrete cubes needs to be consideredalso.

The application of the test methods that need to be considered a standard test for ASR reactions on concrete materials and aggregates. The following test are not performing in thestudy, but it covered lots of information regarding ASR tests information according to Australian Standard.

The following tests were studying in this master thesis, there were not used in this research but it's important for the ASR effects on concrete aggregate reactions.

1. The mortar bar testing of the accelerator type

The accelerator mortar bar test is one of the most used testing methods for the testing of the aggregates that can be considered reactive. It is also used for the determination of the alkali reactiveness of the aggregates in the concrete (AS 1141.60.1). The effect of the chemicals needs to be considered on the cement being used for the consideration, for instance, the Portland cement. Some of the other experiments being considered for consideration are alsothe freezing and the thawing of the aggregates for the evaluation of the reactiveness of the aggregates of the concrete.

The alkali reactivity test is performed to understand and evaluate the potentials of the alkali-silica reaction of the deleterious nature in the mortar bars within a period of 16 days. It also has a capacity of detection of the concrete aggregates for their use in the concrete for the internal deleterious expansions caused by the reaction progresses of the alkali-silica reaction.

2. The Prism Test

The concrete prism test is conducted for the assessment of the potential alkali-aggregate reactivity of the given natural aggregates that are in the process of consideration. It is also used for the evaluation of the aggregates of opal and tridymite that can be considered as being extremely reactive under the circumstances being presented (AS 1141.60.2). It has also been recommended for the usage of the aggregate dry rodded bulk density for the determination of the ratio of the coarse aggregates to the sand particles, instead of the usage of the fixed 60 to 40 ratios.

The concrete blocks and the cubes developed need to be tested for several reasons. The fresh concrete tests that are being considered are commonly known as the tests which are used forthe testing of the strength, the consistency of the concrete, the unit weights and the air content as well as the temperature of the concrete under consideration. The tests being performed help in the detection of the changes that the concrete is going through over a longperiod of time.

4.2 Concrete materials laboratory tests

Before starting of concrete mixes for the first step of research, there has a requirement to measure the material's initial partial size distribution ASTM D6913, specific gravity ASTM D854, and water absorption tests. Different materials have been used, such as glass powder, GGBS, Fly Ash, Cement (Fine aggregate), Natural sand, Glass sand (Coarse aggregate), Natural aggregate, and recycled coarse aggregate for these tests. The researcher must perform thesetests to make the concrete formation table and calculate the percentage of materials per unitweight of samples.

The initial part of the laboratory testing required all the equipment availability and processing information. There are all the tests related materials and their measurement equipment available in the concrete laboratory with the valuable guidance of the lab supervisor. With the help of Australian standards and supervisors' guidance, all the initial materials tests were possible.

Table 2. Material tests details

Material tests	**Equipment's**	**Australian Standards**
PSD	Weight machine, sieves, shaker machine	ASTM-D6913
SG & WAT	Measurement plates, chain, buckets, weight machines, etc.	ASTM-D854

4.2.1 Particle size distribution test (ASTM- D6913)

At the first step of the materials, sieve analysis tests were required different types of steel-based particle size sieves come with 9.60 6.70, 4.75, 2.36, 1.18, 600, 425, 300, 150mm needed for finding the passing materials through them. The coarse aggregates need a considerable sieve size for the tests like 26.5, 19, 16, 13.5 mm. They calculated the particles of each passing material on the weight measurement unit and calculated the cumulative retained percentage and percentage of passing materials. There were only four materials has required to measure the sieve analysis. All particles sieve results include in the Appendix section further.

Table 3. Particle size distribution results

Sr. No	Material Types	Particle Size Distribution
1	Natural Aggregate	6.01%
2	Recycled Aggregate	5.98%
3	Natural Sand	3.86%
4	Glass sand	4.21%

The following bar graph shows the well-graded classification of course and fine aggregates and their particle distribution percentages. The particle size distribution graph is the calculation from the coefficient of uniformity equation, which means in the following bar graph, 6% and 5.98% of particles represent the bigger size of aggregates from the mass of aggregates. On the other hand, the glass sand particles have many crushed glass materials, showing the 4.21% particles passing percentage from sieve analysis.

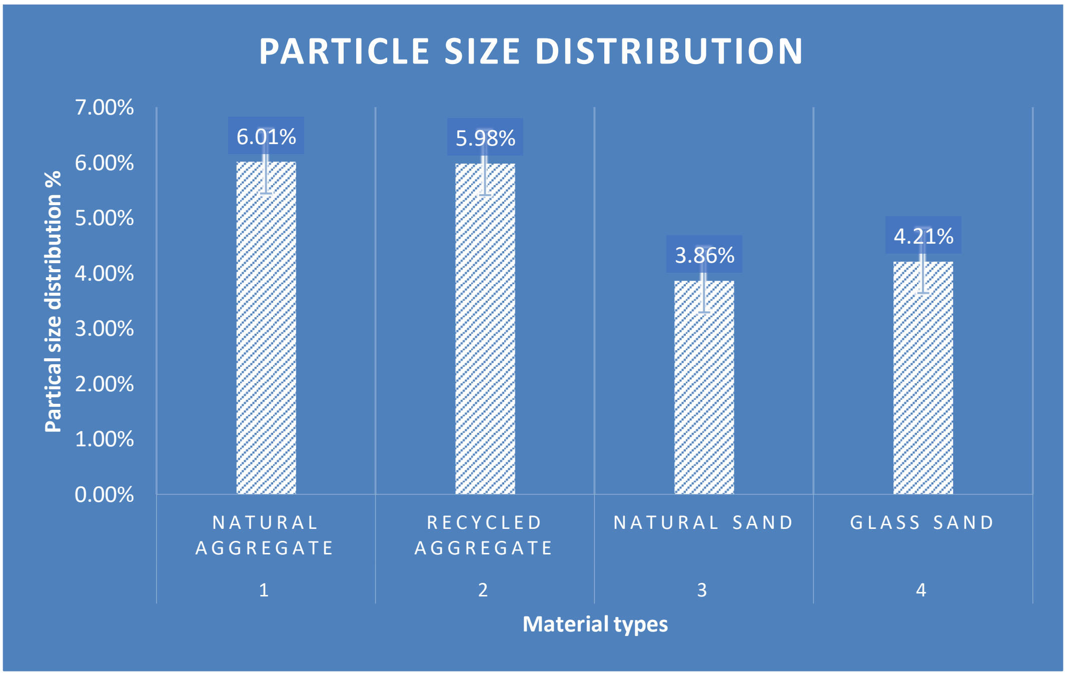


Figure 16 . Sieve analysis bar chart

4.2.2 Specific gravity and water absorption test (ASTM D854)

On the second step of the materials classification, Specific gravity and water absorption tests were required for different types of concrete-based materials. Specific gravity and water absorption test are very important materials tests for the formation of concrete mixes. The coarse aggregates and fine aggregate specific gravity test and water absorption tests required 24hrs.

For finding the water absorption of materials required full buckets of water and thermostatically controlled oven. Set thermostatically oven on 105-degree circus temperature for all types of materials. for 24hrs There were only four materials has requiredto measure the specific gravity and water absorption test. All specific gravity and water absorption results include in the Appendix section further.

Table 4. Specific gravity and water absorption results

Sr.no	Material Types	Specific Gravity	Water Absorption
1	Natural Coarse Aggregate	2.95	1.00%
2	Recycled Coarse Aggregate	2.35	6.70%
3	Natural Sand	2.68	1.12%
4	Glass Sand	2.39	2.16%

The line and bar graph show the following image's 18 specific gravity and water absorption values comparisons. Each x-axis provides the information of specific gravity and water absorption percentage of various waste and ordinary concrete materials. For example, figure 19 shows the high-water absorption value, which is around 6.07%; as per the results from the graph, recycled aggregates need more water for voids filling more than natural aggregate 1%. The following graph information will help make the percentage concrete mix in the following concrete mixing steps.

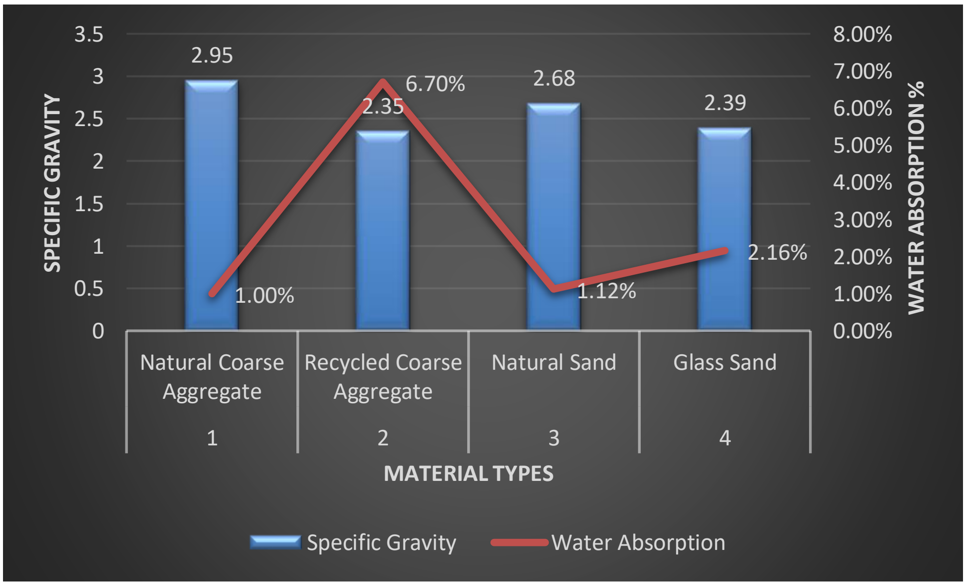


Figure 17 Specific gravity and water absorption comparisons

4.3 Concrete mix sampling and methodology

For the proposed research in this paper to find the acceptability of use of RAC as a cure of ASR in concrete structure the use of different concrete mixtures were used. Some of the concrete mixes were passed from the standards and some were not. There were numbers ofmix samples affected wrong after the mixing in the concrete mixture. Few materials had showed very hilarious affects after the 24hrs of settlements. The failed concrete mixes were used by few waste construction materials such as Glass powder, GGBS, fly ash, Glass sands and LLSB formations. There are some formations describing further for the classify the details of materials use in the future studies. The following images provide the brief view of failure concrete cylinder.

1. Glass powder 50%, GGBS35%, Flay
2. ASH15%Glass powder50%, GGBS50%
3. Water cement ratio problem

Figure 19. GGBS, Fly Ash and RCA failed concrete

Figure 18 Concrete waste sample

4.3.1 Slump analysis (ASTM1012.3.1)

The target slump is 60,100 mm according to Australian standards for all blends mixed for this thesis. Theoretically, this should be constant between different batches of the same assembly. However, concrete may have some deviations in actual conditions due to slight variations in the properties of concrete components. Therefore, to avoid exceeding the deflection specification, 10% of the water specified in the composite design is set aside and not added prior to the first deflection test. In addition, 1 L of water has been reserved for theremaining 90% to prevent dust. In practice, the concrete mix is calculated for these three volumes of water before mixing begins and is measured separately.

Upon completion of the concrete slums test, the concrete is transferred from the base plate to the mixing tank and re-bonded to the remainder of the batch. If the appropriate concrete finds insufficient deflection, additional water is added at this point, and the concrete was mixed and tested for settlement according to the methods described earlier in this thesis. In the initial concrete mix, some concrete samples showed a 20 to 30 mm slum value due to RCA's strong water absorption. after changing the form, and the perfect values of the slums for all mixes are shown in the following table. The Red values showing the low number of slumps found during the concrete mix.

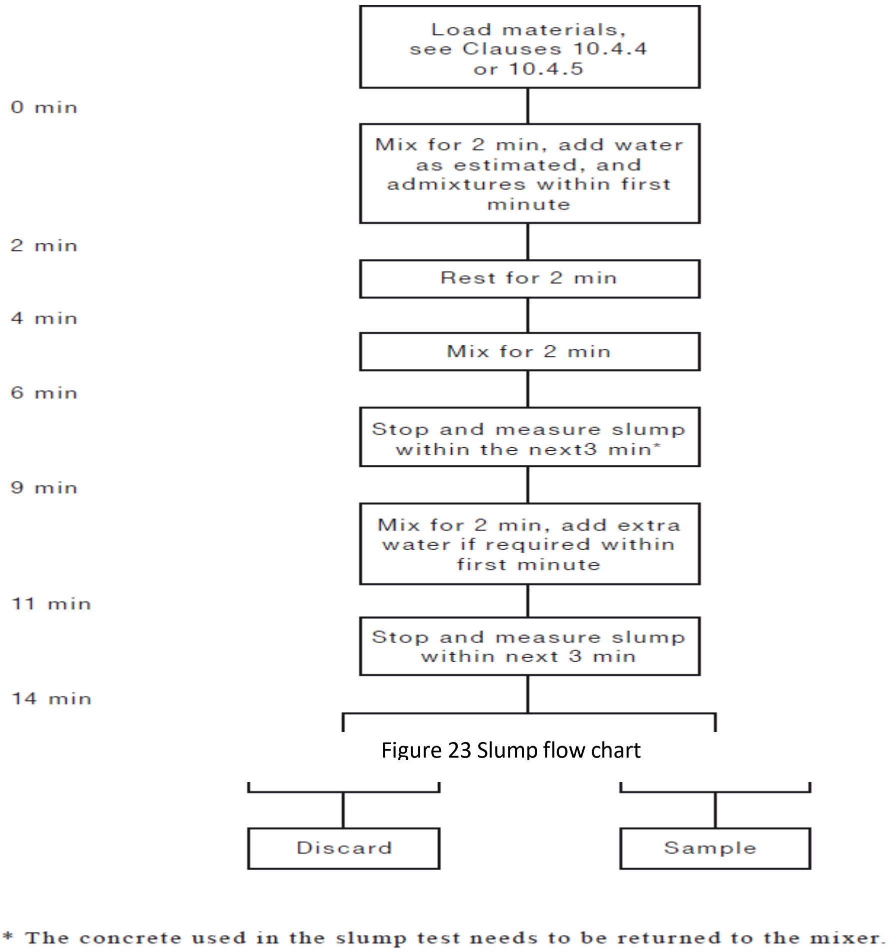


Figure 23 Slump flow chart

Figure 20. Slump test flow chart

Table 5. Slump test result

Sr.no	Material Types	Old slumpValue Unit (cm)	New SlumpValue Unit (cm)
1	Mix-1	60	71
2	Mix-2	54	67
3	Mix-3	35	52
4	Mix-4	48	64
5	Mix-5	38	58

Figure 21. concrete slump corn

4.3.2 Initial and final concrete mixes

- **Initial concrete mixes**

The initial concrete mixing procedure and matrix was created for the purpose of destructive concrete testing and examining different waste construction materials mix designs and their hardened properties. The test matrix was separated in two parts. Part 1 was preparing initial hand calculation formulas and make proposition sheet in excel by the helped of Australian standards, and then find most popular waste concrete material based concrete formation at the initial bases. The initial concrete mixes sample sheets attach further.

