

EXPERIMENTAL STUDY ON SELF COMPACTING CONCRETE USING RECYCLED BRICK AGGREGATES AND STEEL FIBERS IN BEAMS.

Submitted in partial fulfillment of the requirement for the
award of degree of Master of Engineering in Structural engineering

Submitted by,

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of **KAVIRAJ D (Reg No: 41380009)** who carried out the project entitled “**ANALYTICAL AND EXPERIMENTAL STUDY ON THE FLEXURAL BEHAVIOR OF SELF COMPACTING CONCRETE USING STEEL FIBER AND RECYCLED CONCRETE AGGREGATES**” under our supervision from December 2022 to May 2023.

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ABSTRACT

Self-compacting concrete, often referred to as self-consolidating consolidating concrete, can flow, consolidate, and almost entirely dehydrate while flowing in the form work. It is sufficient to completely occupy all available space without segregation or bleeding. This forces SCC to be used to its fullest capacity in areas that cannot properly compact. Most concrete failures are caused by incorrect concrete compaction, which can be prevented by doing so. The optimum answer is self-compacting concrete, and we may reduce waste during structure destruction by using recycled brick materials as a partial replacement for aggregates.

While other waste recycled aggregates have been used in numerous research projects, only a small amount of work has used recycled brick aggregates (RBA). In order to determine whether RBA might be used in SCC, a thorough investigation has been conducted in this paper. The percentages of RBA and steel fibres (SF) combined with the appropriate dosages of super plasticizer (SP) were varied over a series of studies on the fresh state properties of SCC until the perfect mixture proportion was attained. The beam and cubes were then cast and maintained for a maximum of 28 days of cure. Following that, the model is examined using the Finite Element Analysis (FEA) programme Abaqus.

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LIST OF SYMBOLS AND ABBREVIATIONS

ACRONYMS	EXPANSIONS
3D	3 Dimension
CO ₂	Carbon di oxide
FEA	Finite element analysis
GGBS	Ground Granulated Blast-furnace Slag
NA	Natural aggregate
RA	Recycled aggregate
RAC	Recycled aggregate concrete
RBA	Recycled brick aggregate
RBAC	Recycled brick aggregate concrete
RCA	Recycled concrete aggregate
SCC	Self Compacting Concrete
SC	Steel fibers
RBA	Recycled brick aggregates

CHAPTER 1

1. INTRODUCTION

1.1. GENERAL

Self-compacting concrete (SCC) has gained acceptance worldwide in recent years due to its many advantages over conventional concrete. SCC is a highly flowable and homogeneous concrete mix that can fill and compact in every corner of the formwork under its self-weight, without the need for external vibration. One of the key advantages of SCC is its ability to produce durable concrete structures, which is essential for ensuring long-lasting and high-quality concrete constructions. SCC can achieve high strength and durability by eliminating the risk of segregation and reducing the number of voids in the concrete mix. In addition, the enhanced fluidity of SCC enables it to be used in structures with congested and complicated reinforcements. This makes it an ideal choice for constructing buildings and structures that require complex geometries and intricate shapes. Moreover, the elimination of the need for external vibration reduces noise pollution, which is beneficial for workers and nearby residents. The self-compacting nature of SCC also results in a safer and more efficient construction process by reducing the need for manual labour and the risk of injury. Overall, the use of SCC has many benefits for the construction industry, and its popularity is likely to continue to grow in the future.

1.1.1. Self-Compacting Concrete

Self-compacting concrete, also referred to as SCC, is a type of concrete that can fill intricate and crowded spaces without the need for vibration or compaction. It has good flowability and deformability. Due to its numerous benefits, SCC, a relatively recent development in concrete technology, has grown in popularity in recent years..

SCC is typically made using a combination of high-range water reducers, viscosity-modifying agents, and sometimes superplasticizers. These additives improve the flowability of the concrete and allow it to be placed and compacted without the need for external vibration.

SCC is commonly used in applications where traditional concrete placement techniques are difficult or impossible, such as in heavily reinforced structures, complex architectural shapes, and areas with limited access. It also has several benefits, including increased durability, better surface finish, reduced labor costs, and improved safety on construction sites.

However, SCC requires careful mix design, quality control, and testing to ensure its performance and durability. Therefore, it is essential to use experienced contractors and engineers who have the necessary knowledge and expertise to work with SCC.

1.1.2. History Of Self Compacting Concrete

Self-compacting concrete (SCC) is a relatively recent development in concrete technology, and its history can be traced back to the late 1980s and early 1990s. Here is a brief overview of the history of SCC:

Japan: SCC was first developed in Japan in the late 1980s as a response to the labor shortage in the construction industry. Professor Hajime Okamura of Kochi University of Technology and Dr. Masahiro Ouchi of the University of Tokyo were among the first researchers to investigate SCC. They developed a mix design based on the use of high-range water reducers and viscosity-modifying agents that could produce concrete with high flowability and self-compacting ability.

Europe: In the early 1990s, researchers in Europe began to investigate SCC. The European Union funded a research project called "EUCON" in 1994, which brought together researchers from 12 European countries to develop SCC mix designs and test methods. The project led to the publication of the first European standard for SCC in 2002.

United States: The development of SCC in the United States began in the mid-1990s. The National Ready Mixed Concrete Association (NRMCA) formed a task group to investigate SCC and develop guidelines for its use. The American Concrete Institute (ACI) published its first guide for SCC in 2001.

Worldwide adoption: SCC has gained popularity worldwide due to its many advantages, such as ease of placement, improved surface finish, and better

durability. A variety of applications have employed SCC, such as high-rise buildings, bridges, tunnels, and precast concrete elements.

Overall, the development of SCC was driven by the need for more efficient and labor-saving construction methods, as well as the desire to improve the quality and durability of concrete structures. The research and development of SCC have resulted in the establishment of standardized mix designs and testing methods, which have facilitated its adoption and widespread use.

1.1.3. Indian Scenario Of Self Compacting Concrete

Self-compacting concrete (SCC) has gained significant attention in the Indian construction industry in recent years. Here is an overview of the Indian scenario of SCC:

Research and Development: Indian researchers have been actively working on developing SCC mix designs that are suitable for local materials and conditions. Several studies have been conducted on the use of locally available materials such as fly ash, silica fume, and crushed sand in SCC mix designs. Researchers have also investigated the use of various types of fibers, such as steel fibers and polypropylene fibers, to improve the mechanical properties of SCC.

Standards and Guidelines: The Bureau of Indian Standards (BIS) has published the first Indian Standard for SCC, IS 17778:2019, which provides guidelines for the production, testing, and use of SCC. The Indian Concrete Institute (ICI) has also published guidelines for the use of SCC in India.

Applications: SCC has been used in a variety of applications in India, such as high-rise buildings, bridges, tunnels, and precast concrete elements. Some notable projects that have used SCC in India include the Bandra-Worli Sea Link in Mumbai, the Signature Bridge in Delhi, and the Chennai Metro Rail project.

Challenges: Despite the growing popularity of SCC in India, there are still some challenges to its widespread adoption. One of the major challenges is the lack of awareness and expertise among contractors and engineers in the use of SCC. There is also a need for more research and development to develop SCC mix designs that are optimized for Indian materials and conditions.

Overall, the Indian construction industry is showing increasing interest in SCC due to its many advantages, such as improved construction efficiency and durability. With the establishment of standards and guidelines and ongoing research and development, it is expected that the use of SCC will continue to grow in India in the coming years.

1.2. PRODUCTION OF SCC

The production of self-compacting concrete (SCC) involves a mix design that is specifically tailored to produce concrete with high flowability, filling ability, and self-compacting characteristics. Here are the general steps involved in producing SCC

Mix design: The first step in producing SCC is to develop a mix design that is suitable for the specific application and materials being used. The mix design typically includes a combination of Portland cement, aggregates, water, and chemical admixtures such as superplasticizers, viscosity-modifying agents, and air-entraining agents.

Aggregates: The aggregates used in SCC should be carefully selected to ensure that they have the required properties, such as particle size distribution, shape, and texture. The use of crushed sand or manufactured sand is preferred over natural sand to ensure consistent quality and reduce the variability in the mix.

Chemical admixtures: Chemical admixtures play a critical role in the production of SCC. Superplasticizers are typically used to reduce the viscosity of the concrete and improve flowability, while viscosity-modifying agents are used to improve stability and prevent segregation.

Mixing: The mixing of SCC is typically done in a high-capacity mixer, such as a twin-shaft or planetary mixer, to ensure thorough and consistent mixing. The mixing time and speed should be optimized in order to make certain that the concrete has the appropriate flowability and self-compacting properties.

Testing: Once the SCC is produced, it should be tested to ensure that it meets the required specifications. Slump flow, J-ring, L-box, and V-funnel tests, among others, can be used to evaluate the concrete's flowability and filling

capacity. To evaluate the mechanical characteristics of the concrete, tests for compressive strength, flexural strength, and durability may also be performed.

Overall, the production of SCC requires careful attention to the mix design, selection of materials, and use of chemical admixtures. The proper mixing and testing of SCC are critical to ensuring that the concrete has the desired flowability and self-compacting characteristics.

1.3. ADVANTAGES AND DISADVANTAGES OF SCC

1.3.1. Advantages of SCC

1. Improved workability: SCC has excellent flowability and can easily fill complex and congested reinforcement patterns without the need for external vibration.

2. Improved durability: SCC has lower water-cement ratio and less bleeding, which results in a more durable concrete that is less prone to cracking and shrinkage.

3. Improved construction efficiency: The self-compacting nature of SCC allows for faster and easier placement, resulting in reduced labor costs and construction time.

4. Improved aesthetics: SCC can produce high-quality finishes with minimal surface defects and a consistent texture.

5. Improved safety: SCC eliminates the need for external vibration, reducing the risk of worker injury from vibration exposure.

1.3.2. Disadvantages Of SCC

1. Higher cost: SCC typically requires more expensive materials and chemical admixtures than conventional concrete, which can result in higher costs.

2. Limited experience: SCC is still a relatively new technology and may require additional training and experience to produce and place properly.

3. Quality control: The self-compacting nature of SCC can make it more difficult to control and monitor the quality of the concrete during placement and curing.

4. Reduced strength: SCC can have lower compressive strength compared to conventional concrete due to the use of higher water-cement ratios to achieve the desired flowability.

5. Potential for segregation: If not properly mixed or placed, SCC can be prone to segregation, which can result in non-uniform properties and reduced durability.

Overall, the advantages of SCC outweigh the disadvantages, especially in complex applications where the improved workability and durability of SCC can result in significant cost savings and improved performance. However, careful attention to mix design, placement, and quality control is necessary to ensure that SCC is produced and placed properly to achieve the desired properties and performance.

1.4. PRIMARY CONSTITUENTS OF SCC

The primary constituents of self-compacting concrete (SCC) are similar to those of conventional concrete, but with some key differences to achieve the desired flowability and self-compacting characteristics. Here are the primary constituents of SCC:

1. Portland cement: Portland cement is the primary binder used in SCC. It provides the strength and durability of the concrete.

2. Aggregates: In SCC, aggregates are often utilised to give the concrete bulk and volume. According to the intended attributes of the concrete, such as compressive strength, workability, and durability, the kind and size of aggregates used in SCC are commonly chosen.

3. Water: Water is necessary for the chemical reaction between Portland cement and aggregates to form the hardened concrete. In SCC, the water content is carefully controlled to achieve the desired flowability and self-compacting properties.

4. Chemical admixtures: Chemical admixtures are critical components in SCC. They are used to modify the properties of the fresh and hardened concrete. Superplasticizers are commonly used to increase the fluidity and workability of the concrete, while viscosity-modifying agents are used to improve stability and

prevent segregation. Air-entraining agents may also be used to improve durability and freeze-thaw resistance.

5. Reinforcement: Reinforcement, such as steel bars or fibers, may be added to SCC to improve the tensile strength and ductility of the concrete.

Overall, the primary constituents of SCC are similar to those of conventional concrete, but with careful attention to the mix design and use of chemical admixtures to achieve the desired flowability and self-compacting characteristics.

1.5. SCC v/s NCC

SCC (Self-Compacting Concrete) and NCC (Normal Compacting Concrete) are two different types of concrete with distinct properties and characteristics. Here are some key differences between SCC and NCC:

1. Workability: SCC has much better workability compared to NCC. SCC can flow and fill into complex and congested reinforcement patterns without the need for external vibration, whereas NCC typically requires external vibration to achieve the desired compaction.

2. Placement: SCC can be placed faster and more efficiently compared to NCC due to its self-compacting nature, resulting in reduced labor costs and construction time.

3. Durability: SCC has better durability compared to NCC. SCC has a lower water-cement ratio and less bleeding, which results in a more durable concrete that is less prone to cracking and shrinkage.

4. Cost: SCC is typically more expensive compared to NCC. SCC requires more expensive materials and chemical admixtures to achieve the desired flowability and self-compacting properties, resulting in higher costs.

5. Strength: NCC generally has higher compressive strength compared to SCC. SCC typically requires a higher water-cement ratio to achieve its desired flowability, which can result in reduced compressive strength compared to NCC.

In summary, SCC and NCC have distinct advantages and disadvantages, and the choice between them depends on the specific application and requirements. SCC is a good choice for applications where improved workability,

faster placement, and better durability are needed, whereas NCC is a good choice for applications where higher compressive strength is needed at a lower cost.

1.6. MECHANISM OF ACHIEVING SCC

The mechanism of achieving self-compacting concrete (SCC) involves optimizing the mix design and using chemical admixtures to achieve the desired flowability and self-compacting properties. Here are some key mechanisms involved in achieving SCC:

1. Particle packing: The particle packing of the aggregates is optimized to achieve the maximum density and minimum voids. This is typically achieved by using a combination of both fine aggregates and coarse aggregates of different sizes to fill the voids and reduce the interparticle friction.

2. Cementitious materials: The cementitious materials used in SCC are typically selected to achieve a lower water-cement ratio, which results in a more durable concrete with less shrinkage and cracking.

3. Chemical admixtures: Chemical admixtures are critical components in SCC. They are used to modify the properties of the fresh and hardened concrete. Superplasticizers are commonly used to increase the fluidity and workability of the concrete, while viscosity-modifying agents are used to improve stability and prevent segregation. Air-entraining agents may also be used to improve durability and freeze-thaw resistance.

4. Rheology: The rheological properties of SCC are carefully controlled to achieve the desired flowability and self-compacting properties. This involves measuring the viscosity, yield stress, and plastic viscosity of the fresh concrete and adjusting the mix design and chemical admixtures to achieve the desired properties.

Overall, achieving SCC involves optimizing the mix design, selecting the appropriate cementitious materials and aggregates, and using chemical admixtures to modify the characteristics of the newly-poured and hardened concrete. The goal is to achieve a concrete that is highly flowable and self-compacting while maintaining the desired strength and durability.

1.7. APPLICATION OF SCC

Self-compacting concrete (SCC) has a wide range of applications in the construction industry. Here are some of the common applications of SCC:

1. Precast concrete: SCC is widely used in precast concrete applications, where it can be poured into complex molds and reinforcement patterns without the need for external vibration. This results in faster production times and higher quality finished products.

2. High-rise buildings: SCC is also used in high-rise buildings, where it can be easily pumped to higher elevations and poured into formwork without the need for external vibration. This results in faster construction times and reduced labor costs.

3. Bridges and tunnels: SCC is commonly used in bridge and tunnel construction, where it can be easily pumped and placed into formwork in confined spaces. SCC can also be used to repair existing structures and fill voids.

4. Architectural concrete: SCC can be used to produce high-quality architectural concrete finishes, such as exposed aggregate or polished concrete, due to its excellent flowability and self-leveling properties.

5. Industrial floors: SCC is used in industrial floor applications, where it can be easily pumped and placed to produce a level and smooth surface that is highly durable and resistant to abrasion and chemical attack.

Overall, SCC has a wide range of applications in the construction industry, where its excellent workability, flowability, and self-leveling properties can be used to produce high-quality finished products in a variety of applications.

1.8. CONSTRUCTION ISSUES

Although self-compacting concrete (SCC) has many advantages, there are also some construction issues that must be considered. Here are some common construction issues in SCC:

1. Segregation: SCC is highly fluid and can be prone to segregation, where the heavier aggregates settle to the bottom of the formwork and the lighter

cement paste rises to the top. This can result in a non-uniform distribution of aggregates and a weaker, less durable concrete.

2. Bleeding: SCC can also be prone to bleeding, where excess water rises to the surface of the concrete and evaporates, leaving behind a porous surface with reduced durability.

3. Formwork pressure: The high fluidity of SCC can result in higher formwork pressures than conventional concrete. This must be considered when designing and constructing formwork.

4. Slump loss: SCC can experience significant slump loss over time, which can affect the final properties of the hardened concrete.

5. Mix design: SCC requires a carefully optimized mix design, which can be more complex and time-consuming than conventional concrete mix designs.

6. Cost: SCC can be more expensive than conventional concrete due to the cost of chemical admixtures and the additional testing required to ensure the desired properties are achieved.

Overall, the construction issues associated with SCC must be carefully considered to ensure that the concrete is placed correctly and achieves the desired properties. This requires a well-trained and experienced workforce, appropriate testing and quality control measures, and careful attention to the mix design and construction methods.

1.9. CONSTRUCTION AND DEMOLITION WASTES

Waste produced during the building, remodelling, and demolition of other structures is referred to as "construction and demolition" (C&D) waste. Concrete, wood, metal, brick, asphalt, gypsum, and plastics are just a few examples of the various items that might be included in this garbage..

The generation of C&D waste is a significant environmental challenge, as it can result in the depletion of natural resources, increased greenhouse gas emissions, and the pollution of land and water. To address this challenge, many countries and municipalities have implemented programs to reduce, reuse, and recycle C&D waste.

Programmes for trash reduction and recycling are one method of handling C&D waste. These initiatives promote the separation of C&D waste at the point of generation as well as the recycling of building components including metal, wood, and concrete. By doing this, less waste is disposed of in landfills, protecting natural resources.

Another approach is through the use of sustainable building practices, such as designing buildings for disassembly and using durable, low-maintenance materials that can be easily reused or recycled.

Finally, the demolition of buildings and other structures can also be managed in an environmentally responsible manner through the use of deconstruction techniques that carefully dismantle structures and salvage valuable materials for reuse or recycling.

Overall, the management of C&D waste is an important consideration for the construction industry and can be addressed through a combination of waste reduction and recycling programs, sustainable building practices, and responsible demolition techniques.

1.10. BRICK AGGREGATES

Brick aggregates refer to the use of broken and crushed bricks as a substitute for traditional natural aggregates (such as sand, gravel, and crushed stone) in concrete production. This can help to reduce the environmental impact of concrete production by reducing the demand for natural resources and diverting waste from landfill.

The use of brick aggregates in concrete has several advantages, including:

1. Sustainability: Brick aggregates are a sustainable material that can be sourced locally and recycled from demolition waste.

2. Durability: Brick aggregates have a high strength and durability, making them suitable for use in high-performance concrete.

3. Thermal insulation: Brick aggregates have good thermal insulation properties, which can help to reduce the energy required to heat and cool buildings.

4. Aesthetics: Brick aggregates can be used to produce a distinctive appearance in architectural concrete finishes.

However, there are also some potential disadvantages of using brick aggregates in concrete, including:

1. Absorption: The workability of the concrete mix may be impacted by brick aggregates' increased absorption rate compared to conventional aggregates.

2. Cost: Brick aggregates may be more expensive than traditional aggregates due to the cost of crushing and processing.

3. Variability: Brick aggregates can vary in size, shape, and quality, which can affect the properties of the concrete mix.

Overall, the use of brick aggregates in concrete production can provide a sustainable and durable alternative to traditional natural aggregates, but requires careful consideration of the potential advantages and disadvantages, as well as the specific application and properties of the concrete mix.

1.11. RECYCLED BRICK AGGREGATE

Recycled brick aggregates are crushed pieces of brick that are reused as a construction material. They are produced by crushing and screening old bricks that have been collected from demolition sites or other sources. Recycled brick aggregates can be used in a variety of applications, including as a base material for roadways, as a filler for concrete, as landscaping material, and as a decorative element in gardens and other outdoor spaces.

The use of recycled brick aggregates offers a number of benefits. It helps to lessen the volume of rubbish dumped in landfills, as well as the demand for virgin materials. Additionally, it can be a cost-effective alternative to traditional construction materials. Recycled brick aggregates also have a unique aesthetic appeal, with their varied colors and textures adding character to any project.

However, it's worth noting that recycled brick aggregates may not be suitable for every application. They may not meet certain engineering specifications, and their quality can vary depending on the source and processing methods used. Therefore, it's important to work with a reputable supplier and

conduct appropriate testing before using recycled brick aggregates in a construction project.

1.12. PROPERTIES OF RECYCLED BRICK AGGREGATE FOR CONCRETE

Recycled brick aggregate (RBA) is an alternative to traditional virgin aggregates in concrete production. Here are some of the properties of RBA for concrete:

1. Density: RBA has a lower density than virgin aggregates, which can result in a slightly lighter weight concrete mix.

2. Water absorption: RBA absorbs water more quickly than virgin aggregates, which might impact how much water is used in the concrete mix and how quickly the concrete dries.

3. Compressive strength: RBA has a lower compressive strength than virgin aggregates, which can result in a slightly weaker concrete mix.

4. Flexural strength: The addition of RBA to concrete has been shown to increase its flexural strength.

5. Durability: The use of RBA in concrete has been found to increase its resistance to freeze-thaw cycles, sulfate attack, and alkali-silica reaction.

6. Workability: The use of RBA in concrete can affect its workability, requiring adjustments to the mix design to ensure proper placement and finishing.