Table 6. Initial concrete mixes

Concrete mix	Cement				Fine Aggregates		Coarse Aggregates		Water
	Cement	Fly Ash	GGBS	Glass powder	Natural Sand	Glass Sand	Natural Gravel	Recycled Aggregates	
Conventional	100.00%	0.00%	0.00%	0.00%	100.00%	0.00%	100.00%	0.00%	100.00%
F30G35GP35-1	0.00%	30.00%	35.00%	35.00%	100.00%	0.00%	100.00%	0.00%	100.00%
F30G35GP35-2	0.00%	30.00%	35.00%	35.00%	100.00%	0.00%	100.00%	0.00%	100.00%
GSNG-1	0.00%	30.00%	35.00%	35.00%	100.00%	0.00%	100.00%	0.00%	100.00%
GSNG-2	0.00%	30.00%	35.00%	35.00%	0.00%	100.00%	100.00%	0.00%	100.00%
FSNG-1	0.00%	30.00%	35.00%	35.00%	0.00%	100.00%	100.00%	0.00%	100.00%
FSNG-2	0.00%	30.00%	35.00%	35.00%	0.00%	100.00%	100.00%	0.00%	100.00%
FAGGGP-NS-RA50-1	0.00%	30.00%	35.00%	35.00%	100.00%	0.00%	50.00%	50.00%	100.00%
FAGGGP-NS-RA50-2	0.00%	30.00%	35.00%	35.00%	100.00%	0.00%	50.00%	50.00%	100.00%
FAGGGP-GS-RA50-1	0.00%	30.00%	35.00%	35.00%	100.00%	0.00%	50.00%	50.00%	100.00%
FAGGGP-GS-RA50-2	0.00%	30.00%	35.00%	35.00%	0.00%	100.00%	50.00%	50.00%	100.00%
FAGGGP-LSS-RA50-1	0.00%	30.00%	35.00%	35.00%	0.00%	100.00%	50.00%	50.00%	100.00%
FAGGGP-LSS-RA50-2	0.00%	30.00%	35.00%	35.00%	0.00%	100.00%	50.00%	50.00%	100.00%
FAGGGP-NS-RA100-1	0.00%	30.00%	35.00%	35.00%	100.00%	0.00%	0.00%	100.00%	100.00%
FAGGGP-NS-RA100-2	0.00%	30.00%	35.00%	35.00%	100.00%	0.00%	0.00%	100.00%	100.00%
FAGGGP-GS-RA100-1	0.00%	30.00%	35.00%	35.00%	100.00%	100.00%	0.00%	100.00%	100.00%
FAGGGP-GS-RA100-2	0.00%	30.00%	35.00%	35.00%	0.00%	100.00%	0.00%	100.00%	100.00%
FAGGGP-LSS-RA100-1	0.00%	30.00%	35.00%	35.00%	0.00%	100.00%	0.00%	100.00%	100.00%
FAGGGP-LSS-RA100-2	0.00%	30.00%	35.00%	35.00%	0.00%	100.00%	0.00%	100.00%	100.00%

- **Final concrete mixes**

Phase 2 comprised of adding the kaolin material with varying wt. % of binder material to the selected mix design from Phase 1, and to analyze the effect of the additive on the fresh and hardened strength properties of the geopolymer mortar.

To calculation and analysis of build-up and effects of ASR in concrete structure the following mixtures have been examined:

Table 7. Final concrete mixes

Mix Types		
1	Conventional	100% water
2	Glass sand 50% GGBS 50% Natural sand 100% natural aggregate 100%	100% water
3	Glass sand 50% GGBS 50% Glass sand 50% Recycled aggregate 100%	100% water
4	Glass sand 0% GGBS 50% Natural sand 100% natural aggregate 50% recycled aggregate 50%	100% water

5	**Glass sand 0% GGBS 50% Glass sand 100% Natural aggregate 50% recycled aggregate 50%**	**100% water**

Table 9 Final concrete mixes

After attempting several concrete mixes and concrete failure samples, the successful concrete mixes had found with proper cement water ratio and standard hardness after the first initial settlement and final settlement time.

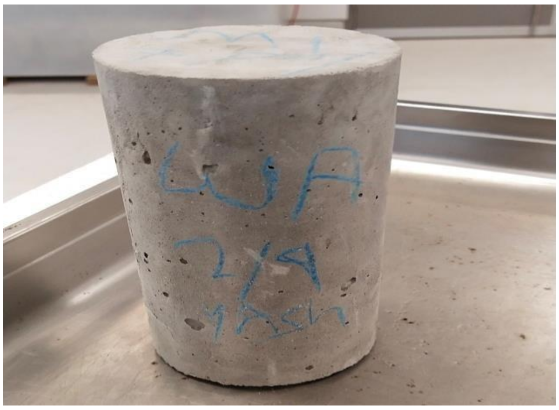


Figure 23. ordinary hard concrete sample

Figure 22 Recycle settled concrete column

The sampling has been conducted among various materials belonging to the construction industry. Four of them are working in a mid-range construction company and others are working part-time or full time in different research studies and thesis. One of the participantsis a vendor, supplies construction material. The sampling questionnaire consisted of open- ended questions to gather valuable information. However, the questions are restricted to theRAC and ASR to make the information convenient to work with.

The sampling research with the existing research articles and journals has taken around 25 papers to make a thorough study on the impact of ASR, usage of RAC, and the practice within the modern construction industry.

4.4 Mixing process and curing

For the concrete mixing RA's and laboratory safety operational process formality require prior to start the mixing concrete materials also workspace and equipment information's were required to start the mixing. Initial materials and equipment's were made readily available before start of the concrete mixing. Steel capped boots, gloves and eye's protective glasses and materials collective buckets were ready before laboratory work.

Figure 24. WC mixing model

4.4.1 Concrete mixing

The concrete mixing and curing testing were completed in the compliance with Australian standards ASTM (1012.8.3 2015) Australian standards for making curing and mortar specimens and process required to follow.

The ordinary and waste materials binder (OPC, and GGBS, Glass powder), fine aggregates such as soil, glass sand and coarse aggregates like natural aggregate, recycled coarse aggregate, were first weighted on the weighting machine on the scale the masses from the design matrix. The fine materials were transferred into the mixer bowl and mixed in the concrete mixer for initial 6 minutes. After water measurement in the bucket and put it in the concrete mixer and mixing for the second round for the 10 mins.

The above figure shows the pouring of the waster concrete mixes into the cube and cylinder molds. The cylindrical molds were left to set for 48 hours, and the cubes for 24 hours at ambient. The aim of leaving the specimens exposed was to observe efflorescence and overall setting time of the specimens, which would be important.

Figure 26. Concrete mix sample

Figure 25 Concrete cast cylinder

4.4.2 Initial and final settlement

After Completing the concrete mix samples andmaking the concrete moles for all five concrete mixes. The initial and final concrete settlementstake a place on the important stage. There were some concrete samples taken more then 24hrs of settling times in the hardness process such as the samples formation were GGBS and Glass powder, GGBS and RCA formations. In the following image, the soil types of samples re showing wet surface on the top of the surface.

In the laboratory, four master thesis students were working on the same time for making their samples. The reason behind to making the concrete samples on the different period and usingthe different circular concrete colors molds.

The initial settling and smoothing process lasted 24 hours and was performed under ambient temperature and humidity conditions in the laboratory. The laboratory space is conditioned so that there is no appreciable variation in atmospheric conditions between the mixtures. However, there is no data to verify this - some of the latest models were wrapped in plastic bags to combat atmospheric temperatures over the weekend.

Figure 27. Casted concrete sample for settlement

4.4.3 Concrete water curing

Once concrete hardness was finished, the water curing takes a place for all types of concrete mixes. One water bath was available at concrete laboratory, tonsely campus. The water bath temperature was around 28 degrees Celsius at atmospheric temperature. Any of the water temperature might be affected on concrete hydration process for the use of destructive strengthening tests.

The initial curing and curing process took 24 hours and more than that of the waste concrete mix and was produced under the temperature and humidity conditions of the laboratory at the test site. The hardening of water in the laboratory affects concrete columns for a period, however, testing of concrete based on ASR requires only 24 hours of water hardening. and samples not intended for testing for one day are transferred to a curing bath filled with constant temperature water.

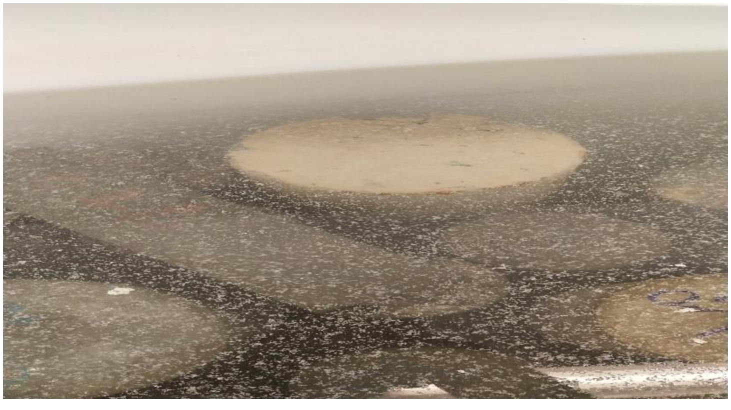


Figure 28. Water curing

4.4.4 Chemical preparation

After finishing of the water curing process, theresearch focused on the ASR conditioning on the concrete samples. Using the atmospheric ASR effects takes a long period of time. The main aim of the research study was getting theinformation and analysis on water concretematerials used concrete samples ASR effects and finding their strength after the certain period.

According to the Australian standard and national concrete research standards, there has been using the chemical components of hydrochloride acid and HCl for affection of ASR condition into the concrete column by manual chemical process. The 24000ml of water dissolved with 158gm of Hydrochloric pellets and measuring the 200ml of HCl for one bucket preparation.

Figure 30. Chemical compound HCL

Figure 29 Chemical preparation

4.4.5 Chemical curing and Thermostatic heating process

After preparing the chemical samples in three different non-heating plastics buckets. Taking out all concrete columns from water bath and dried out with help of clothes. Putting all number mentioned concrete samples inside thechemical prepared buckets by the wearing of safety gloves, safety glasses, and leather safety shoes.

By the help of Wes's moving all the concrete chemical buckets into the thermostatic ovenwith temperature of 105 degree Celsius. Divided different concrete mix cylinders in different story in Thermostatically controlledoven according to the use of 7days tests and28days tests.

Curing concrete cylinders in the chemicals for 7days and 28 days at 80 degrees Celsius according to (ASTM 1293-20).

After seven days, remove concrete cylinders of each mix from the buckets and checked the effects of ASR of 7days and 28 days.

Figure 31. Chemical curing

Figure 32. Thermostatic oval

4.4.6 7 Days and 28 Days ASR reactions

After the thermostatic oven treatment of 7 days the ASR spots has been found on concrete column. Waste material based concrete column spotted high ASR effects. All the columns affected with white surface infection of ASR after 28 days, which is mentioned in figure 36.

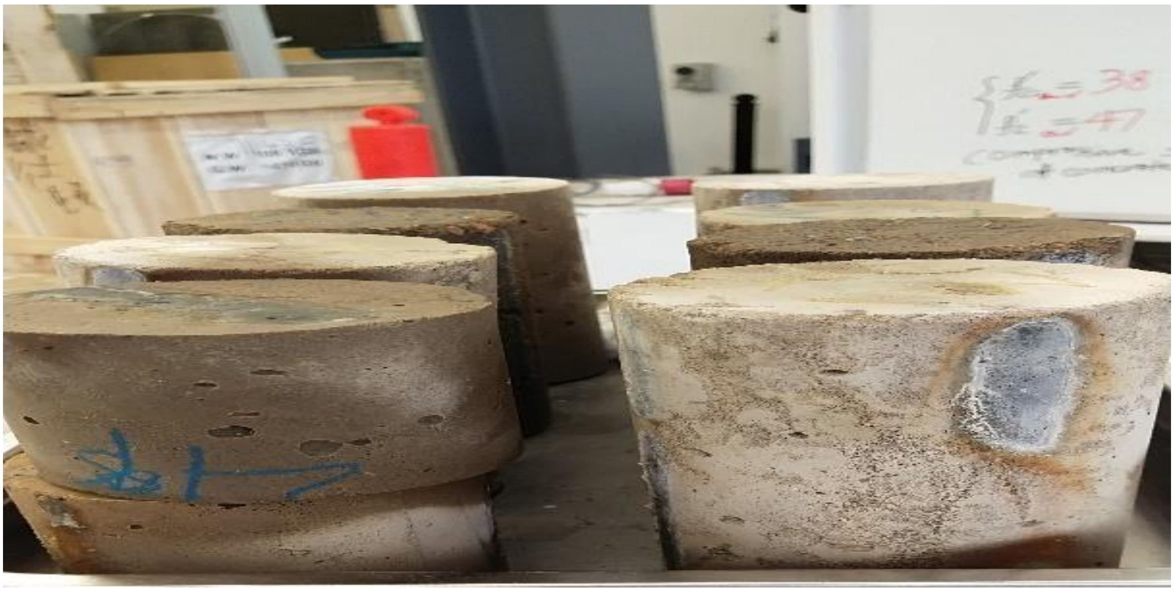


Figure 33. 7 days ASR conditions

Figure 34. High affected ASR after 28days

5. EXPERIMENTAL RESULTAS

5.1 Laboratory experimental tests results

They were finding the strength of ordinary concrete, and ASR-affected concrete required destructive tests. Using different concrete destructive testing was performed, such as compressive shear strength test and splitting tensile strength. Also, performing water absorption tests and drying shrinkage tests for calculating the absorption values and length change values, respectively for calculating the strength of ASR-affected concrete, thesedestructive tests have been required for the comparative strength.

Performing destructive concrete test: -

1. Compressive strength
2. Splitting tensile strength
3. Water absorption
4. Drying shrinkage

Materials names and their sample codes on the concrete cube: -

5. GGBS – Ground Granulated Blast furnace slag
6. GS – Glass sand
7. RA – Recycled Aggregate

5.2 Compressive share strength

The compressive shear strength tests were performed according to the method defined in AS 1012.9: 2014 Compressive strength tests - Concrete, mortar and grinding specimens. A 2000 kN hydraulic stability test bench was used to test the concrete models. It is controlled by the GEOCON MCC8 automatic control test system with a connected computer system and a high pump motor.

Using the formula for the area of a circle in the following formula, a more accurate representation of the cross-sectional area would be 7853.982 mm2.

$$A = \pi \times D^2/2 \quad (1)$$

A = cross-section area,
D = Cylindrical
Diameter

The force sensor has no values to directly measure the distributed stress, moreover, the compressive stress is calculated using the following formula,

$$\sigma = F / A \quad (2)$$

F = Applied load
A = Cross section Areas

The ultimate strength of a cylindrical concrete specimen is defined as the maximum stress the cylinder can withstand, so the final strength is calculated using the following equation,

$$f'_c = F_{max} / A \quad (3)$$

f'_c = Compressive strength Map
F_{max} = Applied Maximum load
A = Cross section area

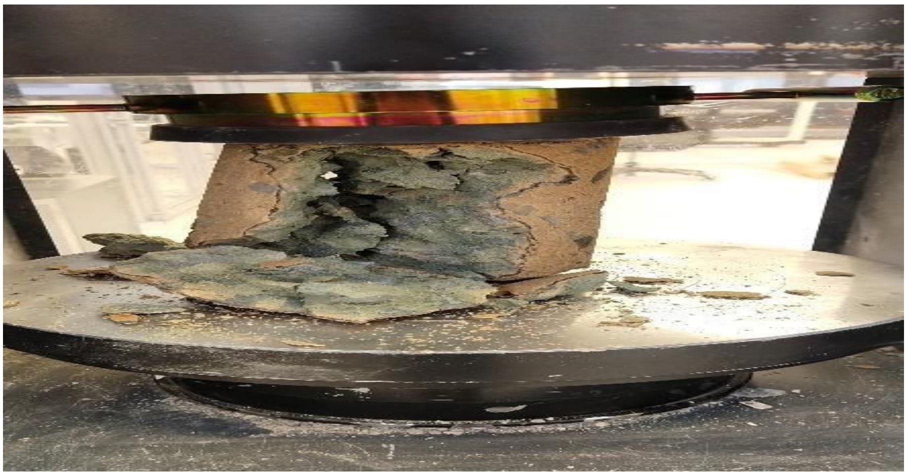


Figure 35. Compressive test machine

5.2.1 Compressive strength results (7 & 28 days)

As with the strengthening and workability, the compressive strength of concrete is majorly influenced by different parameters such as a water-cement ratio. There were using different concrete elements with the mixtures made a different strengthening of 7days columns.

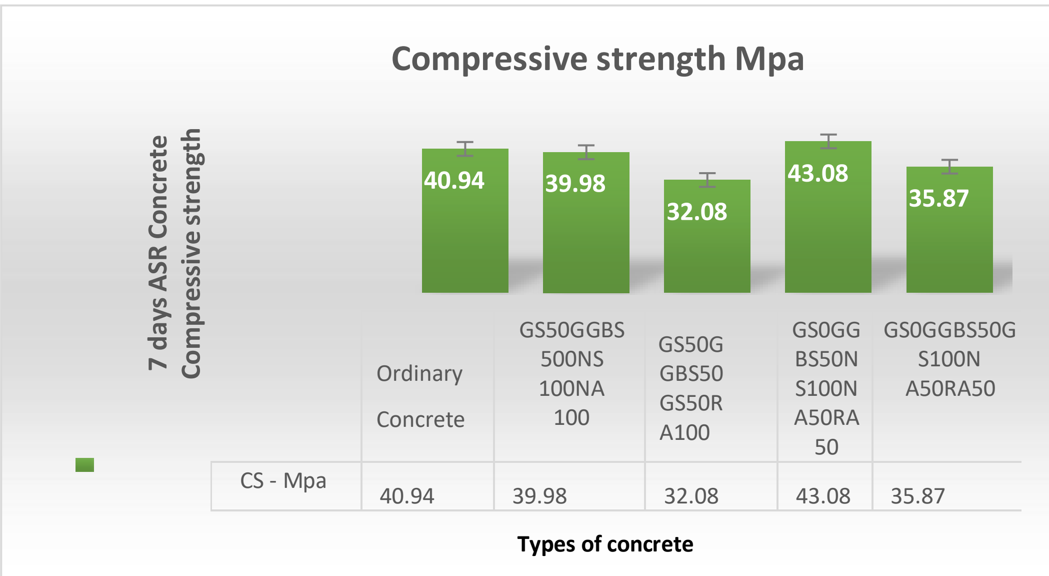


Figure 36. Compressive strength bar graph

After performing the compressive strength tests on ASR affected concrete samples with proper and Australian standards. The conventional or the natural concrete sample's average compressive strength found after seven days was 40.94 Map stress. As discussed previously in the report, compressive strength data for all mixes have conducted for seven days and 28 days from the chemical curing. As a result, the seven-day data for the mixes has projected using data collected for the GGBS and Glass sand formation provided high compressive strength around 39.98Mpa compared to conventional ones. There was significantly less stress from the same second formation, with the fine aggregate of glass sand providing the average 32.08Mpa. Moreover, the complete 100% use of ground granulated blast furnace slag with 100% natural aggregates and 100% recycled aggregate shows the results in the following table.

Table 8. Compressive test result

Time Elapsed (d)	Cylinder ID	Compressive strength Unit (Mpa)	Average Compressive strength	Strength Development %
7	Natural concrete	40.52	40.94	83%
7	GGNN-ASR-7	39.82	39.98	79%
7	GGGR-ASR-7	32.10	32.08	64%
7	GGNN50-ASR-7	43.25	43.08	83%
7	GGGR50-ASR-7	35.81	35.88	64%

After the seven-day tests, the 28days tests have conducted to find the compressive strength under ASR conditioning. The compressive strength of natural aggregate mixes and waste concrete mixes was approximately developing the strength around 90 to 92% greater than the seven days results. Australian standards follow chemical curing for 28 days. In comparison, the increasing the changes on the concrete due to the high absorption of chemical ratio. The ASR effects in the concrete columns and their compressive strength have classified in the following graph. Majorly the graph following shows the comparison between the 7days tests and 28 days compressive results and their strength The literature bao Lu 2019 had 49.08 compressive strength after 28days, 6.012 Mpa less than this study, which is clearly seeing in the following bar graph figure.

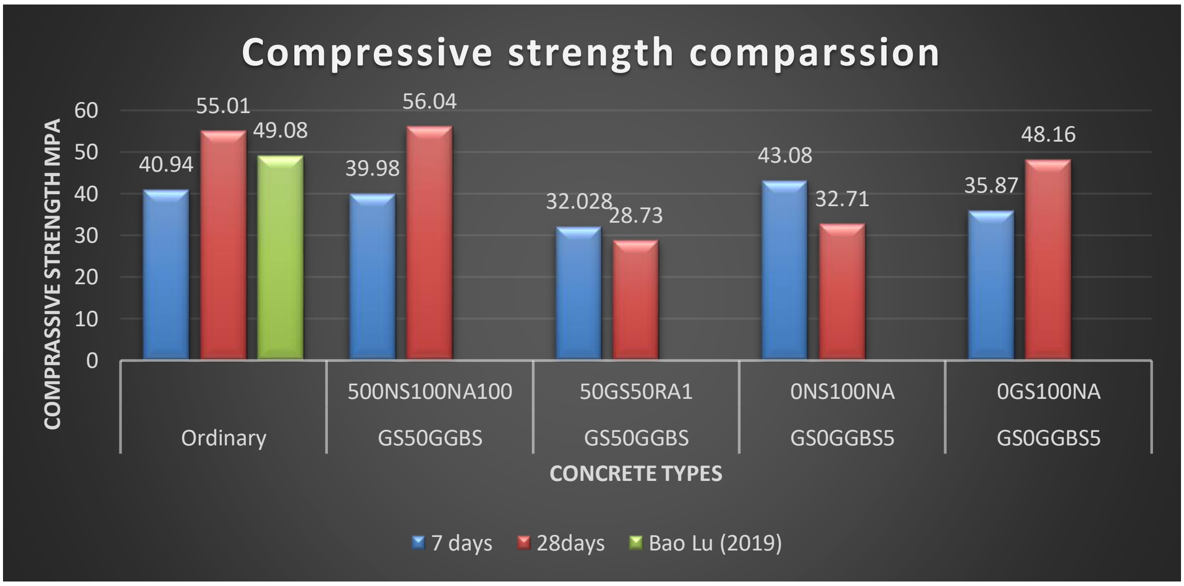


Figure 37. 7Day vs 28days Compressive strength compression

Furthermore, the GSGGBS formation with natural aggregate experienced a 17.03% increase in the compressive strength from 7 days to 28 days in the conditions under ASR effects, while 3.98% compressive strength decreasing was observed of the formation of GSGGBS with RAC 100, which suggested that the significant improvement in compressive strength appeared in higher in Waste material binders with natural aggregate compared to RCA replacement. The ASR effects had found in RCA concrete at 28 days.

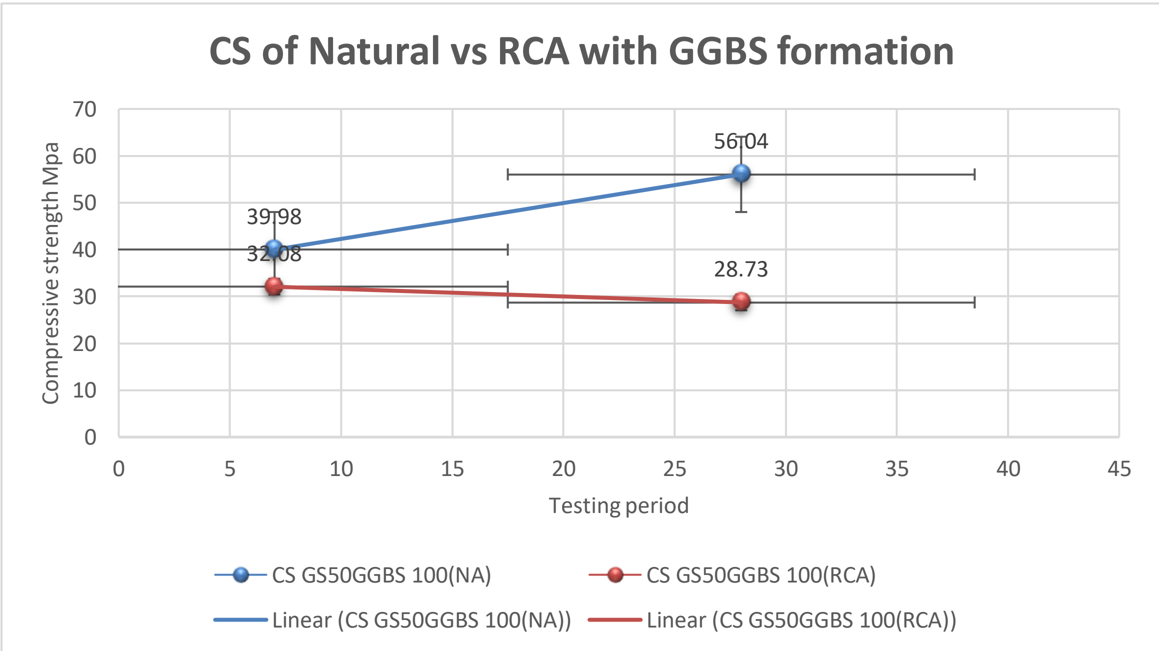


Figure 38. GGBS formation with NA vs RCA compressive strength

In the bar as mentioned above graph, there is clearly showing that the high compressive strength developed in the formation of GGBS and Glass sand concrete mix, which is developed from 39.98Mpa to 56.04Mpa after 28 days curing. The strength has upgraded from 79% to 94% after ASR curing in the Oven. The conventional concrete sample, waste material of GGBS and GS formation, and GGBS and RA formation performed high strength after 28 days compressive strength such as the increment of 55.01, 56.04,48.16Mpa, respectively. There has less strength covered by GGBS and 50% of course aggregate combination. The results show the strength decrease around 43.08mpa to 32.71Mpa.