7. Surface texture: RBA has a rougher surface texture than virgin aggregates, which can affect the appearance of the concrete.

Overall, the properties of RBA for concrete can vary depending on factors such as the source and processing methods of the recycled bricks, the concrete's curing conditions, as well as the kind and quantity of cement used in the mix. Therefore, it's important to conduct appropriate testing and consult with a qualified engineer or material specialist to ensure the suitability of RBA for a given concrete application.

1.13. STEEL FIBERS

Steel fibers are short, discrete lengths of steel that are added to concrete to enhance its mechanical properties. They are typically made from carbon or stainless steel and can be straight or hooked in shape.

When steel fibers are added to concrete, they help to improve its tensile strength, ductility, toughness, and resistance to cracking. This is achieved by increasing the amount of reinforcement in the concrete, which helps to distribute loads more evenly and prevent the propagation of cracks. Steel fibers also improve the concrete's resistance to impact, fatigue, and abrasion, making it more durable in harsh environments.

Steel fibers can be used in a variety of concrete applications, including industrial floors, tunnel linings, precast elements, and shotcrete. They are also commonly used in applications where high-performance concrete is required, such as in the construction of high-rise buildings, bridges, and other critical infrastructure.



Fig 1.1 Steel Fibers

It's worth noting that the effectiveness of steel fibers can depend on several factors, including the fiber geometry, aspect ratio, and volume fraction, as well as the mix design and curing conditions of the concrete. Therefore, it's important to consult with a qualified engineer or material specialist to determine the most appropriate fiber type and dosage for a given application.

1.14. BENEFITS OF STEEL FIBER REINFORCED CONCRETE

There are several benefits to using steel fiber reinforced concrete (SFRC):

1. Improved durability: Steel fibers improve the durability of concrete by increasing its resistance to cracking, impact, abrasion, and fatigue. This can lead to a longer lifespan of the concrete structure.

2. Increased strength: Steel fibers increase the tensile strength of concrete, allowing it to better withstand the forces of tension and bending.

3. Enhanced toughness: Steel fibers improve the toughness of concrete by preventing the propagation of cracks and reducing the risk of brittle failure.

4. Reduced maintenance costs: Because SFRC is more durable than traditional concrete, it may require less maintenance over its lifetime, leading to cost savings for the owner.

5. Improved safety: The use of SFRC can improve the safety of concrete structures by reducing the risk of sudden failure or collapse.

6. Design flexibility: The addition of steel fibers to concrete can offer greater design flexibility, allowing for thinner and more lightweight concrete elements, as well as more intricate shapes and forms.

7. Faster construction: The use of SFRC can speed up construction by reducing the need for traditional reinforcing methods such as steel bars or mesh, and by allowing for quicker placement and finishing.

Overall, SFRC is a cost-effective and durable alternative to traditional reinforced concrete, offering a range of benefits for a variety of construction applications.

1.15. SCOPE

1. The study involved the utilization of recycled brick aggregates (RBA), Class-C fly ash, and steel fibers along with regular concrete ingredients to prepare self-compacting concrete (SCC). Through a trial-and-error process, optimal mixture proportions were determined.

2. The research aimed to investigate the feasibility and overall behavior of using RBA and SF in SCC.

3. The study aimed to produce SCC with varying strength and performance levels by partially replacing natural coarse aggregates with RBA.

4. The influence of RBA and SF on the fresh-state properties of SCC, including flowability, passing ability, and segregation resistance, as well as its hardened properties, including compressive strength, split tensile strength, and flexural strength, were examined.

5. In this study, SCC was fabricated into beams and subjected to testing and analysis.

6. Experimental results were compared to those obtained from nonlinear analysis using Abaqus software.

7. The mixture proportions that produced the best SCC were determined through a trial-and-error process that incorporated RBA, SF, fly ash, SP, and other components.

8. The research sought to understand the impact of incorporating RBA and SF on the SCC's mechanical and durability properties.

9. The fresh-state properties of SCC, such as flowability, passing ability, and segregation resistance, were examined to assess the effects of RBA and SF.

10. The research aimed to develop sustainable SCC that incorporated recycled materials such as RBA and fly ash while still providing adequate strength and durability.

1.16. NEED FOR STUDY

1. The goal of the experiment was to determine the ideal mix proportion of SCC utilizing RBA and steel fibers to achieve the desired fresh and hardened properties.

2. Three beams were prepared using the obtained mix proportion and subjected to loading.

3. The study focused on the behavior of the beam with partial replacement of coarse aggregate with RBA and the addition of small doses of SF under normal loading conditions.

4. The experiment was carried out to investigate the effectiveness of incorporating RBA and SF in SCC.

5. The objective was to find the optimum mix proportion that would result in satisfactory performance in both the fresh and hardened states.

6. The beams were designed to test the influence of RBA and SF on the mechanical properties of SCC.

7. The study sought to establish whether the replacement of natural coarse aggregates with RBA and the addition of steel fibers could improve the properties of SCC.

8. The beams were subjected to loading to evaluate their performance under normal conditions.

9. The research aimed to contribute to the development of more sustainable and eco-friendly construction practices.

10. The study sought to determine whether SCC with RBA and SF could be used in real-world construction applications.

CHAPTER 2

2. LITERATURE REVIEW

2.1. WORKS OF LITERATUREURES

Esraa Emam Ali & Sheriff H Al-Tersely (2012) carried out an experimental investigation using waste glass as a partial replacement for concrete. More quality-controlled SCC was achieved by conducting and analyzing various test results. SCC mix with the various cement content and fine aggregates in the proportion of 0-50% were tested. The use of more glass fiber increased the slump flow and tensile and flexural strength of SCC. The results showed that the glass fiber can be successfully used as an effective replacement for SCC.

Kazim Turk (2012) investigated To enhance the qualities of SCC when it is fresh and hardened, various cementitious materials were examined. Analyses were done on a number of fresh and mechanical characteristics. A little higher flexural strength was attained. Fly ash, silica fume, and Portland cement are all mixed together in the binary and ternary mixtures. With various cementitious mixes employed as a partial replacement, the outcome demonstrates that better fresh characteristics and hardened qualities are attained.

Gritsada Sua-iam & Natt Makul (2013) The study deals with the use of alumina in SCC. The study says that alumina can be practically used as a substitute for fine aggregate in SCC. The mixture was optimized to bring a controlled slump flow diameter. The fine aggregate was substituted by 100 alumina by its weight. By adding alumina to the filling, passing abilities decreased.

Givanildo Azeredo & Marcelo Diniz (2013) carried out a study on the usage of industrial products as a replacement for cement. Kaolin waste inclusion in SCC enhanced its fresh properties like a filling, passing and resistance to segregation. Several trials were done to investigate the fresh state properties and arrived at the specified limits according to the guidelines. Mix design with an optimum dosage of materials arrived.

Bernardinus Herbudimana & Adhi Mulyawan Saptajia (2013) investigated the behaviour of SCC by making use of roof tile powder as a replacement material

for fine aggregate. He arrived at an ideal mix proportion which yielded satisfactory flow and passing properties.

Mostafa Jalal et al (2013) investigated the split tensile strength characteristics of SCC. The manufacture of the crystalline TiO₂ at a weight of more over 4% was found to reduce the split tensile strength in an experimental setting. They also did research on SCC mixtures with the ideal TiO₂ dosage and less Flyash.

Adel Gorjinia Khoshkenari et al (2012) conducted research to determine the optimum way to incorporate recycled aggregates with a size range of 0 to 2 mm into a concrete mix that would produce concrete with the required standard strengths and workability. The study found that using RCA reduced splitting and compressive strength compared to regular aggregates. It has been discovered that silica fume can enhance the RCA's strength qualities.

Bibhuti Bhusan Mukharjee & Sudhirkumar V Barai (2014) examined the mechanical behaviour of concrete containing nano-silica and recycled aggregates. He realised that the qualities of the hardened state were significantly affected by the complete substitution of natural coarse aggregate with recycled aggregates. Additionally, it was discovered that the nano-silica significantly improved the microstructure and compressive strength of the concrete.

Ali Abbas et al (2014) analyzed to investigate the practicability of steel-fibre concrete in beam-column connections for an effective precaution against seismic forces. ABAQUS software experimentally showed the results of FEA of beam-column connections embedded with steel fiber-reinforced concrete. The 3D analysis of the frame was subjected to cyclic loading and an axial force on the column. This investigation reveals that the optimum usage of steel- fibre was an effective substitute for normal reinforced concrete.

Soylev, TA, & Ozturan, T (2014) investigated the durability of concrete using steel, polypropylene, and glass fibres. The influence of fiber on the properties of concrete has been investigated.

Tomasz Ponikiewski & Jacek Katzer (2014) determined the 3D porosity in steel fibre-reinforced SCC beams using X-ray computed tomography. A study

was conducted on air voids in fibre-reinforced SCC. Specimens with volumes up to 1.5% were subjected to non-destructive testing by X-ray computing tomography. The distribution of air, its volume, spacing and the amount of air trapped were analyzed.

Kabir Shakya et al (2012) studied the role of steel fiber reinforcement by reducing steel fibers in the beam-column joints. It was found that the addition of 1.5 % of steel bars effectively reduced the number of steel rebars in the beam-column joint.

Kazim Turk et al. (2021) investigated the effect of volume fraction and the combination of macro and microfibers on the workability, mechanical properties and flexural behaviour of SCC. The workability decrease with an increase in the volume of fiber fraction but the flexural toughness is increased with an increase in the volume of fiber fraction. Superior Ductility was also observed. The microfibers gave best results than the macro fibre in all aspects. To achieve better workability macro fiber of low aspect ratio than microfiber is used.

Tarek Uddin Mohammed et al (2014) In comparison to concrete made with first-class brick aggregate, there is no appreciable drop in compressive strength for partial replacement up to 50%, and recycling allows for the production of concrete with higher strength than that of concrete left in place.

Tarek Uddin Mohammed et al (2017) When compared to virgin brick aggregate, the use of recycled brick aggregate in concrete does not reduce the cracking moment or the ultimate moment capacity of reinforced concrete. No discernible difference was found between the load-displacement behaviour of reinforced concrete beams made with recycled aggregate and virgin brick aggregates. Beams

Fernando Lopez Gayarre et al (2019) This research examines the use of recycled brick aggregates (RBA) in concrete to replace both the fine and coarse fractions of natural aggregates used to make prestressed joists. For structural purposes, concrete with a 35% RBA displays acceptable shrinkage values, but the decline in elasticity modulus may call for more research.

Pei Ge et al (2021) The compressive strength of RBAC is at its highest when the volume fraction of RBA is between 44% and 47% and the overall volume fraction of RBA and sand is about 70%. In this test, the volume fraction of RBA, sand/cement and water/cement ratio were taken into consideration. It was established that the RBAC mix percentage design method was based on the aggregate skeleton theory. In comparison to ACI 211.2 and ACI 211.6, the mix proportion design approach suggested in this work involves mixing more RA and less sand and cement in the concrete mix proportion while maintaining concrete strength and slump, which is advantageous for environmental protection.

BoWang et al. (2021) provided a comprehensive review of the RA and RCA about their history, manufacturing process and their material properties etc. A summary is also provided of the techniques for enhancing the mechanical characteristics and durability of RACs. Addition to the challenges in the application of RAC is also reviewed in this study. Artificial Intelligence methods are employed to predict the RAC compressive properties.

ChangSun et al. (2020) evaluate the feasibility of preparing SCC by incorporating waste concrete recycling materials. The investigation carried on both fresh and hardened properties of self-compacting concrete with recycled concrete. There is a decrease in the workability and mechanical properties of SCC and the replacement percentage is also limited. The high water absorption rate decreases the workability with an increase in the waste concrete recycling materials. The mechanical properties also decrease with an increase in rates of waste concrete recycling materials.

GuoliangBalet al. (2020) The performance of RA at the material level and the amount of old attached mortar were shown to have a quantitative relationship. The presence of the old mortar in RA accounts for the differences in characteristics between recycled aggregate and natural aggregate. The performance of RA is enhanced not only by removing the old mortar, but also by regulating the water-cement ratio and modifying the aggregate moisture content. This straightforward and cost-effective technique can also be used to obtain higher RA quality. The key factor contributing to the RA's worse quality compared to the NA is the presence of adhering mortars.

Kho PinVerian et al. (2018) The original aggregate's characteristics and the state of the demolished concrete affect the RCA's quality. The presence of mortar on the surface of recycled aggregate is what causes its different qualities when compared to natural aggregate. This literature mentions a number of strategies to raise the calibre of concrete incorporating RCA.

HuiGuo et al (2018) Inadequate durability is caused by the decline in recycled aggregate. Utilising pozzolanic materials, either as a surface coating or combined with the concrete, increases the durability. Concrete's durability and the characteristics of recycled aggregate are improved by the CO₂ treatment. The durability is inversely related to the amount of adhering mortar.

StefaniaManzi et al. (2017) investigated the creep and shrinkage of Self-compacting concrete with coarse and fine recycled concrete aggregate. It is feasible to use coarse and fine recycled concrete aggregates up to 40 vol% in the Self-compacting concrete. The mechanical properties also give good results under the use of Recycled aggregate in Self-compacting concrete. The creep is more influenced than shrinkage by the presence of recycled aggregate.

2.2. SUMMARY

The literature reviews cover various studies related to improving the quality of concrete by using different materials and techniques. Some studies focused on using waste materials, such as waste glass, alumina, and kaolin waste, as a partial replacement for fine aggregates or cement to enhance the fresh and hardened properties of self-compacting concrete (SCC). Other studies examined the effects of adding cementitious materials, such as fly ash and silica fume, or nano-silica, to improve the mechanical and microstructural properties of concrete.

Steel fibers and their combination with other types of fibers, such as polypropylene and glass fibers, were also investigated to enhance the durability and seismic resistance of concrete in beam-column connections. Moreover, the use of recycled aggregates and their impact on the compressive and splitting strength of concrete were explored. Finally, X-ray computed tomography was used to study the 3D porosity in steel fiber-reinforced SCC beams.

Overall, the studies suggest that using waste materials and various fibers, cementitious materials, and nano-silica can effectively improve the properties of concrete. Furthermore, the use of recycled aggregates can be a sustainable alternative to virgin aggregates without sacrificing the strength and durability of concrete.

CHAPTER 3

3. METHODOLOGY

3.1. GENERAL

This chapter is briefing the selection of materials for the preparation of self-compacting concrete beam partially replaced with Recycled brick aggregate (RBA) and steel fibers (SF), the various test to be conducted with fresh concrete and hardened concrete to determine the various properties such as compressive, tensile, and flexural strength and modelling of lightweight concrete beam using FEM software ABAQUS.

3.2. METHODOLOGY

This flowchart provides a step-by-step process for determining the various properties of concrete.

1. The first step is to study the literature related to the material which is going to replace and identify the material properties which affect the concrete which helps in the selection of suitable replacement material.
2. The study on determining the properties of materials to be conducted that can be useful in increasing the desirable properties of the concrete.
3. The structural element (beam) is modelled using FEM software and analysis will be carried out.
4. In this study for the research, the mix design for self-compacting concrete of grade M30 will be completed.
5. The casting of the specimen to conduct the experimental investigation for determining the properties of the concrete will be carried out.
6. The outcomes of the experimental study will be contrasted with those of the FEM software ABAQUS.

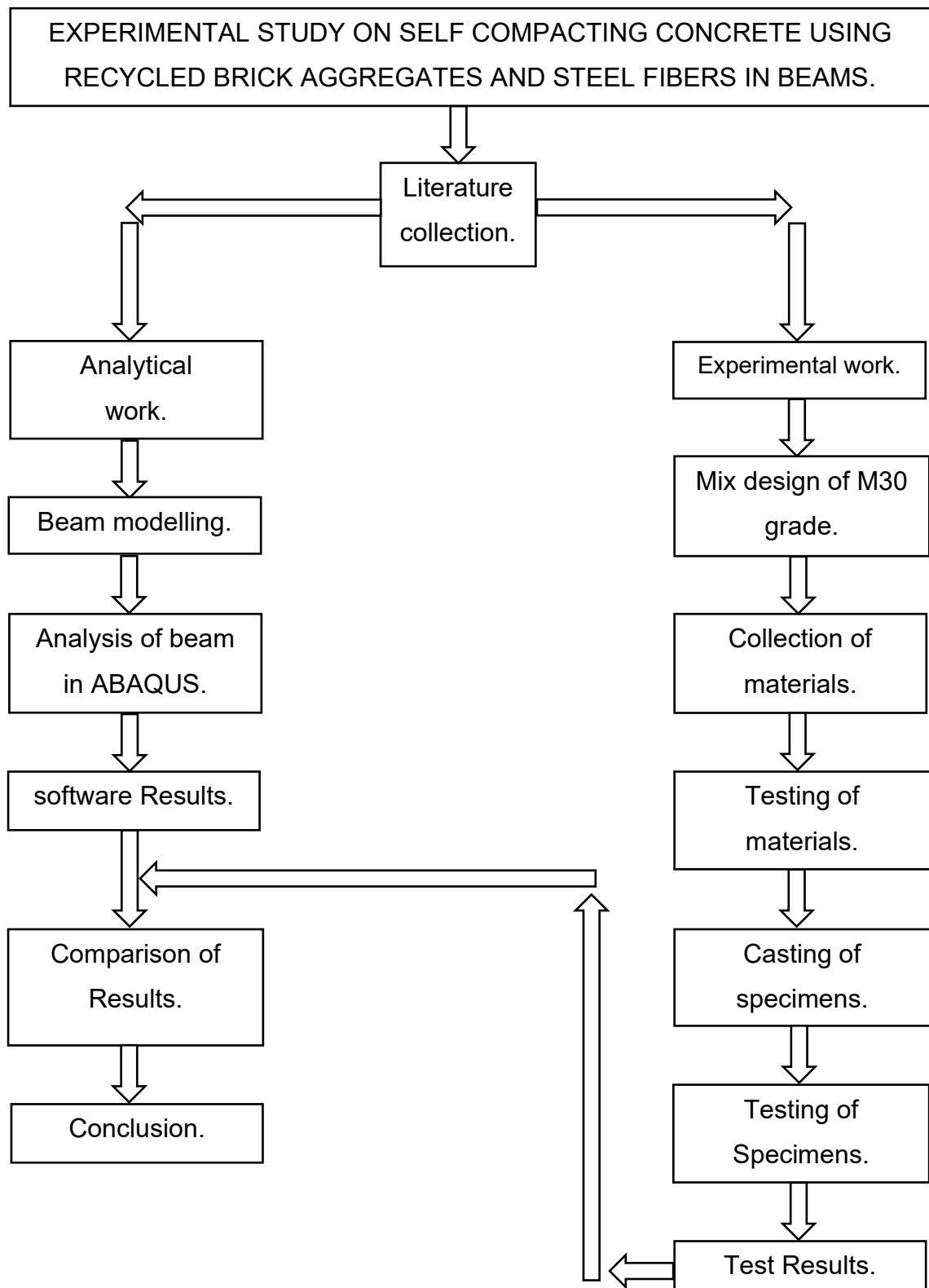


Fig 3.1 Flow chart

CHAPTER 4

4. MATERIALS INVESTIGATION

4.1. GENERAL

In this chapter there is a brief explanation about the materials used in both the normal self compacting concrete (NSCC) and the self compacting concrete which is partially replaced by Recycled Brick Aggregate (RBA) and Steel Fibers (SF). Then the concrete specimens are casted and tested in laboratory for the concrete compressive, split-tensile, and flexural behaviour.

4.2. MATERIALS

In traditional concrete, mechanical compaction is needed to eliminate voids and ensure uniform distribution of the aggregates. However, self-compacting concrete (SCC) is designed to flow and fill every corner of the formwork without the need for mechanical vibration.

SCC includes the same primary constituents as traditional concrete, but the proportion and properties of the ingredients are adjusted to achieve self-compacting behaviour. Cement is the binding agent in concrete, and fine aggregate (sand) provides most of the volume. Coarse aggregate, such as gravel or crushed stone, adds strength and stability to the concrete. Water is required for the chemical reaction with cement and to enable workability. Chemical admixtures, such as superplasticizers, are added to increase flowability and reduce water content. Mineral admixtures, such as fly ash and silica fume, are used to improve the strength, durability, and workability of concrete. Reinforcing bars, welded wire fabric, and reinforcing fibres are added to concrete to increase tensile strength and prevent cracking.

In SCC, the proportions of these ingredients are adjusted to achieve a high level of flowability and filling ability, without compromising the strength and durability of the concrete. The use of SCC has numerous benefits, including faster construction times, reduced labour costs, improved durability, and increased design flexibility.

4.3. MATERIALS USED

4.3.1. Cement

Cement is a powder-like substance made of various materials, including limestone, clay, and other minerals. It is an essential building material that is used to bind other materials together to form concrete, mortar, and other construction materials. The production of cement involves grinding and heating the raw materials to high temperatures in a kiln, which results in a chemical reaction that forms a clinker. The clinker is then ground into a fine powder and mixed with gypsum and other additives to create the final cement product. Cement is used in a variety of construction projects, including the construction of buildings, bridges, dams, and roads. It is a versatile material that provides strength, durability, and water resistance to structures. However, the production of cement is energy-intensive and can result in significant greenhouse gas emissions, contributing to climate change.

4.3.1.1. Physical properties of cement

the physical properties of cement include:

1. **Fineness:** The fineness of cement refers to the particle size distribution of the cement powder. Finer particles provide better workability and cohesiveness, but can also lead to increased heat generation during hydration.
2. **Setting time:** The setting time of cement is the time it takes for the cement paste to harden and set. It is important to control the setting time to ensure that the concrete can be properly placed and finished.
3. **Soundness:** The soundness of cement refers to its ability to resist volume changes during the hardening process. Excessive volume changes can lead to cracking and other durability issues.
4. **Strength:** The strength of cement refers to its ability to resist compression and tension forces. The compressive strength is typically measured in pounds per square inch (psi) and is an important factor in determining the structural integrity of the concrete.