The following table provides 28 days of waste concrete and ordinary concrete compressive strength development % after manual ASR effects. The table clearly shows that the GGGR-ASR and GGNN_ASR formation have meager strength decrement compared with other mixes. Its shows 59% and 50% respectively.

Table 9. Strength development % of CS

Time Elapsed (d)	Cylinder ID	Compressive strength Unit (Mpa)	Average Compressive strength	Strength Development %
28	Natural concrete	55.04	55.01	94%
28	GGNN-ASR-28	55.98	56.04	95%
28	GGGR-ASR-28	29.34	28.73	59%
28	GGNN50-ASR-28	32.81	32.71	50%
28	GGGR50-ASR-28	48.50	48.71	82%

5.3 Splitting tensile strength

The indirect tensile test was performed according to the method defined in AS 1012.10:2000 Determination of the indirect tensile strength of concrete pillars ("Brazil" or delamination test). Unlike much of AS 1012, Method 10 was not updated in 2014, as the relevant technical committee reconfirmed the 2000 version of AS 1012.10. Therefore, AS 1012.10:2000 can be considered as the latest version of the standard at the time of testing. A 2000 kN hydraulically operated test stand was used to test concrete samples and tested using the GEOCON MCC8 Controls automated test system and the GEOCON MCC Multisets software package.

Using the formula for the area of a circle in the following formula, a more accurate representation of the cross-sectional area would be 19650 mm2.

$$A = \pi \times D^2/2 \qquad . (1)$$

A = cross-section area,
D = Cylindrical
Diameter

The force sensor has no values to directly measure the distributed stress, moreover, the compressive stress is calculated using the following formula,

$$\sigma = F / A \tag{2}$$

F = Applied load
A = Cross section Areas

The ultimate strength of a cylindrical concrete specimen is defined as the maximum stress the cylinder can withstand, so the final strength is calculated using the following equation,

$$f'_c = F_{max} / A \tag{3}$$

f'_c = Compressive strength Map
F_{max} = Applied Maximum load
A = Cross section area

Figure 39. Splitting tensile test

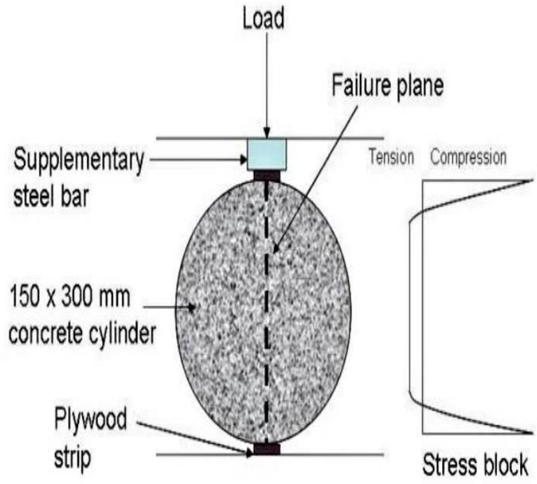


Figure 40. Splitting tensile mechanism

5.3.1 Splitting tensile results (7 & 28 days)

Like the compressive strength stability and strength workability parameters, the indirect tensile strength of concrete is strongly influenced by the water-cement ratio. Therefore, the "concrete waste materials of GGBS and Glass Sand" blend will be selected as the reference compound for this test if tensile tests are performed on all west product mixture. Although itis possible to predict tensile data using the same principle as that of compressive strength data, additional assumptions are required that are of questionable value and introduce a degree of uncertainty. Undesirable guarantees in the results. This rationale is explained in more detail in the following vertical bar graph of 7days results. Therefore, the "recycled aggregate" materials were chosen instead, although the water-cement ratio was significantlyhigher than that of the "Natural Aggregate" materials. The results of the tensile tests for the "7 days provided in further.

After conducting the splitting tensile strength on the ASR based concrete samples, there were number of variations found with compressive values. In the above-mentioned vertical graph showing the tensile values of 28 days and 7 days in Mpa unit. It clearly seen in the graph that the high splitting values got after 28 days of ASR concrete. There are majorly the GGBS, and GS formation provide a high strength of tensile strength after 28 days which is around 4.76Mpa as compare with 4.01Map at 7 days.

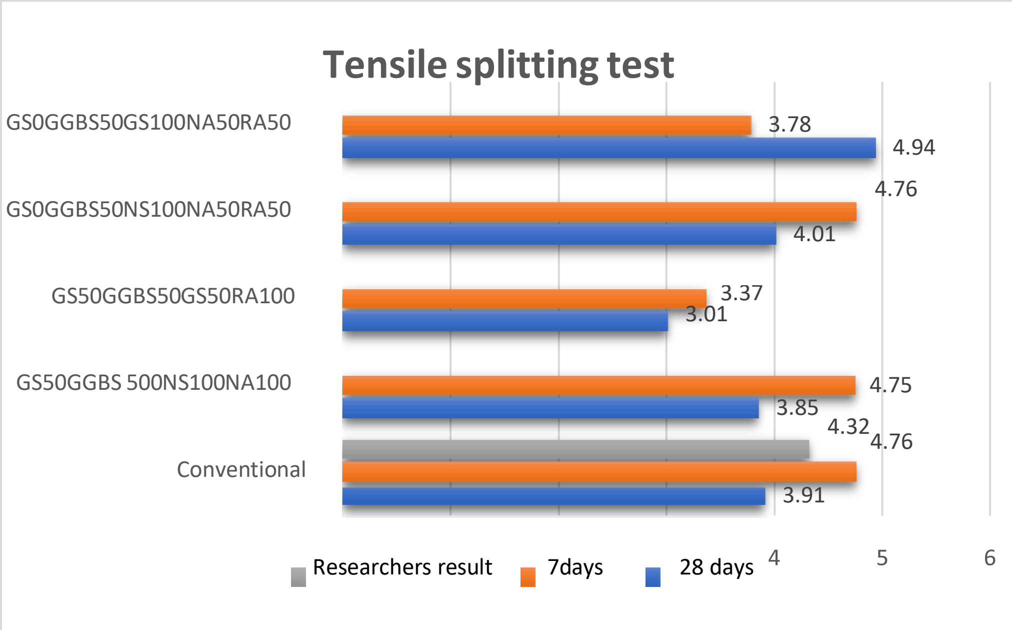


Figure 41. Tensile splitting comparison

After conducting the splitting tensile strength on the ASR based concrete samples, there were number of variations found with compressive values. In the above-mentioned vertical graph showing the tensile values of 28 days and 7 days in Mpa unit. It clearly seen in the graph that the high splitting values got after 28 days of ASR concrete. There are majorly the GGBS, and GS formation provide a high strength of tensile strength after 28 days which is around 4.76Mpa as compare with 4.01Map at 7 days.

Natural concrete sample identified the stress of 3.78Mpa at 7 days, which would the lowest performing values in the 7 days tests. On the other hand, there were only recycled aggregates based concrete samples shows very less value of 28days results of tensile.

Table 10. Tensile strength development result

Time Elapsed (d)	Cylinder ID	Tensile strength Unit (Mpa)	Average tensile strength	Strength Development %
28	Natural concrete	3.70	3.78	70%
28	GGNN-ASR-28	4.58	4.76	95%
28	GGGR-ASR-28	3.40	3.37	79%
28	GGNN50-ASR-28	4.70	4.75	90%
28	GGGR50-ASR-28	4.72	4.6	82%

Development of the strength after 28 days are varied from the percentage of strength in some waste concrete mixes. The less strength identified in the mixes of GGGR formation after 28 days.

Table 11. 7- & 28-days tensile strength

Cylinder ID	7 Days tensile stress (Mpa)	28 days tensile stress (Mpa)
Natural concrete	4.94	3.78
GGNN-ASR	4.01	4.76
GGGR-AS	3.01	3.37
GGNN50-ASR	3.85	4.75
GGGR50-ASR	3.91	4.76

The indirect tensile strength of the "Natural Aggregate" mix was approximately 3.78Mpa less than of the natural concrete sample after 7 days. Although this increase seems significant, it is mainly due to the difference in water-cement ratio. It can be concluded that the substituteof waster construction materials with natural concrete does have a significant effect on the tensile strength after the chemical curing period of 28 days. The waste concretes products related and their behavior for the tensile strength broadly applicable to the compressive strength. GGNN concrete samples and GGBS with RCA samples were performing very well atthe certain amount of period under the ASR effects.

After Considering ASTM 1012.10 to determine tensile values in Mpa, the comparative tensile values have been mentioned in the above table, mentioning that waste material-based concrete columns have good tensile strength after ASR condition more than the other ordinary concrete sample.

5.4 Water absorption

Water absorption method used for calculating how much quantity of water absorbed by the concrete material after some period such an initial observation, 3 days, 7days and 28days. The quantity of water absorption depends on the amount of used material in the sample. Onan initial concrete mixing steps there were so many water-cement ratio problem faced due to waste concrete materials used. Recycled aggregate has taken a high amount of water during the mixing and that was the reason behind a high amount of hydration effect on an RCA mix samples.

Calculating the weight of each concrete samples, the natural aggregate concrete water absorption was drastically increase after 28 days. On the other hand, The GGBS with Glass sand and natural sand formation were performing few amounts of increment after 28 days around 70 gm, 25 gm respectively. The compression between the percentage of natural aggregate and recycled aggregate water absorption, it can be drastic changed after 28 days of curing process.

Table 12. Water absorption test results

CONCRETE MIX	7 days	28days	Standard
Conventional	1881.2 gm	1897.3 gm	1805 gm
GS50GGBS 500NS100NA100	1881.7 gm	1887.3 gm	
GS50GGBS50GS50RA100	1680.0 gm	1697.3 gm	
GS0GGBS50NS100NA50RA50	1822.6 gm	1828.3 gm	
GS0GGBS50GS100NA50RA50	1806.5 gm	1858.3 gm	

Boiling water absorption method used from Australian standers for the measurement of AS based concrete samples. In the following line, the amount of various of waster absorptionpercentage after 7days and 28 days. The 5.20% percentage of water absorbed by the GGBSand Glass sand formation and that would be the highest water taken in this research study. Very less amount of water taken by Natural aggregate combination with concrete wastematerials. The following line graph shows the information of immersed absorption of concrete specimens by using the following equation from AST 1012.21. The specimen's water immersed absorption in the following line graph.

$$Ai=(M2i-M1)/Ml\times 100\% \quad (1)$$

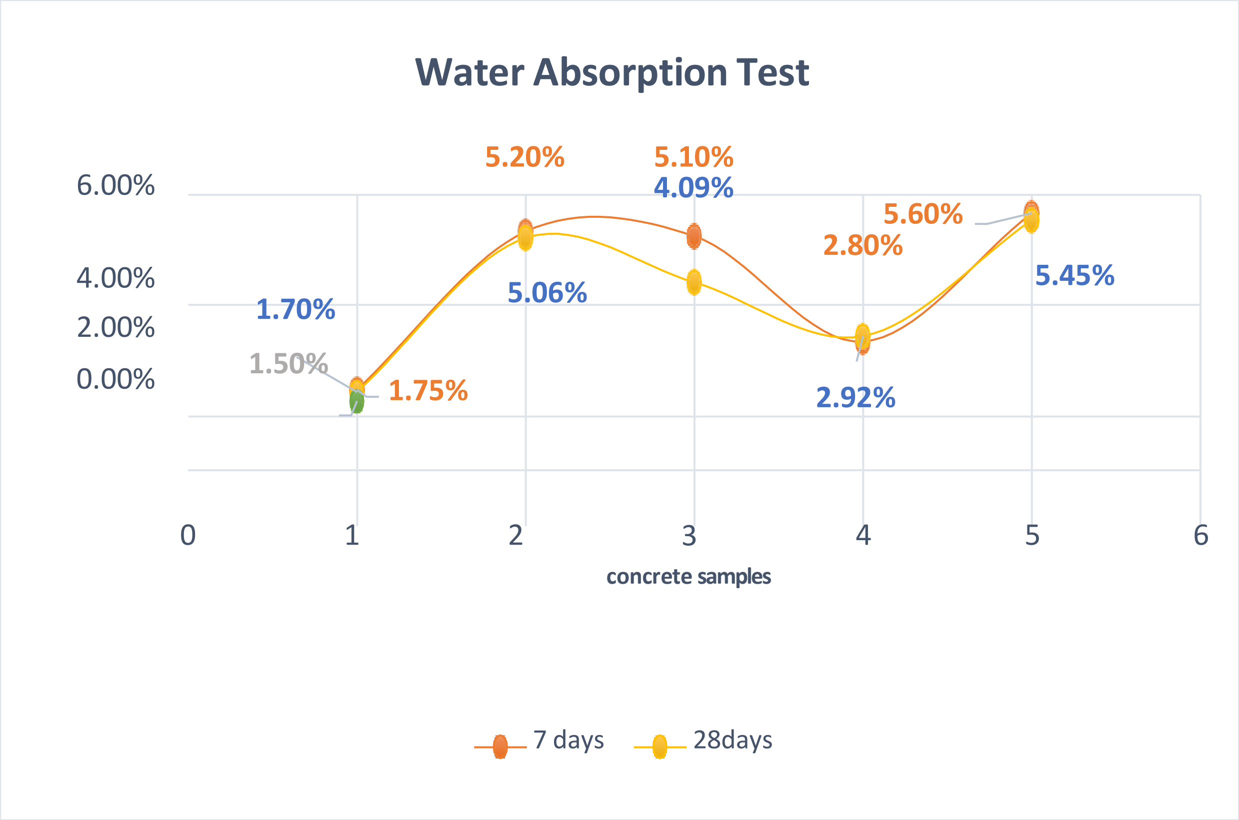


Figure 42 water absorption %

5.5 Drying Shrinkage

Construction requirements so that the concrete can be easily poured and pumped often requires the use of more than volumes of water required for continued hydration. This excesswater is then lost from the concrete base as it hardens resulting in a decrease in volume in the concrete. This dry shrinkage can, with sufficient retention in the structure and when the induced tensile stress exceeds the tensile strength in the concrete, cause cracking of the concrete component.

Figure 43. Drying shrinkage equipment

Drying shrinkage test performed for the identifying the length changes in the hydration atmospheric condition. The vertical bar graph and line graph showing the information of drying shrinkage values at 7 days and 28 days. The GGBS formation has developed length variation from 291.2 to 308 mm after the chemical curing and oven drying technics. There areonly few values changed during the testing of drying shrinkage. The following figure showing the result suggested that the GGBS formation with NA aggregate has broad amount of shrinkage after 7 days and it will dramatically decease the size under ASR condition after 28 days, which is around 289.63.

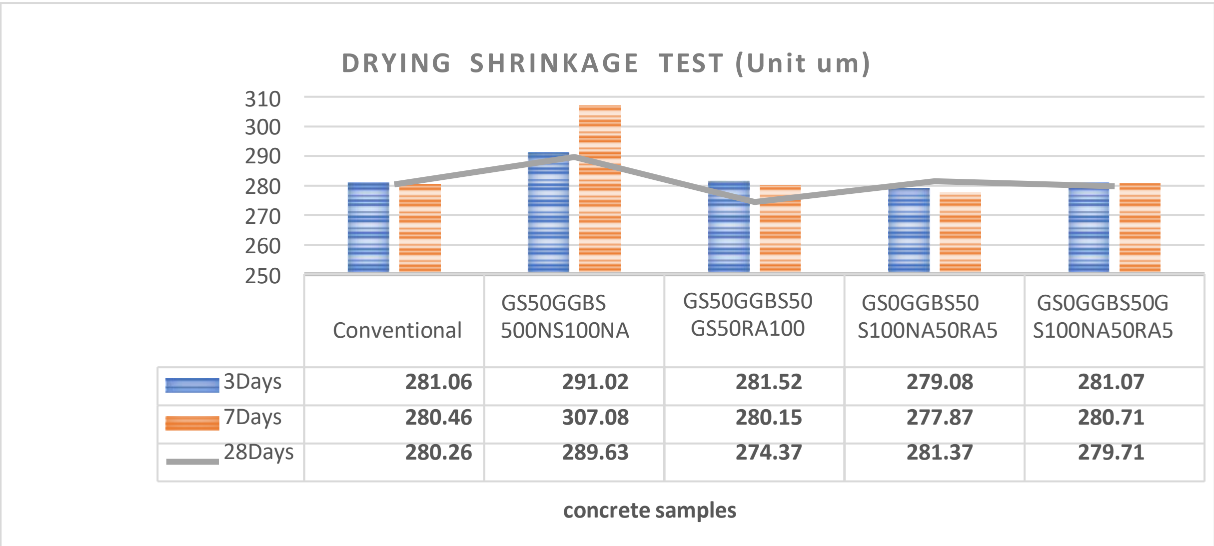


Figure 44. Drying shrinkage values (7 days vs 28 days)

displays the drying shrinkage development of all the specimens. The result clearly suggested that the NAC exhibited a lower drying shrinkage compared with waste material-based RAC at all curing ages. Furthermore, increasing the replacement ratio of either the GGBS (ground glass furnish sleg) or glass powder coarse RCA gave rise to a corresponding increase in the drying shrinkage of their host RAC. However, the RAC prepared with the GGBS formation GS50GGBS50NA100 with natural aggregate showed a higher level of drying shrinkage. For instance, the drying shrinkages of the GS50GGBS50RCA100 and GPGGBS-100 were approximately 13.5% and 22.1% lower than that of RAC-50 and RAC100 at 28d, respectively.

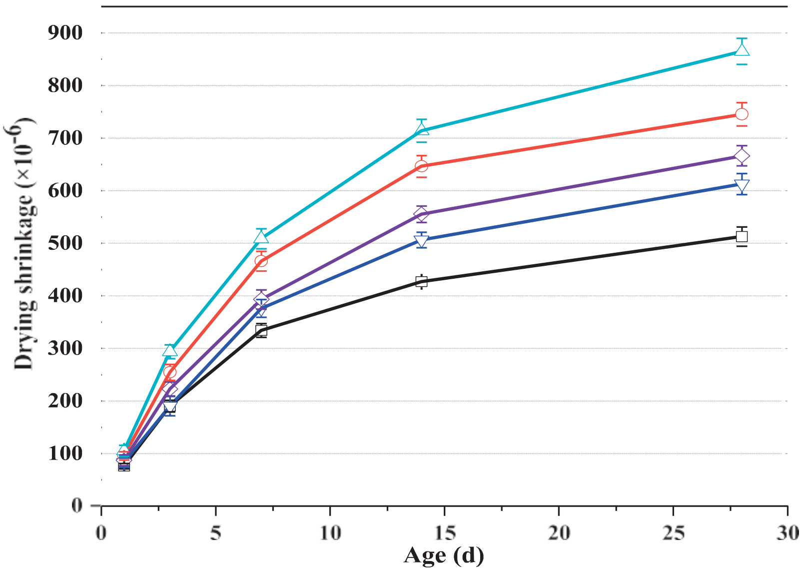


Figure 45. Drying shrinkage values of 7, 14 and 28 days

6. RESEARCH DISCUSSION

As the failure in the building of a durable and strong concrete structure may be proved as fatal and harmful for nature so in time of building them precautions should be taken at any cost. Previous research has shown that the internal deformity caused by the build-up of ASR and the characteristic cracks can be pointed as one of the prime reasons for any concrete structures losing their strength and durability. As this deformity takes time to build up so its initial presence does not seem harmful but with the passage of time, it destroys the concretestructure both from inside and outside by creating pressure due to the volume expansion by the accumulation of atmospheric water. For all these reasons stated above this is also called concrete cancer.

Alkali-silica reaction is one of the main problems of concrete structure durability that was recognized back in 1940 as a degradation mechanism. This situation happens due to the formation of a hygroscopic gel by the reaction of silica present in the fine or coarse aggregate and the alkali in the form of sodium or potassium oxide present in the cement. Thus, formed gel, which is basically hydrated sodium or potassium silicate, being hygroscopic, attracts water from the atmosphere nearby either through adsorption or through osmotic pressure (Wang, *et al*, 2021). Due to this reason, the volume expansion of the gel happens gradually and that creates pressure on the concrete structure from inside the structure and thus characteristic cracks appear in that specific concrete structure.

In this research study, the focus has been given on the investigation of the effects of the reaction on the expansion test of mortars produced with recycled aggregates. It is well knownthat the characteristic cracks of the so call 'concrete cancer' or the ASR happens as the ordinary concrete cannot withstand the pressure created by the sodium or potassium silicategel so the main test on the RAC as the replacement of the ordinary concrete and natural aggregate needs to be the expansion test. In the pre various sections, it has been discussed in a detailed manner how this RAC is prepared by crushing concrete collected from various sources (Barreto Santos, De Brito, and Santos Silva, 2020.). For the above-mentioned test, the samples were exposed to different environments to accelerate the ASR build-ups and then were tested through the mortar bar test. The results coming from these tests show the benefits of the application of RA instead of the natural ones.

For the determination of the risk status and to reduce the ASR value the implementation of the recycled aggregates into the concrete instead of the previously used natural aggregates various types of sampling has been done. In which glass sand, GGBS, natural sand and natural aggregates have been accumulated in various ratios. Also, the use of clay bricks, fly ash marble waste, and lead-zinc mine waste can be noted for the same purpose (Kulick, 2020). As a result,it was proved by the laboratory test results that the recycled aggregates were reactive for ASRfor all the right reasons. For this purpose, to test the build-up of ASR that is the formation of Na_2SiO_3 , nH_2O the sample is let to react with sodium hydroxide and hydrochloric acid of selected concentration. The results obtained from the tests are gathered for further use as the problem of ASR has become quite a headache for researchers from the construction industry.

The use of RAC in the concrete mix was introduced to reduce the cost of construction as well as to reduce the amount of concrete demolition waste (CDW) to be used in the landfills. But now it has become a trend to use the various construction waste or concrete demolition waste (CDW) to achieve significant durability and sustainability by reducing the effect of climate. However, the use of RAC depends on its previous ASR history because if the RAC is already contaminated by a high degree of ASR, it will just reduce the durability of the newly built structure even more than the expectation.

7. CONCLUSION

Alkali-Silica Reaction is a persistent problem in concrete structures caused due to the expansion of the silica mix over time. The outcome of the phenomenon is common and needsto be taken care of by processes that limit the expansion process over time. The reaction is named "concrete cancer" among civil engineers as it slowly creeps within the bound structure of the concrete structures and creates cracks that slowly brittle the whole structure. The brittle or breaking of the solid structure leads to total failure of the structure. The major problem with the concrete mixtures is the use of alkali silicate which is a necessary element in the mix. A high level of the mix will cause the structure to crack whereas too little will do the same thing but differently. ASR can cause serious damage to building foundations if the proportions of the mix are not in accordance with the requirements.

The way it functions is that the cement mix contains a mix of siliceous aggregate particles reacting with the hydroxyl ions of the alkali solutions in the cement mix. The silicate particles absorb water and branch out. The growth is slow and occurs over a long period of time, mostly a month or so. The saturation is reached when there is no more reacting substance in the mix. If the swelling of the mix is right enough it will counteract the growing force of the silica crystals to the compressive force of the structure. If the swelling is more than the compressive load or if the compressive load is more than the expansion force of the silica it will go lateral
and create cracks that later will break the structure. The process usually takes 28 days to complete with regular provision of water on the cemented structure.

Recycled Aggregate Concrete (RAC) is the material that is being tested for the reaction of alkali silicate. RAC is collected from the waste of broken concrete structures. As the name suggests, the concrete has been discarded after being broken from demolished buildings or other concrete structures. The aggregates contain not only concrete but other building materials like clay bricks, sand, and other elements. The aggregates are oftentimes in large qualities andhence these foreign elements are discarded in the best possible ways to reduce the quantities of foreign objects in concrete aggregates. The recycled aggregate is then often crushed to uniform sizes for better usefulness. The crushed concrete aggregate acts as a binding filler.

The aggregate is then fused with the Alkali silica reaction. Just like natural aggregates (NA) the recycled aggregate concrete (RAC) are potent enough to be reused as a building material. Although it does not provide the same strength as fresh concrete would, it does help reduce waste a lot as well as the cost of construction. Hence these materials are used in places where human life cannot be endangered, like building roads, footpaths, dividers, and other such structures that do not endanger human life. The statement does not imply that the structures are not strong enough, but it is not as strong as the newly unreacted concrete. The crystals formed will not be as firmly interlocked if aggregates are used rather than actual concrete and mortars.

The thesis is based on the use of Alkali-Silica Reaction using the Recycled Aggregate Concrete to test the integrity of the formed structure and test at what ratio the mix is to be used for maximum strength. The thesis ponders over the deleterious nature of the ASR on structures.

The reaction is performed on a concrete gel that is created during the mixing process and contains sodium silicate gel (N-S-H) that is the main source of expansion. The pore solutions created are collected inside the hooves or pores within the concrete structures and acceleratethe crystal formation process of the structure. The reaction takes place between the ph levelsof 0-7 of the pore solutions and thus is named as such. The thesis tests the solution for various amounts of expansions for their relative samples. The primary research done includes an experiment that contains an accelerator mortar test bar and a concrete prism test. These testsconfirm the amount of effect that ASR has on concrete structures, especially when RAC is used for constructing structures. The ASR on RAC structures are tested on different forms like surveys, literature reviews and by physically experimenting with a sample of RAC and introducing ASR for 28 days with regular watering. All samples made had varying amounts ofalkali elements in them. The samples are created by mixing components like Portland cement, sand, natural coarse aggregate, recycled coarse aggregate and glass sand.

The components were used to create sample groups with one having the normal cement, sand, and natural aggregate and the other having cement, sand, and RAC. The test reveals similar numbers for both the samples and the proportion of compounds used. The concrete, natural aggregate and sand mix performed relatively better than the RAC, confirming the factthat reused materials are fundamentally weaker alternatives to fresh compounds. The resultsare well within the expected results and hence is concluded successfully. Comparing the budget, the RAC mix fared much lesser than the normal Natural aggregates and has better cost-effectiveness or value for the money being paid to construct structures. The budget for a sample is taken and extrapolated to realize that RAC costs more than 10 times less than normal procedures.