5. Heat of hydration: The heat of hydration is the heat generated during the chemical reaction between cement and water. Excessive heat generation can cause cracking and other durability issues.

6. Color: The colour of cement can vary depending on the source of raw materials and manufacturing processes. The most common colour of cement is grey, but it can also be white or other colours.

Understanding the physical properties of cement is important for selecting the right type of cement for specific applications and ensuring that the concrete mix has the desired properties.

Table 4.1 Physical Properties of cement

S.No	Physical Properties	Results
1	Normal Consistency Test	32%
2	Fineness of cement	4.80%
3	Specific Gravity of cement	3.14
4	Setting Time (initial)	34 min
5	Setting Time (final)	615 min

The normal consistency of the cement is 32%, which indicates the amount of water required to produce a paste of standard consistency. The fineness of the cement is 4.8%, which is a measure of the particle size distribution of the cement. The specific gravity of the cement is 3.14, which is a measure of the density of the cement compared to water. The initial setting time of the cement is 34 minutes, which indicates the time taken for the cement paste to harden and set. The final setting time of the cement is 615 minutes, which indicates the maximum time taken for the cement paste to harden and set. The soundness of the cement is 5 mm, which is a measure of the ability of the cement to resist volume changes during the hardening process. These physical properties of cement can provide important information about its quality and performance in construction applications. It is also important to note that these values may vary depending on the type of cement, source of raw materials, and manufacturing processes used.

4.3.2. Fine aggregate

Fine aggregate is a type of building material that is typically made up of sand, crushed stone, or gravel. It is used in construction as a component of concrete, along with cement and coarse aggregates, to create a strong and durable building material. Fine aggregate is smaller in size compared to coarse aggregate, with particles ranging in size from 0.075 mm to 4.75 mm. The properties of fine aggregate, such as its shape, texture, and grading, can affect the workability, strength, and durability of the resulting concrete mix. Fine aggregate is usually obtained from natural sources such as river beds, beaches, or quarries, or can be manufactured through the crushing of rock or gravel. The use of high-quality fine aggregate is important in ensuring the overall quality and performance of the concrete mix.

4.3.2.1. Physical Properties of Fine Aggregates

The physical properties of fine aggregates include particle size distribution, shape, texture, specific gravity, absorption, and surface moisture. Particle size distribution is an important factor that affects the workability and strength of the resulting concrete mix. The shape and texture of the fine aggregate particles can affect the interlocking between the particles and the bond with the cement paste. Specific gravity is a measure of the density of the fine aggregate compared to water, while absorption refers to the amount of moisture that the fine aggregate can absorb. Surface moisture affects the workability of the concrete mix, and it should be taken into account when determining the amount of water needed in the mix design. The physical properties of fine aggregates play a crucial role in determining the quality and performance of the concrete mix in construction applications.

Table 4.2 shows the physical properties of a fine aggregate (M-sand). These properties include:

Specific Gravity - It is the ratio of the weight of a given volume of material to the weight of an equal volume of water. The specific gravity of the fine aggregate is 2.46.

Table 4.2 Physical properties of M-sand

S.No	Contents	Results
1	Specific Gravity	2.46
2	Fineness Modulus	2.65
3	Bulk Density (kg/m ³)	
i)	Loose	1620
ii)	Compacted	1820
4	Absorption of Water	1.2

Fineness Modulus - It is a measure of the fineness of the aggregate. The fineness modulus of the fine aggregate is 2.65.

Bulk Density - It is the weight of material per unit volume. The bulk density of the fine aggregate is given for two conditions:

Loose - The bulk density of the fine aggregate in loose condition is 1620 kg/m³.

Compacted - The bulk density of the fine aggregate in compacted condition is 1820 kg/m³.

Absorption of Water - It is the increase in weight of an aggregate due to the presence of water. The absorption of water for the fine aggregate is 1.20.

Table 4.3 Sieve Analysis Of M-Sand

S.No	Sieve size	Mass retained Kg	% of mass retained	Cumulative % of retained	% of passing
1	4.75 mm	0.034	0.034	3.4	96.6
2	2.36 mm	0.028	0.062	6.2	93.8
3	1.1 mm	0.1	0.162	16.2	83.8
4	600 μ	0.4	0.562	56.2	43.8
5	300 μ	0.31	0.872	87.2	12.8
6	150 μ	0.088	0.96	96	4
7	Pan	0.02	0.98	98	2

4.3.3. Coarse aggregate

Coarse aggregate is a construction material that is used in the production of concrete and is composed of large particles, such as gravel, crushed stone or recycled concrete. The physical properties of coarse aggregates, such as shape, size, texture, and density, play an important role in determining the workability, strength, durability, and overall quality of concrete. The grading of coarse aggregates is determined by conducting a sieve analysis, where the aggregate is separated into different sizes based on the size of the sieve openings. The results of the sieve analysis are presented in a tabular form that shows the percentage of aggregate retained on each sieve, the cumulative percentage retained, and the percentage passing.

4.3.3.1. Physical properties of coarse aggregate

The physical properties of coarse aggregate include the following:

1. **Specific Gravity:** The specific gravity of coarse aggregate ranges from 2.5 to 3.0. It is a measure of the ratio of the density of a substance to the density of a reference substance.
2. **Bulk Density:** The bulk density of coarse aggregate ranges from 1400 to 1800 kg/m³. It is the mass of the aggregate per unit volume, including both the solid material and the voids between the particles.
3. **Water Absorption:** The water absorption of coarse aggregate is generally less than 2%. It is the percentage of water absorbed by the aggregate when immersed in water for a specific duration.
4. **Crushing Value:** The crushing value of coarse aggregate ranges from 20 to 45%. It is a measure of the strength of the aggregate. A lower crushing value indicates a stronger aggregate.
5. **Impact Value:** The impact value of coarse aggregate ranges from 15 to 30%. It is a measure of the resistance of the aggregate to sudden shock or impact.

6. Fineness Modulus: The fineness modulus of coarse aggregate ranges from 6.0 to 8.0. It is a measure of the average size of the particles in the aggregate, and it affects the workability and strength of the concrete.

Table 4.4 Sieve analysis of coarse aggregate 20mm.

20 mm normal aggregate				
Sieve size in (mm)	Wt. retained (kgs)	Cumulative Wt retained (kgs)	Wt. passing (kgs)	Wt. passing (%)
25	0	0	5	100
20	0.32	0.32	4.68	93.6
16	3.086	3.406	1.594	31.88
12.5	1.342	4.748	0.252	5.04
10	0.162	4.91	0.09	1.8
4.75	0.022	4.932	0.068	1.36

This table 4.4 represents the results of sieve analysis conducted on 20 mm normal aggregate. The aggregate was passed through a series of sieves of different sizes and the weight of aggregate retained on each sieve was measured. From the results, it can be concluded that the aggregate has a maximum particle size of 20 mm and the percentage of material passing through the 4.75 mm sieve is 98.64%. The fineness modulus of the aggregate can be calculated from the cumulative weight retained values.

4.3.4. Recycled Brick Aggregates (RBA)

BS 882: 1992 provides guidance on the use of recycled aggregates in concrete. According to this standard, recycled aggregates must meet certain requirements to be suitable for use in prescribed or designed concrete mixes. The flakiness index of coarse recycled aggregates should not exceed 30 and 40 for prescribed and designed mixes, respectively. In addition, the maximum allowable amount of foreign material in coarse recycled aggregates is specified in table 4.5 in the standard.



Fig 4.1 Recycled Brick Aggregate

Table 4.5 Permissible limits for foreign matter in recycled coarse aggregate

Type of material	Max % (By mass)
Wood	0.5
Materials like metals, clay lumps, Tar, glass, asphalt, etc.	1.0

Table 4.5 provides permissible limits for foreign matter in recycled coarse aggregate according to the BS 882:1992 standard. It specifies the maximum percentage (by mass) of different types of foreign materials that can be present in recycled coarse aggregates.

For instance, the maximum allowable percentage of wood in recycled coarse aggregates is 0.5%, while the maximum allowable percentage of materials like metals, clay lumps, tar, glass, asphalt, etc. is 1.0%. These limits are important to ensure that the quality of the recycled aggregates used in concrete production meets the required standards and specifications.

Table 4.6 The results of the tests conducted on the RBA

Property	Test value
Specific gravity	2.19
Aggregate crushing value	23.8
Aggregate Impact Value	27.6
Aggregate water absorption	4.2

The table presents the results of tests conducted on recycled brick aggregates. The following properties were determined:

1. Specific gravity: The specific gravity of the recycled brick aggregate was found to be 2.19. Specific gravity is the ratio of the density of a material to the density of a reference substance (usually water). A higher specific gravity indicates a denser material.

2. Aggregate crushing value: The aggregate crushing value (ACV) of the recycled brick aggregate was determined to be 23.8. ACV is a measure of the resistance of an aggregate to crushing under a gradually applied compressive load. A lower ACV indicates a stronger aggregate.

3. Aggregate impact value: The aggregate impact value (AIV) of the recycled brick aggregate was found to be 27.6. AIV is a measure of the resistance of an aggregate to sudden impacts. A lower AIV indicates a tougher aggregate.

4. Aggregate water absorption: The aggregate water absorption of the recycled brick aggregate was determined to be 4.2%. Water absorption is a measure of the porosity of an aggregate, which is important in determining the amount of water that will be absorbed by the aggregate in concrete mixtures. A lower water absorption indicates a less porous material.

In summary, the test results suggest that the recycled brick aggregate has a moderate specific gravity, moderate resistance to crushing and impact, and a relatively low water absorption. These properties may influence the suitability of

the recycled brick aggregate for various applications, such as in concrete mixtures.

4.3.5. Fly ash

Fly ash is a popular filler used in self-compacting concrete (SCC) that contributes to its increased workability and long-term strength. By using fly ash, the dosage of super plasticizer can be reduced, and the density of concrete can be increased, which reduces permeability and prevents aggressive compounds from penetrating the surface. Fly ash is also resistant to sulphate attack and reduces efflorescence. Moreover, the partial replacement of cement with fly ash offers numerous benefits, such as improved durability and reduced heat of hydration, permeability, and bleeding. In this study, fly ash was used as a partial replacement for cement and classified as class F or low calcium fly ash based on its chemical composition. The chemical compounds present in the fly ash met the requirements specified by IS: 456-2000.