It is found that the process of ASR on RAC will not be a problem if the material is used in places like pavements, road dividers and other such structures. Mixing of stones and rocks is an alternative that has been found in literature reviews conducted but haven't grabbed attention enough to be analyzed here. Overall, the thesis successfully tests the swelling effect of the alkali-silica gel reaction that absorbs moisture to form crystals that push concrete structuresto form cracks. The reaction is found to be beneficial if a proper mix is used and has a positive effect in binding the RAC structure together. Future studies can use this data to extrapolate the effects of ASR under various compositions to find the best composition for other aggregate materials other than natural and recycled aggregates.

8. REFFERENCES

Abbas, S., Arshad, U., Abbass, W., Nehdi, M. L., & Ahmed, A. (2020). Recycling untreated coal bottom ash with added value for mitigating alkali–silica reaction in concrete: A sustainable approach. *Sustainability*, *12*(24), 10631. https://doi.org/10.3390/su122410631

Adams, M. P., & Ideker, J. H. (2020). Using Supplementary Cementitious Materials toMitigate Alkali-Silica Reaction in Concrete with Recycled-Concrete Aggregate. *Journal of Materials in Civil Engineering*, *32*(8), 04020209.

Ahmed, H., Tiznobaik, M., Huda, S. B., Islam, M. S., & Alam, M. S. (2020). Recycled aggregate concrete from large-scale production to sustainable field application. *Construction and Building Materials*, *262*, 119979. https://doi.org/10.1016/j.conbuildmat.2020.119979

Alnaggar, M., Di Luzio, G. & Cusatis, G., (2017). Modeling time-dependent behavior of concrete affected by alkali silica reaction in variable environmental conditions. *Materials*, *10*(5), p.471.

Barreto Santos, M., De Brito, J., & Santos Silva, A. (2020). A review on alkali-silica reaction evolution in recycled aggregate concrete. *Materials*, *13*(11), 2625. https://doi.org/10.3390/ma13112625

Bueno, E.T., Paris, J.M., Clavier, K.A., Spreadbury, C., Ferraro, C.C. & Townsend, T.G., (2020). A review of ground waste glass as a supplementary cementitious material: A focus on alkali-silica reaction. *Journal of Cleaner Production*, *257*, p.120180.

De Maeijer, P.K., Craeye, B., Snellings, R., Kazemi-Kamyab, H., Loots, M., Janssens, K. & Nuyts, G., (2020). Effect of ultra-fine fly ash on concrete performance and durability. *Construction and Building Materials*, *263*, p.120493.

Duan, J., Asteris, P. G., Nguyen, H., Bui, X. N., & Moayedi, H. (2020). A novel artificial intelligence technique to predict compressive strength of recycled aggregate concrete using ICA-XGBoost model. *Engineering with Computers*, 1-18. https://doi.org/10.1007/s00366-020-01003-0

El-Hawary, M., Al-Yaqout, A., & Nouh, K. (2019, November). Durability of recycled aggregate concrete incorporating slag. In *Proceedings of the Institution of Civil Engineers-*

Bob Bornstein1, David Hocking2, Johwelvic Bacolod3 and Vute Sirivivatnanon4 1 Manager Technical Services, Baral Construction Materials Australia, The Use of Reaction Kinetics in Classifying Alkali Silica Reactivity Potential of Aggregates.

Waste and Resource Management (Vol. 172, No. 4, pp. 107-117). Thomas Telford Ltd.

Gautam, B. P., Panesar, D. K., Sheikh, S. A., & Vecchio, F. J. (2017). Multiaxial Expansion-Stress Relationship for Alkali Silica Reaction-Affected Concrete. *ACI Materials Journal*, *114*(1).

German Institute for Standardization. DIN 4226–100: Aggregates for mortar and concrete; Part 100: Recycled aggregates: DINBerlin, Germany. Japanese Industrial Standards Committee. 5023, Recycled Concrete Using Recycle

Guo, S., Dai, Q., Sun, X., Xiao, X., Si, R., & Wang, J. (2018). Reduced alkali-silica reaction damage in recycled glass mortar samples with supplementary cementitious materials. *Journal of Cleaner Production*, *172*, 3621-3633. DOI: https://doi.org/10.1016/j.jclepro.2017.11.119

Gupta, A., Gupta, N., Shukla, A., Goyal, R., & Kumar, S. (2020, April). Utilization of recycled aggregate, plastic, glass waste and coconut shells in concrete-A review. In *IOP Conference Series: Materials Science and Engineering* (Vol. 804, No. 1, p. 012034). IOP Publishing.

Jiang, K., Cheng, Z., Lou, Z., Wang, L., Lu, H., Xu, B., & Jin, N. (2021). Chemical and olfactive impacts of organic matters on odor emission patterns from the simulated construction and demolition waste landfills. *journal of environmental sciences*, *103*, 196-206.

Kazmi, S. M., Munir, M. J., Wu, Y., & Patnaikuni, I. (2020, April). Mechanical and post-cracking performance of recycled aggregate concrete incorporating synthetic fibers. In IOP Conference Series: Materials Science and Engineering (Vol. 829, No. 1, p. 012003). IOP Publishing.

Ke, G., Li, W., Li, R., Li, Y., & Wang, G. (2018). Mitigation effect of waste glass powders on alkali–silica reaction (ASR) expansion in cementitious composite. *International Journal of Concrete Structures and Materials*, *12*(1), 1-14.

Khan, M.N.N., Saha, A.K. and Sarker, P.K., 2020. Reuse of waste glass as a supplementary binder and aggregate for sustainable cement-based construction materials: A review. *Journal of Building Engineering*, *28*, p.101052.

Külekçi, G. (2021). The Effect of Pozzolans and Mineral Wastes on Alkali-silica Reaction in Recycled Aggregated Mortar. *Periodica Polytechnica Civil Engineering*. DOI: https://doi.org/10.3311/PPci.17355

Lahdensivu, J., Kekäläinen, P. & Lahdensivu, A., (2018). Alkali-silica reaction in Finnish concrete structures. Nordic Concrete Research. Publication, (59), pp.31-44.

Leemann, A. (2017). Raman microscopy of alkali-silica reaction (ASR) products formed in concrete. *Cement and Concrete Research*, *102*, 41-47.

Liang, C., Cai, Z., Wu, H., Xiao, J., Zhang, Y., & Ma, Z. (2021). Chloride transport and induced steel corrosion in recycled aggregate concrete: A review. *Construction and Building Materials*, *282*, 122547.

Liaudat, J., Carol, I. & López, C.M., (2020). Model for alkali-silica reaction expansions in concrete using zero-thickness chemo-mechanical interface elements. *International Journal of Solids and Structures*, *207*, pp.145-177.

Ma, Z., Tang, Q., Yang, D., & Ba, G. (2019). Durability studies on the recycled aggregate concrete in China over the past decade: a review. *Advances in Civil Engineering*, *2019*.

Mariaková, D., Jirkalová, Z., Fořtová, K., Pavlů, T., & Hájek, P. (2021, February). Potential alkali-silica reaction in recycled concrete. In *AIP Conference Proceedings* (Vol. 2322, No. 1, p. 020029). AIP Publishing LLC.

Martins, F. S., da Cunha, J. A. C., & Serra, F. A. R. (2018). Secondary data in research–uses and opportunities. *PODIUM sport, leisure and tourism review*, *7*(3).

Ozbakkaloglu, T., Gholampour, A., & Xie, T. (2018). Mechanical and durability properties of recycled aggregate concrete: effect of recycled aggregate properties and content. *Journal of Materials in Civil Engineering*, *30*(2), 04017275. https://doi.org/10.1016/j.conbuildmat.2020.119979

PCA. (2019). Alkali-Aggregate Reaction. *Portland Cement Association.* <Online> Retrieved from https://www.cement.org/learn/concrete-technology/durability/alkali-aggregate-reaction [Accessed on 9 September 2021]

Ramjan, S., Tangchirapat, W., & Jaturapitakkul, C. (2018). Influence of bagasse ash with different fineness on alkali-silica reactivity of mortar. *Materiales de Construcción*, *68*(332), 169.

Ramjan, S., Tangchirapat, W., Jaturapitakkul, C., Chee Ban, C., Jitsangiam, P., & Suwan, T. (2021). Influence of Cement Replacement with Fly Ash and Ground Sand with Different Fineness on Alkali-Silica Reaction of Mortar. *Materials*, *14*(6), 1528. https://doi.org/10.3390/ma14061528

Rashidian-Dezfouli, H., Afshinnia, K., & Rangaraju, P. R. (2018). Efficiency of Ground Glass Fiber as a cementitious material, in mitigation of alkali-silica reaction of glass aggregates in mortars and concrete. *Journal of Building Engineering*, *15*, 171-180.

Revilla-Cuesta, V., Skaf, M., Faleschini, F., Manso, J. M., & Ortega-López, V. (2020). Self-compacting concrete manufactured with recycled concrete aggregate: An overview. *Journal Of Cleaner Production*, *262*, 121362.

Shi, Z., Park, S., Lothenbach, B., & Leemann, A. (2020). Formation of shlykovite and ASR-P1 in concrete under accelerated alkali-silica reaction at 60 and 80° C. *Cement and Concrete Research*, *137*, 106213. DOI: https://doi.org/10.1016/j.cemconres.2020.106213

Shi, Z., Shi, C., Wan, S. & Ou, Z., (2017). Effect of alkali dosage on alkali-silica reaction in sodium hydroxide activated slag mortars. *Construction and Building Materials*, *143*, pp.16-23.

Sun, L., Zhu, X., Zhuang, X., & Zi, G. (2020). Chemo-mechanical model for the expansion of concrete due to alkali silica reaction. *Applied Sciences*, *10*(11), 3807.

Taylor, B., Henshall, C., Kenyon, S., Litchfield, I., & Greenfield, S. (2018). Can rapid approaches to qualitative analysis deliver timely, valid findings to clinical leaders? A mixed methods study comparing rapid and thematic analysis. *BMJ open*, *8*(10), e019993.

Teramoto, A., Watanabe, M., Murakami, R., & Ohkubo, T. (2018). Visualization of internal crack growth due to alkali–silica reaction using digital image correlation. *Construction and Building Materials*, *190*, 851-860.

Tittarelli, F., Giosuè, C., & Mobili, A. (2018). Recycled glass as aggregate for architectural mortars. *International Journal of Concrete Structures and Materials*, *12*(1), 1-11.

Verian, K. P., Ashraf, W., & Cao, Y. (2018). Properties of recycled concrete aggregate and their influence in new concrete production. *Resources, Conservation and Recycling*, *133*, 30-49.

Viganó, J., Braccini, A.L., Schuster, I. & Menezes, V.M.P.S., (2018). Microsatellite molecular marker-assisted gene pyramiding for resistance to Asian soybean rust (ASR). *Acta Scientiarum. Agronomy*, *40*.re

Wang, B., Yan, L., Fu, Q. & Kasal, B., (2021). A Comprehensive Review on Recycled Aggregate and Recycled Aggregate Concrete. *Resources, Conservation and Recycling*, *171*, 105565.

Wang, B., Yan, L., Fu, Q. and Kasal, B., 2021. A Comprehensive Review on Recycled Aggregate and Recycled Aggregate Concrete. *Resources, Conservation and Recycling*, *171*, p.105565.

Wright, J. R. (2021). Developing Predictive Tools and Guidance to Increase the Durability of Concrete Infrastructure by Reducing Alkali-Silica Reaction (ASR) and Early-Age Cracking.

Zhu, Y. (2020). *Assessing Condition on Alkali-Silica Reaction (ASR) Affected Recycled Concrete* (Doctoral dissertation, Université d'Ottawa/University of Ottawa). 1-60.

9. APPENDIX

9.1 Laboratory safety induction

Process to the drawing of work on sites and in the concrete laboratories. Safety induction was the first step of the research. The safety induction was completed for both the location of concrete laboratories such as concrete materials mixing lab and concrete sample testing lab. The reason behind this induction was introducing with safety mitigation strategies. The general lab safety included in this induction such as preparing TRA and completing safety forms, food and drinks are prohibited in the library.

9.2 Risk management

Risk assessment was the most important part of the research for this laboratory experiment. The purpose of the risk assessment is identified the hazardous risks by the used of different chemical products and experiment on concrete conducting equipment's. The risk assessments are defining in different level of stages. The safety stages are depended on the level of hazardous situations. Once the risks have been viewed and evaluated, removable strategies are developed in accordance with the Hierarchy of Risk Management in the following figure.

The following figure 13 discussing the risk matrix information with all the control hierarchy such as remove hazard, fume cupboard and gloves and other protective equipment. The probabilities of these hazards indicate with colors of green, yellow, and red with the consequence's performance of low, medium, and high respectively.

Table 13 Risk matrix table

Consequence	Very likely	Likely	Possible	Unlikely	Highly unlikely	Elimination	*Remove hazard*
Fatality	Extreme	High	High	High	Medium	Substitution	*Use a less hazardous alternative*
Major injury	High	High	High	Medium	Medium	Isolation	*Restrict access, use in a closed container*
Minor injury	High	Medium	Medium	Medium	Medium	Engineering	*Fume cupboard*
First aid	Medium	Medium	Medium	Low	Low	Administration	*Eg:Training, Safe Work Procedure*
Negligible	Medium	Medium	Low	Low	Low	PPE - Personal Protective Equipment	*Eg: Gloves, respirator, safety glasses*

Prioritising Hazards			
Risk Level	**Prio rity**	**Action**	**Timeframe for implementation of corrective action**
Extreme	**1**	The activity should cease immediately and short term safety controls implemented. Notify manager and assess activity.	Immediate
High	**2**	Implement short term safety measures immediately. Notify manager and assess activity.	Within 24 hours
Medium	**3**	Implement short term safety controls. Notify manager and assess activity.	Within 14 days
Low	**4**	Implement long term safety controls. Notify manager and assess activity.	Within 28 days (if possible) or demonstrate that it is not reasonably practicable to achieve further minimization of the risk

See Risk Management Policy for further details.