Table 4.7 Chemical composition of fly ash

Type of Chemicals	% by Weight
Silica (SiO ₂)	63.53
Alumina (Al ₂ O ₃)	27.40
Calcium oxide (CaO)	1.26
Ferric oxide (Fe ₂ O ₃)	3.67
Potassium oxide (K ₂ O)	0.85
Magnesium oxide (MgO)	0.35
Sodium oxide (Na ₂ O)	0.19
Phosphorus pentoxide (P ₂ O ₅)	-
Sulphuric anhydride (SO ₃)	0.01
Loss on ignition (LOI)	0.9
Titanium Dioxide	1.84

4.3.6. Steel fibers

In this study, hooked end steel fibers were utilized as reinforcement. These fibers are made of cold-drawn wire with high tensile strength and have hooked ends. They are known to enhance the ductility, toughness, and crack resistance of concrete, making them ideal for ground-supported slabs, jointless floors, and external road pavements.

Table 4.8 Properties of hooked end steel fibre

S. No.	Properties	Value
1	1. Diameter	0.60 mm
2	Length	30 mm
3	Aspect ratio	50
4	Tensile strength	>1450MPa
5	Melting point	2760 °F (1516 °C)
6	Strain at failure	< 4 MPa

Table 4.8 provides details about the properties of a specific type of steel fiber, including its diameter, length, aspect ratio, tensile strength, melting point, and strain at failure. The diameter of the fiber is 0.60 mm, and its length is 30 mm. The aspect ratio, which is the ratio of the length to diameter, is 50. The fiber has a high tensile strength of over 1450 MPa and a high melting point of 2760 °F (1516 °C). Additionally, the strain at failure is less than 4 MPa.



Fig 4.2 Steel Fibers

4.3.7. Admixture

An admixture in concrete is a material added to the concrete mixture other than cement, water, and aggregates. Admixtures are added to enhance the properties of concrete, such as workability, strength, durability, setting time, and resistance to the effects of weather and chemical attack. There are various types of admixtures available for use in concrete, including water-reducing, accelerating, retarding, air-entraining, and superplasticizing admixtures. The choice of admixture depends on the specific requirements of the concrete mix and the application for which it is intended. Admixtures are typically added in small quantities and should be carefully selected and tested to ensure compatibility with the other components of the concrete mixture.

Table 4.9 Properties of superplasticizer

Sl. No.	Properties	Super plasticizer contents
1	Colour	Reddish brown liquid
2	Specific gravity	1.14
3	Solid contents	40%
4	pH	8.6
5	Relative density	1.08 $\pm$ 0.02 at 25°C

Table 4.7 provides information about the properties of the polycarboxylate-based superplasticizer used in the study. The brand name of the superplasticizer is Master Glenium from BASF. It is a new-generation admixture designed for high-performance and high-workability concrete. The superplasticizer is based on Poly-Carboxylic Ether (PCE). The properties of the superplasticizer have been confirmed by ASTM C494- 2017 Type F and IS 9103:1999 (R2004) standards. The properties listed in the table include the colour, specific gravity, solid contents, pH, and relative density of the superplasticizer.

4.3.8. water

The water used for the experiment was found to be of good quality and met the maximum permissible limits for all parameters tested, including pH value, hardness, sulphate, and chlorides. The pH value of the water was 8.9, which falls within the acceptable range of 6.0-9.0. The hardness of the water was 403 ppm, which is well below the maximum permissible limit of 1000 ppm. The sulphate content of the water was 100 ppm, which is also within the permissible limit of 400 ppm. The chlorides content of the water was 137 ppm, well below the maximum permissible limit of 500 ppm. Overall, the water used in the experiment was of good quality and did not pose a risk to the quality or durability of the concrete.

4.4. MIX PROPORTION

The mix proportion for Self-Compacting Concrete (SCC) is specified in IS10262:2019, which is the Indian Standard code for concrete mix design. The following are the steps involved in the mix proportioning of SCC as per IS10262:

Step 1: Target strength and maximum size of aggregates

The first step is to determine the target strength of the concrete and the maximum size of aggregates to be used in the mix. The target strength is based on the requirements of the structure and the exposure conditions. The maximum size of aggregates is usually limited to 20mm to ensure good workability of the SCC.

Step 2: Selection of w/c ratio and water content

The next step is to select the water-cement (w/c) ratio and water content based on the target strength, maximum size of aggregates, and other mix design considerations. The water content is calculated based on the w/c ratio and the weight of cement.

Step 3: Determination of fine aggregate content

The fine aggregate content is determined based on the water content and the selected w/c ratio. The amount of fine aggregate is calculated using the following equation:

Fine aggregate content = (water content / w/c ratio) - cement content

Step 4: Selection of admixtures

Admixtures such as superplasticizers, viscosity modifiers, and stabilizers are added to improve the workability, flowability, and stability of the SCC. The amount of admixture is selected based on the specific requirements of the mix.

Step 5: Calculation of coarse aggregate content

The coarse aggregate content is calculated based on the maximum size of aggregates, fine aggregate content, and the volume of the concrete. The volume of the concrete is calculated based on the required strength and the selected w/c ratio.

Step 6: Adjustment of mix proportion

The mix proportion is adjusted based on the trial mixes to achieve the desired properties of SCC such as flowability, passing ability, and stability. The adjustments may include changes in the amount of admixture, fine aggregate content, and cement content.

Overall, the mix proportion for SCC is designed to ensure good workability, flowability, and stability while meeting the requirements of the structure and the exposure conditions.

Table 4.10 The Mix Proportions of M30 Grade conventional and self-compacting concrete with partial replacement of RBA and SF

M30 Grade Of Self Compacting Concrete									
Sl. NO	MIX	CEMENT (Kg/m³)	FLY ASH (Kg/m³)	Water (L/m³)	FA (Kg/m³)	CA (Kg/m³)	RBA (Kg/m³)	SP (l/m³)	SF (Kg/m³)
1	NS CC	287	155	190	975	737	-	2.65	-
2	RB ASF 1	287	155	190	975	553	184	2.65	11.7
3	RB ASF 2	287	155	190	975	553	184	2.65	17.6
4	RB ASF 3	287	155	190	975	553	184	2.65	23.5

The above table shows the mix proportion of M30 grade Self-Compacting Concrete (SCC) with different percentages of steel fibers according to the IS 10262 code.

The mix proportion includes the following materials:

- Cement (in Kg/m³)
- Fly ash (in Kg/m³)
- Water (in L/m³)
- Fine aggregates (FA) (in Kg/m³)
- Coarse aggregates (CA) (in Kg/m³)
- Recycled Building Aggregate (RBA) (in Kg/m³)
- Superplasticizer (SP) (in L/m³)
- Steel fibers (SF) (in Kg/m³)

The different mixes mentioned in the table are:

1. NSCC - This is the mix without any steel fibers added. The mix proportion includes 287 Kg/m³ of cement, 155 Kg/m³ of fly ash, 975 L/m³ of water, 737 Kg/m³ of fine aggregates, 552.75 Kg/m³ of coarse aggregates, and 2.65 L/m³ of superplasticizer.

2. RBASF1 - This mix includes 0.50% of steel fibers by volume. The mix proportion is the same as NSCC but with the addition of 11.73 Kg/m³ of steel fibers.

3. RBASF2 - This mix includes 0.75% of steel fibers by volume. The mix proportion is the same as NSCC but with the addition of 17.60 Kg/m³ of steel fibers.

4. RBASF3 - This mix includes 1% of steel fibers by volume. The mix proportion is the same as NSCC but with the addition of 23.47 Kg/m³ of steel fibers.

The addition of steel fibers in the mix is done to improve the mechanical properties of the concrete, such as tensile strength, flexural strength, and toughness. The amount of steel fibers added to the mix depends on the specific requirements of the project.

The use of fly ash in the mix is to enhance the workability, durability, and strength of the concrete. The superplasticizer is added to improve the flowability of the concrete, ensuring good filling and compaction of the formwork without any segregation.

The recycled building aggregate is used to reduce the environmental impact of concrete production by reusing the demolished concrete waste as a partial replacement of natural coarse aggregates. The proportions of fine aggregates and coarse aggregates depend on the specific requirements of the project, such as the workability, strength, and durability of the concrete.

4.5. EFNARC V/S IS10262

The two most commonly used codes for Self-Compacting Concrete (SCC) are the European Federation of National Associations Representing for Concrete (EFNARC) and Indian Standard Code IS 10262.

EFNARC was introduced in 2002 and is widely used in Europe and other parts of the world. It is a performance-based code that emphasizes the properties of SCC, such as flowability, viscosity, and segregation resistance, rather than prescribing specific mix proportions. EFNARC provides guidelines for testing and evaluating SCC, including methods for measuring slump flow, viscosity, segregation resistance, and hardened properties such as compressive strength and durability. EFNARC also provides guidelines for quality control and mix design optimization. One of the advantages of the EFNARC code is its flexibility, which allows for a wide range of mix proportions and materials to be used, depending on the specific requirements of the project.

IS 10262, on the other hand, is a prescriptive code that was introduced in 1982 by the Bureau of Indian Standards (BIS). It specifies the minimum requirements for the materials, mix proportions, and testing methods for SCC. The code emphasizes the use of locally available materials and provides detailed guidelines for mix proportioning based on the desired strength and workability of the concrete. The code also includes guidelines for quality control and testing, as well as recommendations for curing and protection of the concrete.

One of the main differences between the two codes is the approach to mix proportioning. EFNARC focuses on the performance characteristics of SCC and allows for greater flexibility in selecting mix proportions and materials, while IS 10262 provides specific guidance on the materials and mix proportions to be used for different strength and workability requirements. Additionally, EFNARC allows for the use of admixtures to achieve desired properties, while IS 10262 has more limited provisions for the use of admixtures.

In summary, EFNARC is a performance-based code that emphasizes the properties of SCC and provides guidelines for testing and evaluation, while IS 10262 is a prescriptive code that specifies the minimum requirements for materials, mix proportions, and testing methods for SCC. The two codes have different approaches to mix proportioning and material selection, and their application may depend on the specific requirements and conditions of a project.

The casting process for self-compacting concrete (SCC) specimens, including cubes, cylinders, and reinforced concrete (RC) beams, is similar to the

casting process for conventional concrete. However, SCC has unique properties that require special consideration during the casting process.

4.6. SPECIMEN CASTING PROCESS

To cast SCC cubes, cylinders, and RC beams, the following steps are generally followed:

1. Formwork preparation: The formwork for SCC specimens should be smooth and free of defects to allow for easy flow and filling of the concrete. The formwork can be made of wood, steel, or plastic.



Fig 4.3 Cube, cylinder and beam mould with oil applied and casting process

2. Reinforcement placement: If reinforcement is required for the SCC specimens, it should be placed in the formwork before pouring the SCC. The reinforcement should be securely positioned to prevent any movement during casting.

3. SCC mixing: SCC is typically mixed in a concrete mixer using a high-speed mixing process. The mixing time for SCC is longer than conventional concrete to ensure that all ingredients are thoroughly mixed.

4. Pouring: SCC is poured into the formwork using a hopper or pump. It is important to avoid any air pockets or voids during pouring to ensure the quality of the SCC specimens.

5. Consolidation: SCC does not require external consolidation or compaction, as it is designed to flow and fill the formwork under its own weight. However, it may be necessary to vibrate the formwork to remove any trapped air pockets or voids.