Table 14 Identification of risks and controls

Identified Hazards		Risk Assessment		Risk Level	Required Controls	Controls implemented		Residual Risk		Risk Level
	Description	Consequences ?	Likelihood ?			Yes	No	Consequences ?	Likelihood ?	
1. THE CHEMICAL:	1.5 Potential for skin contact	Minor injury	Possible	MEDIUM	Chem gloves (Butyl/Neoprene), Glasses, masks. Nitrile gloves are suitable for short term exposure if better alternative is unavailable.	☒	☐	First aid	Unlikely	LOW
	1.6 Potential for eye contact	Major injury	Possible	HIGH	Chem gloves (Butyl/Neoprene), Glasses, masks. Nitrile gloves are suitable for short term exposure if better alternative is unavailable. Be aware of location of emergency eye wash.	☒	☐	First aid	Unlikely	LOW
	1.4 Can be breathed in	Major injury	Possible	HIGH	Use in fume cupboard/hood. Suitable respirator/face mask to be worn if mechanical extraction unavailable - refer to MSDS.	☒	☐	First aid	Highly unlike	LOW
	-Select-	-Select-	-Select-	-Select-		☐	☐	-Select-	-Select-	-Select-
	-Select-	-Select-	-Select-	-Select-		☐	☐	-Select-	-Select-	-Select-
	-Select-	-Select-	-Select-	-Select-		☐	☐	-Select-	-Select-	-Select-
	-Select-	-Select-	-Select-	-Select-		☐	☐	-Select-	-Select-	-Select-
2. THE PROCESS:	2.1 Can be breathed in due to particular action	First aid	Unlikely	LOW	Use in fume cupboard/hood. Suitable respirator/face mask to be worn if mechanical extraction unavailable - refer to MSDS.	☒	☐	First aid	Highly unlike	LOW
	2.4 Can contact skin due to particular actions	Major injury	Likely	HIGH	Gloves must be worn when handling chemicals. Lab coat must be worn. Enclosed footwear must be worn at all times. Wash hands after use. Nitrile gloves are suitable for short term exposure if better alternative is unavailable.	☒	☐	Minor injury	Possible	MEDIUM
	2.6 Is transferred: container compatible/label?	Major injury	Possible	HIGH	Do not use aluminium or galvanised steel containers. Only plastic or plastic lined containers to be used for storing, transporting and using chemicals. Refer manufacturers reccomendations. Sodium Hydroxide can react violently with water/moisture - ALWAYS add material to water and NEVER water to material. Ensure work area is dry.	☒	☐	Major injury	Highly unlike	MEDIUM
	-Select-	-Select-	-Select-	-Select-		☐	☐	-Select-	-Select-	-Select-
	-Select-	-Select-	-Select-	-Select-		☐	☐	-Select-	-Select-	-Select-
3. THE WORK	-Select-	-Select-	-Select-	-Select-		☐	☐	-Select-	-Select-	-Select-
ENVIRONMENT:	-Select-	-Select-	-Select-	-Select-		☐	☐	-Select-	-Select-	-Select-
	-Select-	-Select-	-Select-	-Select-		☐	☐	-Select-	-Select-	-Select-
	-Select-	-Select-	-Select-	-Select-		☐	☐	-Select-	-Select-	-Select-
4. INDIVIDUAL/USER	4.7 Unaware of consequences of mixing chem	Fatality	Possible	HIGH	Refer to MSDS for guidance on safe handling and mixing.	☒	☐	Negligible	Unlikely	LOW
CHARACTERISTICS:	-Select-	-Select-	-Select-	-Select-		☐	☐	-Select-	-Select-	-Select-
	-Select-	-Select-	-Select-	-Select-		☐	☐	-Select-	-Select-	-Select-
5. MANAGEMENT:	-Select-	-Select-	-Select-	-Select-		☐	☐	-Select-	-Select-	-Select-
	-Select-	-Select-	-Select-	-Select-		☐	☐	-Select-	-Select-	-Select-
	-Select-	-Select-	-Select-	-Select-		☐	☐	-Select-	-Select-	-Select-

S:\CSE-CSEM esg\Workplace Health and Safety\Risk Assessments & Safe Work Procedures\RA's + SWP's - AWAITING APPROVAL\RA_Sodium Hydroxide Pellet, HCl (Hydrochloric Acid) ENG-00093.docx

Page **2** of **3**

9.3 Task Allocation and Breakdown structure

- **Work breakdown structure**

The current study has maintained three different areas to evaluate the research objectives. It started with a thorough literature review on RCA and the impact of ASR on concrete structures. The literature review will provide information regarding the RCA and the replacement of RCA with old materials in reducing the ASR rate. It will then help in comparing the old and new concrete samples to identify their durability. The second element at the WBS is the laboratory examination with the old concrete element. It is linked with preparing the concrete cube and conducting ASR tests with specific duration gaps. It will help in finalizing the result of ASR conducting on the concrete samples. The work breakdown structure diagram attached in the appendix 8.

- **Gantt bar task information**

The current master thesis has been started on 04-03-2021 and is expected to finish by 04-11-2021. The initial stage is related to the topic selection, project registration, literature review, identifying the project aim and objectives, considering the project budget and resources, and analyzing the project risks. The project proposal has been submitted by 31st March 2021. The data collection and analysis stage are related to the laboratory tests to calculate the ASR rate and conducting tests with existing methods. The current study has been delivered within 4th November 2021 and there was a result seminar for submitting the generated result. The university expo helped in finalizing the current study. All project management included Gantt bar chart image is explaining in the appendix 9.

- **Stakeholders**

The current research is going to have several stakeholders who are interested in the research being conducted successfully. It includes the people directly involved in the conduction of the research as well as the people who are going to be more affected by the results that are going to be published as a product of the research work conducted. Some of the groups of the stakeholders that are concerned with the research project are the support teams for the education reports, the governmental and the private bodies as well as the other group of industries. The table below tabulates the stakeholder of the current research project. The table of stakeholder's information including in the appendix 1

9.4 Ethical consideration

Maintaining ethical aspects in any research process throughout all the stages of planning and execution of the tests are mandatory. For this reason, in this thesis during the conduction of tests and collection of data that care has been taken to maintain ethics. The following things have been considered,

- Acknowledgement of the works of the previous research has been done.

- Maintaining objectivity in discussion and analysis.
- Not accepting any illegal or unethical measures

For the survey process, the current study has been maintained the following ethical considerations,

- The participants were anonymous, and the current study has not disclosed their personal details. The only detail that the current study has is related to their position atthe construction industry
- The current research has presented their participation without fabricating any information
- The participants were given the right to withdraw from the survey.

9.5 Risk management

The measurement of risk can be done with the help of the following risk assessment method that uses the severity indices in the current details and the risk management ratings that are applied in the further tables.

Before the conduction of the research work, all the three problems that might be encountered were considered for the research purposes. During the research work, the problem that was encountered was the errors that were seen in the laboratory equipment while pursuing the concrete tasks. Although the likelihood of the errors occurring is significantly low, some errors did creep up during the conduction of the research work whichmade it necessary for the researcher to seek for professional help to move ahead with the research work.
The instrument was taken care of at the earliest with the necessary fittings and repair. Some minor adjustments were necessary for the physical body of the instrument and the instrument was working in a good manner to provide better results. The fixing problems beingencountered in the machine were the reason for the repair being felt necessary to get the appropriate results. The errors were seen to be wrong in nature.

The results being obtained were removed from the initial work and a fresh set of the results data were obtained to be presented in the research work. For mitigation purposes, the testswere completed under the supervision of the supervisor to prevent any further miscalculations to affect the course of the study being conducted during the research work. This ensured that the results received from the research project were free of errors to the extent possible. The observation of the supervisor was necessary to reduce the occurrence oferrors in the research project.

Table 15. Risk Management 1

Risk management 1	
Description of therisk	Effects on the environment on both of the ordinary cubes made ofconcrete and the recycled aggregate concrete cubes
Indication of the likelihood of the risk	Possible
Indication of theseverity	Moderate
Results of the occurrence of therisk	The cubes are observed to be from the environmental gases from the atmosphere and the cubes are seen to be impacted not in a direct manner from the results
The strategy adopted for the mitigation	The cube is properly covered, and the proper curing is required for testing the results among the 28 days being considered for the conduction of the research project

Table 16. Risk Management 2

Risk management 2	
Description of the risk	Errors in the laboratory equipment that are seen while doingthe tests relate to the concrete
Indication of the likelihood of the risk	Unlikely
Indication of theseverity	Minor
Results of the occurrence of the risk	Some problems are seen to arise that are related to the fixingof the pieces of equipment and are also damaged. It is also seen to lead to the calculation of wrong results.

Risk management 3	
Description of the risk	Problems that might be faced with the recycled concrete of theaggregate nature
Indication of the likelihood of the risk	Rare
Indication of theseverity	Insignificant
Results of the occurrence of the risk	The recycled aggregate concrete is not found to be available from the construction sites as well as recycled waste materials are collected from the other resources
The strategy adoptedfor the mitigation	Nearby demolition sites need to be found out

Figure *46*. Appendix 1 Specific gravity results of natural sand and RCA

	NCA		
	Sample 1	Sample 2	Average
Wt of Dry Agg +Pan	2450	2450	2450
Dry Agg	1932.3	1932.3	1932.3
SSD + Pan weight	2483.9	2483.5	2483.7
Wt of Pan	517.7	517.7	517.7
SSD (c)	1966.2	1965.8	1966
Wt of Basket + chain In water	1617.19	1617.19	1617.19
Wt of Chain	281.8	281.8	281.8
wt of empty basket in water B	1335.39	1335.39	1335.39
Wt of NCA + Basket + chain in water	2950.75	2897.54	2924.145
wt of NCA + Bucket in water A	2668.95	2615.74	2642.345
saturated Agg	1333.56	1280.35	1306.955
Oven dried Sample + Pan	2473.5	2474.6	2474.05
Dried NCA	1953.6	1939.5	1946.55
Specific Gravity	3.088012	2.8295280	2.95877
Apparent S.G	3.150764	2.942425851	3.04341
Water Absorption	1%	1.4%	1.0%
Bulk SG	3.107929	2.867897002	2.983104

RCA			
	Sample 1	Sample 2	Average
Wt of Dry Agg +Pan	2300	2300	2300
Dry Agg	1782.3	1782.3	1782.3
SSD + Pan weight	2484.3	2484.3	2484.3
Wt of Pan	517.7	517.7	517.7
SSD (c)	1964.8	1966.6	1965.7
Wt of Basket + chain In water	1617	1617.19	1617.095
Wt of Chain	281.8	281.8	281.8
wt of empty basket in water B	1335.2	1335.39	1335.295
Wt of NCA + Basket + chain in water	2795.58	2805.4	2800.49
wt of NCA + Bucket in water A	2513.78	2523.6	2518.69
saturated Agg	1178.58	1188.21	1183.395
Oven dried Sample + Pan	2328.6	2329.1	2328.85
Dried NCA	1840.5	1844.5	1842.5
Specific Gravity	2.340948	2.36963	2.355291
Apparent S.G	2.780547	2.8105	2.795521
Water Absorption	6.8%	6.6%	6.7%
Bulk SG	2.499046	2.5265	2.512703

Figure 47 Appendix 2 Specific gravity results of Glass sand and NS

Pan weight	556.4	556.4	556.4
Saturated surface dried FA	500	500	500
measuring equipment + sample+water	3223.5	3229.5	3226.5
measuring equipment+water	2910.5	2911.4	2910.95
Oven dried sample	1050.4	1052.6	1051.5
Pan - oven dried	494	496.2	495.1
Specific gravity	2.64	2.72	2.68
Apperent S.G	2.72	2.78	2.75
Water Absorption	1.21%	0.80%	1.10%

Pan weight	556.4	556.4	556.4
Saturated surface dried FA	500	500	500
measuring equipment + sample+water	3245.2	3254.7	3249.95
measuring equipment+water	2951.4	2951.5	2951.45
Oven dried sample	1045.9	1043.7	1044.8
Pan - oven dried	489.5	487.3	488.4
Specific gravity	2.37	2.41	2.39
Apperent S.G	2.5	2.51	2.505
Water Absorption	2.14%	2.18%	2.16%

Figure 48 Appendix 3 Particle size distribution (Coarse aggregate)

Sieve	Weight of empty sieve	Weight of soil retained + sieve	Retained material	Persentage of retained	Camulative retained	Pecentage of passing
	A Gm	B Gm	C Gm	%	%	%
26.5mm	1553.9	1553.9	0	0	0	100
19.00mm	1471.8	1471.8	0	0	0	100
16.00mm	1430.7	1441.5	10.8	2.158187123	2.15	97.85
13.20mm	1302.1	1466.1	164	32.77247112	34.92247112	65.07752888
9.60mm	1243.1	1547.2	304.1	60.76895408	95.6914252	4.308574797
6.70mm	1207.49	1224.7	17.21	3.439111147	99.13053635	0.869463651
4.75mm	1226.3	1226.3	0	0	99.568845	0.431155
Pan	844.79	849.1	4.31	0.861276528	100	0
			500.42			368.5367223

4.68 FINENESS MODULEF

Material q 500gm

ted material or 849.1 GM

Sieve	Weight of empty sieve	Weight of soil retained + sieve	Reained material	Persentage of retained	Camulative retained	Pecentage of passing
	A	B	C	%	%	%
2.36 mm	517.4	517.7	0.3	7.142857143	7.14	92.86
1.18 mm	497.1	497.3	0.2	4.761904762	11.90190476	88.09809524
600 um	450.1	450.2	0.1	2.380952381	14.28285714	85.71714286
425 um	428.2	428.3	0.1	2.380952381	16.66380952	83.33619048

Figure 49 Appendix 4 Particle size distribution (Fine aggregate)

	A Gm	B Gm	C Gm	%	%	%
26.5mm	1553.9	1553.9	0	0	0	100
19.00mm	1471.8	1471.8	0	0	0	100
16.00mm	1430.7	1430.7	0	0	0	100
13.20mm	1302.1	1302.1	0	0	0	100
9.60mm	1243.1	1255	11.9	3.085939526	3.085939526	96.91406047
6.70mm	1207.49	1319.6	112.11	29.07266221	32.15860173	67.84139827
4.75mm	1226.3	1358.1	131.8	34.17872517	66.3373269	33.6626731
Pan	844.79	974.6	129.81	33.6626731	100	0
			385.62			598.4181318

5.98 FINENESS MODULER

material or 974.69

Sieve	Weight of empty sieve	Weight of soil retained + sieve	Reained material	Persentage of retained	Camulative retained	Pecentage of passing
	A	B	C	%	%	%
2.36 mm	517.4	588.1	70.7	54.21779141	7.14	92.86
1.18 mm	497.1	510.3	13.2	10.12269939	17.26269939	82.73730061
600 um	450.1	456	5.9	4.524539877	21.78723926	78.21276074
425 um	428.2	431.4	3.2	2.45398773	24.24122699	75.75877301
300 um	424.7	428.2	3.5	2.68404908	26.92527607	73.07472393
150 um	393.4	403.3	9.9	7.59202454	34.51730061	65.48269939
75 um	404.7	412.9	8.2	6.288343558	40.80564417	59.19435583

Figure 50 Appendix 5 Particle size distribution (Recycled Aggregate)

Sieve	Weight of empty sieve	Weight of soil retained + sieve	Reained material	Persentage of retained	Camulative retained	Pecentage of passing
	A gm	B gm	C gm	%	%	%
2.36 mm	517.4	531.3	13.9	1.388750125	1.4	98.6
1.18 mm	497.1	512.9	15.8	1.578579279	2.978579279	97.02142072
600 um	450.1	570	119.9	11.9792187	14.95779798	85.04220202
425 um	428.2	651.8	223.6	22.3398941	37.29769208	62.70230792
300 um	424.7	683.9	259.2	25.89669298	63.19438505	36.80561495
150 um	393.4	698.7	305.3	30.50254771	93.69693276	6.303067239
75 um	404.7	463	58.3	5.824757718	99.52169048	0.478309521
Pan	398	402.9	4.9	0.489559397	100	0
			1000.9		213.5253872	386.4746128
					2.13	3.86 Fineness M

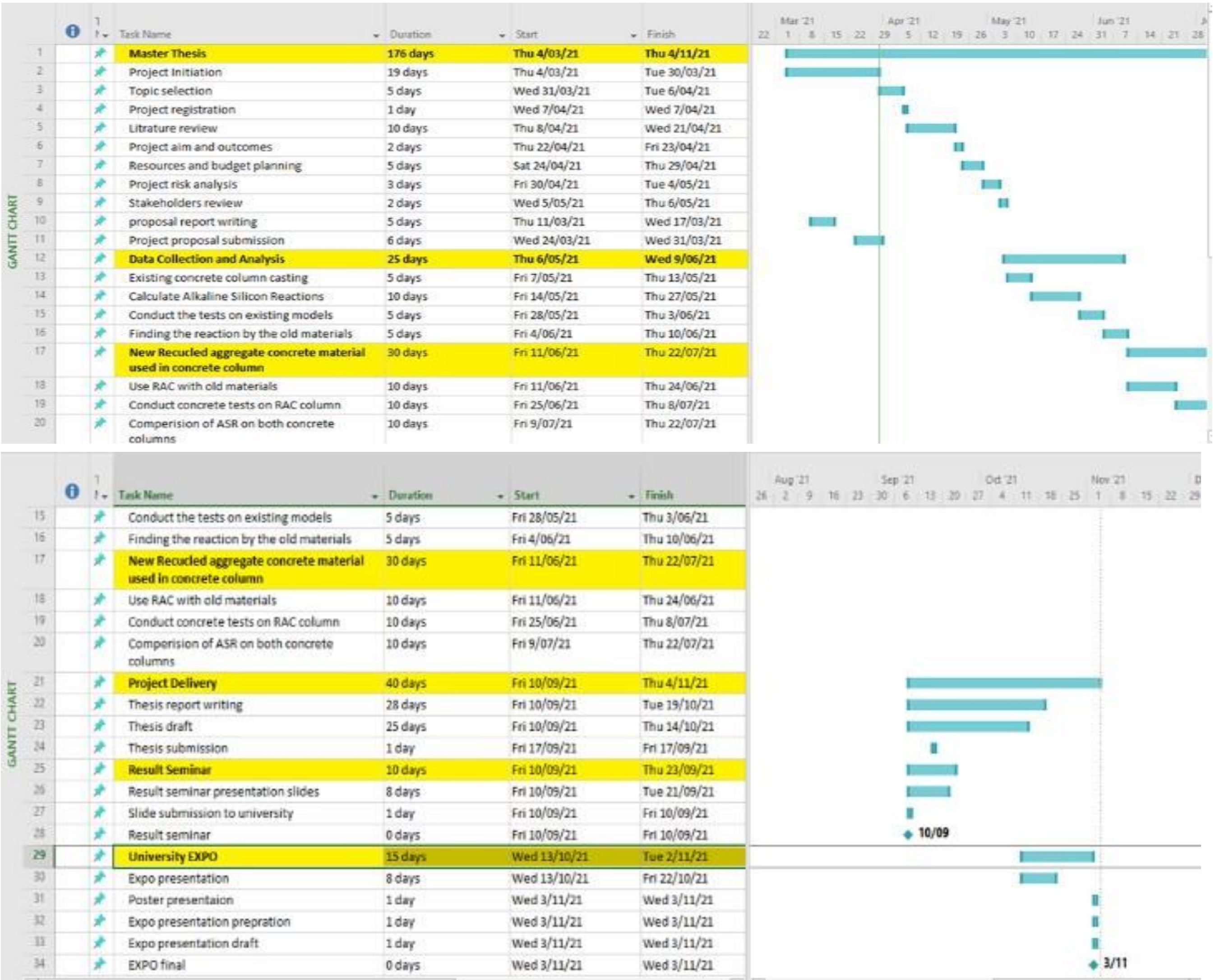
Semple siz 1000 gm

Sieve	Weight of empty sieve	Weight of soil retained + sieve	Reained material	Persentage of retained	Camulative retained	Pecentage of passing
	A gm	B gm	C gm	%	%	%
2.36 mm	517.4	517.4	0	0	1.4	98.6
1.18 mm	497.1	497.7	0.6	0.060204696	1.460204696	98.5397953
600 um	450.1	450.7	0.6	0.060204696	1.520409392	98.47959061
425 um	428.2	430.1	1.9	0.190648204	1.711057596	98.2889424
300 um	424.7	426.8	2.1	0.210716436	1.921774032	98.07822597
150 um	393.4	398.2	4.8	0.481637568	2.403411599	97.5965884
75 um	404.7	1101.8	697.1	69.9478226	72.3512342	27.6487658
Pan	398	687.5	289.5	[illegible]	100	0

Figure 51 Appendix 6 Broken water material concrete sample

Figure 52 Appendix 7 28 days Asr affected concrete columns

Figure 53 Appendix 8 Gantt bar chart



	Task Name	Duration	Start	Finish
1	**Master Thesis**	**176 days**	**Thu 4/03/21**	**Thu 4/11/21**
2	Project Initiation	19 days	Thu 4/03/21	Tue 30/03/21
3	Topic selection	5 days	Wed 31/03/21	Tue 6/04/21
4	Project registration	1 day	Wed 7/04/21	Wed 7/04/21
5	Litrature review	10 days	Thu 8/04/21	Wed 21/04/21
6	Project aim and outcomes	2 days	Thu 22/04/21	Fri 23/04/21
7	Resources and budget planning	5 days	Sat 24/04/21	Thu 29/04/21
8	Project risk analysis	3 days	Fri 30/04/21	Tue 4/05/21
9	Stakeholders review	2 days	Wed 5/05/21	Thu 6/05/21
10	proposal report writing	5 days	Thu 11/03/21	Wed 17/03/21
11	Project proposal submission	6 days	Wed 24/03/21	Wed 31/03/21
12	**Data Collection and Analysis**	**25 days**	**Thu 6/05/21**	**Wed 9/06/21**
13	Existing concrete column casting	5 days	Fri 7/05/21	Thu 13/05/21
14	Calculate Alkaline Silicon Reactions	10 days	Fri 14/05/21	Thu 27/05/21
15	Conduct the tests on existing models	5 days	Fri 28/05/21	Thu 3/06/21
16	Finding the reaction by the old materials	5 days	Fri 4/06/21	Thu 10/06/21
17	**New Recucled aggregate concrete material used in concrete column**	30 days	Fri 11/06/21	Thu 22/07/21
18	Use RAC with old materials	10 days	Fri 11/06/21	Thu 24/06/21
19	Conduct concrete tests on RAC column	10 days	Fri 25/06/21	Thu 8/07/21
20	Comperision of ASR on both concrete columns	10 days	Fri 9/07/21	Thu 22/07/21

	Task Name	Duration	Start	Finish
15	Conduct the tests on existing models	5 days	Fri 28/05/21	Thu 3/06/21
16	Finding the reaction by the old materials	5 days	Fri 4/06/21	Thu 10/06/21
17	**New Recucled aggregate concrete material used in concrete column**	30 days	Fri 11/06/21	Thu 22/07/21
18	Use RAC with old materials	10 days	Fri 11/06/21	Thu 24/06/21
19	Conduct concrete tests on RAC column	10 days	Fri 25/06/21	Thu 8/07/21
20	Comperision of ASR on both concrete columns	10 days	Fri 9/07/21	Thu 22/07/21
21	**Project Delivery**	40 days	Fri 10/09/21	Thu 4/11/21
22	Thesis report writing	28 days	Fri 10/09/21	Tue 19/10/21
23	Thesis draft	25 days	Fri 10/09/21	Thu 14/10/21
24	Thesis submission	1 day	Fri 17/09/21	Fri 17/09/21
25	**Result Seminar**	10 days	Fri 10/09/21	Thu 23/09/21
26	Result seminar presentation slides	8 days	Fri 10/09/21	Tue 21/09/21
27	Slide submission to university	1 day	Fri 10/09/21	Fri 10/09/21
28	Result seminar	0 days	Fri 10/09/21	Fri 10/09/21
29	**University EXPO**	15 days	Wed 13/10/21	Tue 2/11/21
30	Expo presentation	8 days	Wed 13/10/21	Fri 22/10/21
31	Poster presentaion	1 day	Wed 3/11/21	Wed 3/11/21
32	Expo presentation prepration	1 day	Wed 3/11/21	Wed 3/11/21
33	Expo presentation draft	1 day	Wed 3/11/21	Wed 3/11/21
34	EXPO final	0 days	Wed 3/11/21	Wed 3/11/21

Figure 54 Appendix 9 work breakdown structure

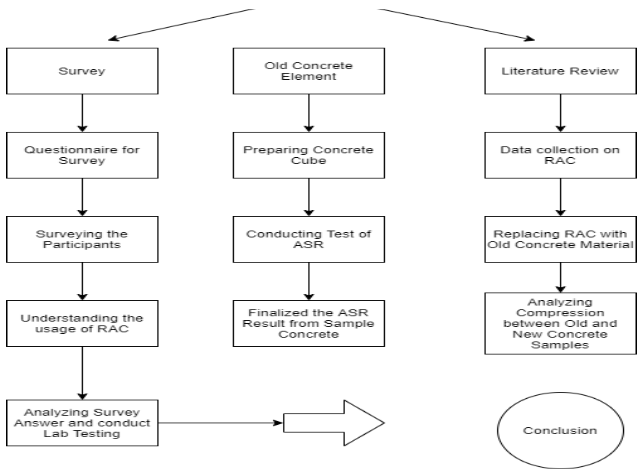


Table 17 Appendix 10 Stakeholders

Name of the stakeholder	**Role of the stakeholder in the project**	**Mode of assistance provided**	**Communication method**	**Regularity needed for the communication**
Yash Patel	As a student	Completion of the project on time for submission with results	The student himself	The student himself
Aliakbar Gholampour	Works as a supervisor	Helped for the completion of the project with the required guidance	Through emails, wells by meeting the person personally	Twice a month
Wes's perry	Team for the engineering services	For the engineering assistance required during the completion of the project	With emails	A single month
Concrete Institute of Australia	Standards set in Australia	Helped in the completion of the research work since the research is in the concerned department	Through emails	NIL