6. Curing: The SCC specimens are cured in a standard curing room for a specified period of time, usually 28 days, to allow them to gain strength and durability.

7. Demoulding: Once the SCC specimens have hardened, the formwork is removed, and the SCC specimens are released.

In the case of RC beams, special attention should be paid to the placement of the reinforcement to ensure that it is properly positioned within the SCC. The formwork for RC beams should also be designed to support the weight of the SCC and any reinforcement.

Overall, the casting process for SCC specimens requires careful attention to ensure that the unique properties of SCC are properly accommodated.

4.7. EXPERIMENTAL INVESTIGATION

This chapter provides a brief overview of the different tests carried out on SCC, including fresh and hardened tests, along with their corresponding results.

4.8. TEST ON SCC

SCC (Self-Compacting Concrete) undergoes various tests to determine its properties and ensure its quality. These tests can be broadly classified into fresh and hardened tests.

4.8.9. Fresh test on scc

Fresh tests involve measuring properties such as workability, filling ability, passing ability, and segregation resistance. The slump flow test, V-funnel test, L-box test, and U-box test are commonly used to evaluate these properties

4.8.9.1. Slump flow test

The experimental procedure for the slump flow test involves the following steps:



Fig 4.4 Slump flow test

1. Preparation of the SCC mix: The SCC mix is prepared according to the desired proportions of the ingredients, including cement, aggregates, water, and admixtures.
2. Setting up the test apparatus: The slump cone is placed on a flat and smooth surface, and a round base plate is placed underneath the cone.
3. Filling the cone: The SCC mix is slowly poured into the cone in three equal layers, and each layer is tamped with 25 strokes of a standard tamping rod.
4. Lifting the cone: The cone is lifted vertically, allowing the SCC mix to flow and spread out. The cone is lifted in a smooth and steady motion, without any twisting or rotation.
5. Measuring the slump flow: The diameter of the spread SCC mix is measured in two perpendicular directions, and the average value is recorded as the slump flow.
6. Cleaning the apparatus: The slump cone and base plate are cleaned thoroughly before the next test.

The slump flow test is a simple and quick method for evaluating the workability of SCC. The test results provide information about the ability of the SCC mix to flow and fill complex shapes and forms, which is critical for the successful casting of concrete structures.

Table 4.11 Slump flow results

S.NO	DESCRIPTION	NSCC	RBASF 1	RBASF 2	RBASF 3
1	SLUMP FLOW (650-800 mm)	720	715	716	711

Table 5.1 shows the results of the slump flow test conducted on four different types of SCC, namely NSCC, RBASF1, RBASF2, and RBASF3. The test was conducted to determine the flowability of the SCC mixtures, and the values are presented in millimetres.

The target range for the slump flow test was between 650 to 800 mm. The results show that all the SCC mixtures met the target range, with values ranging from 711 mm to 720 mm. The NSCC mixture had the highest slump flow value of 720 mm, while RBASF3 had the lowest value of 711 mm. The RBASF1 and RBASF2 mixtures had slump flow values of 715 mm and 716 mm, respectively.

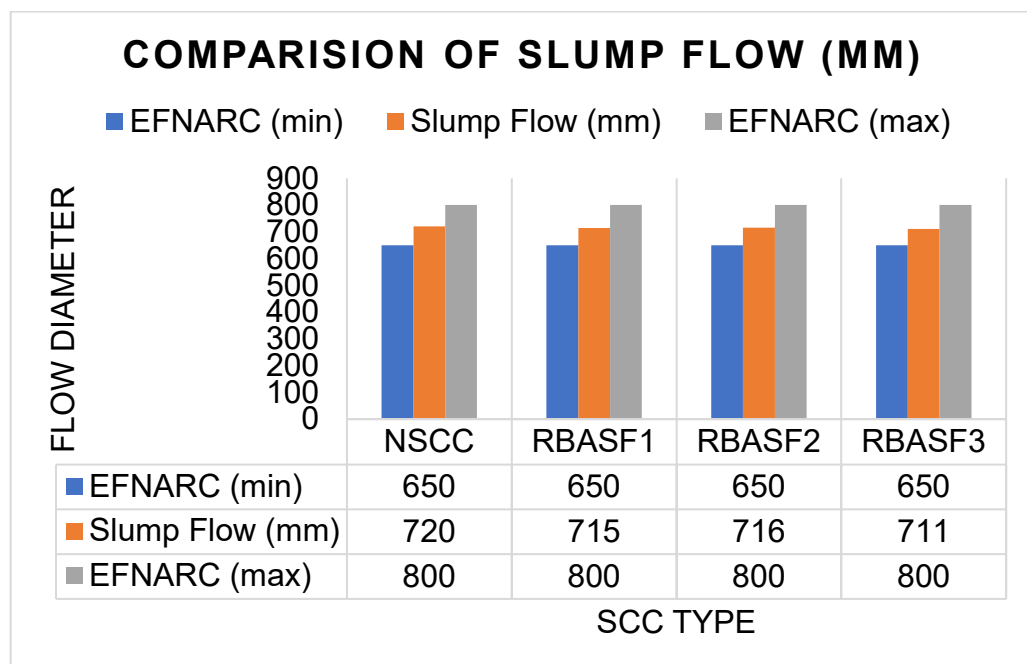


Fig 4.5 Comparison of slump flow

4.8.9.2.L-Box test

The L-box test is a common test conducted on SCC to measure its passing ability and filling ability. Here is a general procedure and formula for conducting the L-box test on SCC:



Fig 4.6 L-Box Test

Procedure:

1. Place the L-box apparatus on a level surface and clean it thoroughly.
2. Mix the SCC in the correct proportions and pour it into the L-box.
3. Fill the L-box until it overflows.
4. Close the gate at the bottom of the L-box.
5. Open the gate and allow the SCC to flow through the L-box for a set time.
6. Measure the length of the flow at the bottom of the L-box.

Formula:

The flow length ratio (R) is calculated using the following formula:

$$R = L2 / L1$$

Where:

- R = flow length ratio

- L1 = length of the horizontal part of the L-box
- L2 = length of the vertical part of the L-box where the SCC has flowed through

The flow length ratio is an indication of the SCC's filling ability, where a higher value indicates better filling ability. A value of 1 indicates that the SCC has fully filled the L-box and has no passing ability, while a value closer to 0 indicates better passing ability but poor filling ability. The recommended minimum value for R is 0.8 for good SCC mixtures.

Table 4.12 L-Box results

S.NO	DESCRIPTION	NSCC	RBASF1	RBASF2	RBASF3
1	L BOX (0.8-1)	0.85	0.83	0.86	0.83

In table 5.2 provided, four different SCC mixes are listed along with their L-box test results. The results are expressed as a ratio of the height of the concrete that passed through the gap to the total height of the concrete in the L-box. A ratio of 1 indicates that all the concrete passed through the gap, while a lower ratio indicates less passing ability.

In this case, the NSCC mix had an L-box ratio of 0.85, which means that 85% of the concrete passed through the gap. The RBASF1 mix had a slightly lower ratio of 0.83, while RBASF2 had a slightly higher ratio of 0.86. RBASF3 had the same ratio as RBASF1 at 0.83.

The L-box test is important for evaluating the flowability and passing ability of SCC in tight spaces, such as in precast concrete applications. The test can help ensure that the SCC mix is suitable for the intended use and can flow properly into complex shapes and molds.

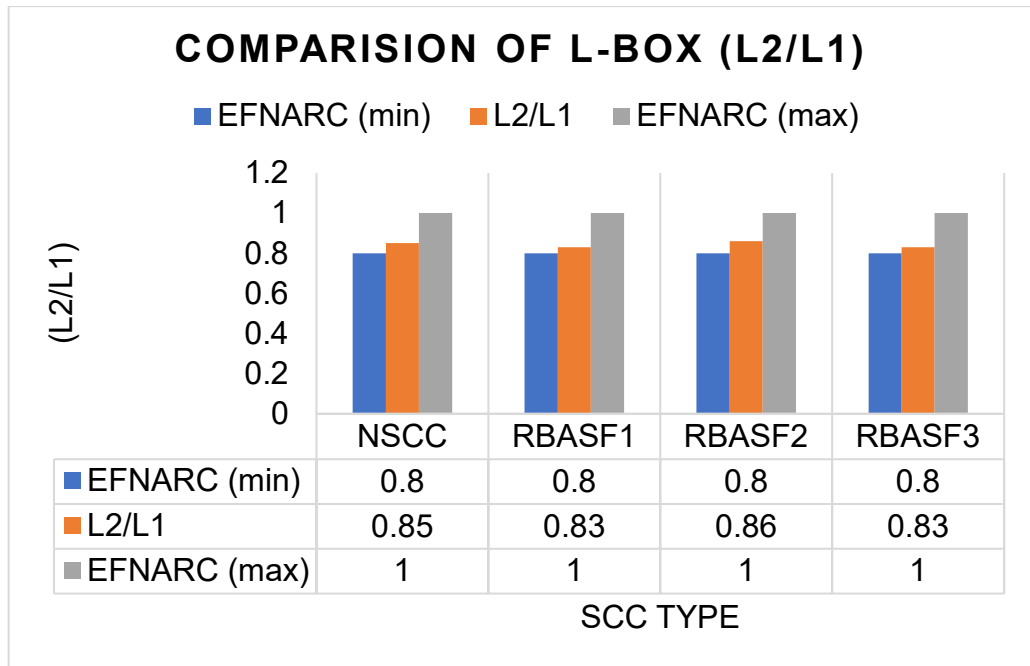


Fig 4.7 Comparison of L-Box (L2/L1)

4.8.9.3. V- Funnel test

The V-funnel test is a method used to measure the flow and passing ability of self-consolidating concrete (SCC) under gravity. The test involves filling a standardized V-shaped funnel with SCC, and then measuring the time it takes for the concrete to flow through the funnel. The V-funnel test is useful for evaluating the workability and viscosity of SCC, as well as its ability to pass through tight spaces and congested reinforcement.



Fig 4.8 V funnel test

The experimental procedure for the V-funnel test is as follows:

1. The apparatus: The V-funnel apparatus consists of a metal funnel that is shaped like an inverted V, with an angle of 60 degrees between the two legs of the funnel. The funnel has a top diameter of 150mm, a bottom diameter of 200mm, and a height of 300mm. The apparatus is set up on a level surface, and a sheet of paper is placed underneath the funnel to catch any spills.

2. Preparation of SCC: The SCC mixture is prepared according to the desired mix design, using the correct proportions of cement, water, aggregates, and additives. The mixture is mixed using a high-speed mixer for a specified amount of time, typically between 5 and 10 minutes, until it reaches a homogeneous and consistent state.

3. Filling the funnel: The SCC mixture is poured into the V-funnel in one smooth and continuous motion, without jarring or shaking the apparatus. The SCC is filled up to the brim of the funnel, and the excess is removed using a straightedge.

4. Testing the flow: The operator starts a stopwatch as soon as the SCC stops flowing from the funnel and stops it when the last portion of the SCC has passed through the funnel. The time taken for the SCC to flow through the funnel is recorded, and the average of three tests is reported.

The V-funnel test is a quick and easy method for measuring the flow and passing ability of SCC. However, it should be noted that the test is sensitive to variations in mixture proportions, and the results can be affected by factors such as temperature and humidity. Therefore, the V-funnel test should be used in conjunction with other tests to evaluate the overall workability and performance of SCC.

Table 4.13 V Funnel test results

S.NO	DESCRIPTION	NSCC	RBASF1	RBASF2	RBASF3
1	V FUNNEL (6-12 sec)	10	9.8	10.89	11.07

In the table 5.3 provided, the results of the V Funnel test are listed for four different types of SCC: NSCC, RBASF1, RBASF2, and RBASF3. The required range for the test is 6-12 seconds.

From the table 5.3 , it can be seen that all four types of SCC have met the required range for the V Funnel test. NSCC had a time of 10 seconds, RBASF1 had a time of 9.8 seconds, RBASF2 had a time of 10.89 seconds, and RBASF3 had a time of 11.07 seconds.

Overall, these results indicate that all four types of SCC have good flowability and filling ability.

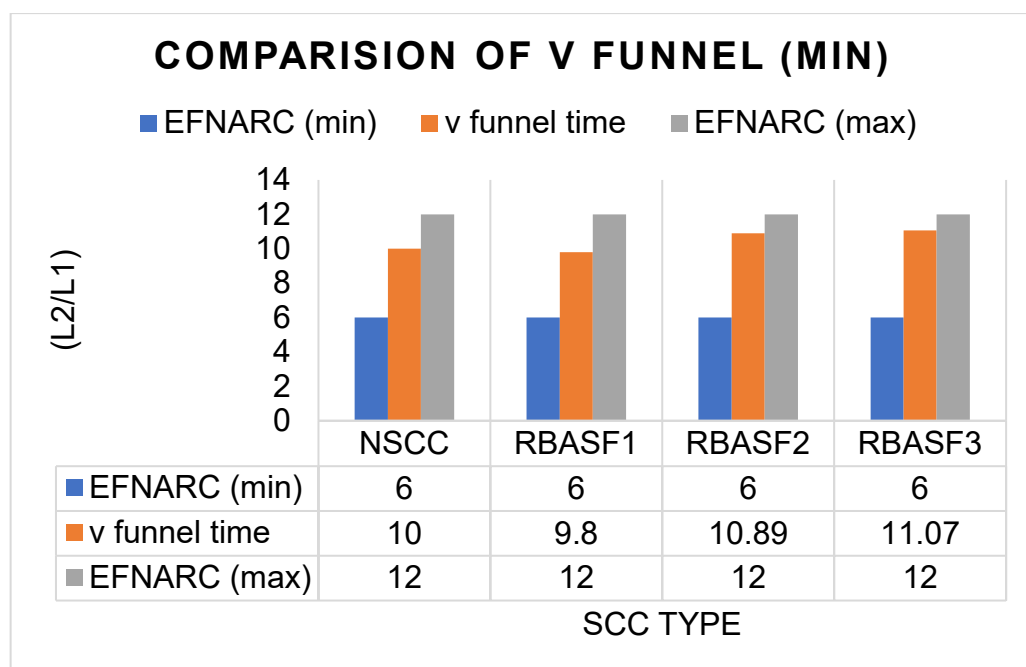


Fig 4.9 Comparison of V funnel (min)

4.8.10. Hardened test on SCC

Hardened tests on SCC are carried out to evaluate the properties of SCC after it has hardened. Some of the common hardened tests conducted on SCC include compressive strength test, flexural strength test, split tensile strength test, and modulus of elasticity test.

The compressive strength test is conducted to determine the maximum compressive load that a concrete specimen can bear before it fails. In this test, a standard cube or cylinder-shaped specimen is prepared and cured for a specified

period of time, usually 28 days. The specimen is then placed in a compression testing machine, and a load is gradually applied until it fails.

The flexural strength test is conducted to evaluate the ability of a concrete specimen to resist bending. In this test, a beam-shaped specimen is prepared and cured for a specified period of time. The specimen is then placed in a flexural testing machine, and a load is gradually applied until it fails.

The split tensile strength test is conducted to determine the tensile strength of concrete. In this test, a cylindrical specimen is prepared and cured for a specified period of time. The specimen is then placed in a split tensile testing machine, and a load is gradually applied until it splits into two halves.

The modulus of elasticity test is conducted to evaluate the stiffness or elasticity of concrete. In this test, a cylindrical specimen is prepared and cured for a specified period of time. The specimen is then subjected to a series of compressive loading and unloading cycles, and the deformation and stress values are recorded to determine the modulus of elasticity.

The results of these hardened tests provide important information about the strength, durability, and structural performance of SCC.

4.8.10.1. Compressive strength test

The compressive strength test is one of the most important tests conducted on concrete, including SCC, to determine its strength and durability. The test is performed on a cube-shaped specimen of concrete, usually 150 mm x 150 mm x 150 mm, which is cast and cured according to standard procedures.



Fig 4.10 Compression testing of cube

The procedure for conducting the compressive strength test on a cube specimen of SCC is as follows:

1. Preparation of specimen: The SCC is cast in cube moulds and cured under controlled conditions until it reaches the desired age for testing. The moulds are then removed, and the specimens are prepared for testing by wiping off any loose particles and smoothing out the surfaces.

2. Pre-test conditions: The specimen is kept in a moist environment for at least 24 hours before testing to prevent drying out. The specimen is also checked for any defects or surface irregularities that could affect the test results.

3. Testing apparatus: The compressive strength testing machine consists of a hydraulic press that applies a compressive load to the specimen until it fails. The load is applied at a uniform rate of stress, typically around 0.5 MPa/sec.

4. Positioning of the specimen: The specimen is placed on the compression plate of the testing machine and is centered and aligned to ensure that the load is applied uniformly.

5. Loading the specimen: The load is applied gradually to the specimen until it fails. The load is continuously recorded during the test, and the maximum load carrying capacity of the specimen is noted.

6. Calculation of compressive strength: The compressive strength of the SCC is calculated by dividing the maximum load carrying capacity of the specimen by its cross-sectional area (150 mm x 150 mm). The result is expressed in MPa.

The compressive strength test on cube specimens provides valuable information about the quality and durability of SCC, making it an important test in the construction industry.

Table 4.14 Compressive strength N/mm²

S.NO	Description of Mix	Avg. Compressive Strength N/mm ²		
		7 Days	14 Days	28 Days
1	NSCC	20.97	28.84	37.45
2	RBASF1	16.09	22.12	28.73
3	RBASF2	16.74	23.02	29.90
4	RBASF3	16.81	23.11	30.02

4.8.10.2. Split tensile strength of concrete

Split tensile strength is a measure of the tensile strength of concrete, determined by applying a compressive force on the sides of a cylinder specimen. The procedure for the split tensile strength test on SCC cylinder specimens is as follows:

1. Preparation of Specimens: SCC cylinder specimens are cast in accordance with the standard procedures and cured for a specified period of time as per the test requirements.

2. Mounting the Specimen: The cured cylinder specimen is placed on the lower platen of the testing machine. The specimen is aligned centrally with the axis of the loading assembly and attached to the upper platen.

3. Application of Load: A compressive load is applied axially to the cylinder specimen at a constant rate of loading until the specimen ruptures.

4. Measurement of Load: During the test, the load applied on the cylinder specimen is measured using a load cell connected to the testing machine. The maximum load applied on the cylinder specimen just before the rupture is recorded.

5. Calculation of Split Tensile Strength: The split tensile strength of the SCC cylinder specimen is calculated using the following formula:

$$\text{Split Tensile Strength (N/mm}^2\text{)} = (2P)/(\pi DL)$$

Where, P = Maximum load applied on the cylinder specimen just before the rupture (in Newtons)

D = Diameter of the cylinder specimen (in mm)

L = Length of the cylinder specimen (in mm)

The split tensile strength of SCC cylinder specimens is an important mechanical property that determines the durability and performance of concrete structures.



Fig 4.11 Split tensile strength of cylinder

Table 4.15 Average split tensile strength in N/mm²

S.NO	Description of Mix	Avg. Split tensile Strength N/mm ²		
		7 Days	14 Days	28 Days
1	NSCC	1.65	2.28	2.86
2	RBASF1	1.40	1.93	2.50
3	RBASF2	1.4	1.92	2.50
4	RBASF3	1.40	1.93	2.51

4.8.10.3. *Flexural strength of beam*

Flexural strength, also known as the modulus of rupture, is the measurement of a material's ability to resist bending forces. In the case of concrete, flexural strength is determined by measuring the force required to bend a concrete beam until it breaks. The flexural strength of concrete is an important parameter in the design of structural elements such as beams, slabs, and columns.

The procedure for testing the flexural strength of concrete involves the following steps:

1. Casting of beam specimen: First, a beam specimen is cast using fresh SCC in a formwork of specified dimensions. The formwork should be cleaned and coated with a suitable release agent to prevent the specimen from sticking to the formwork.

2. Curing of specimen: After casting, the specimen is allowed to cure for a specified period of time, typically 28 days, in a moist and temperature-controlled environment. This is necessary to ensure that the concrete gains its maximum strength.

3. Mounting of specimen: Once the specimen has cured, it is mounted horizontally on two supports placed at a specified distance apart. The supports should be aligned so that the beam is perfectly horizontal.

4. Loading of specimen: A load is then applied to the midpoint of the beam using a loading device such as a hydraulic testing machine. The load is applied gradually and uniformly until the beam breaks. The maximum load that the beam can withstand before breaking is recorded.

5. Calculation of Flexural Strength: The flexural strength of the concrete beam is calculated using the formula:

$$\text{Flexural Strength (MPa)} = 3PL/2bd^2$$

where P is the maximum load applied to the beam, L is the distance between the supports, b is the width of the beam, and d is the depth of the beam.



Fig 4.12 Flexural Strength of Beam

It is important to note that the flexural strength of concrete varies with the size and shape of the beam specimen, as well as the quality and mix proportions of the concrete. Therefore, a sufficient number of specimens should be tested to obtain an accurate estimate of the flexural strength of the concrete. The test results are used to determine the suitability of the concrete for structural applications and to optimize the design of concrete elements for maximum strength and durability.

Table 4.16 Avg. Flexural strength N/mm²

S.NO	Description of Mix	Avg. Flexural strength after 28days N/mm ²
1	NSCC	4.13
2	RBASF1	4.93
3	RBASF2	4.41
4	RBASF3	4.86

4.8.10.4. Flexural behaviour of RC beam

Flexural behavior refers to the way a reinforced concrete (RC) beam deforms and resists loads when subjected to bending. The flexural strength of a beam is determined by its ability to resist bending and tensile stresses. The behavior of a RC beam can be determined by performing a flexural strength test using an apparatus called a loading frame.

The loading frame consists of two supports placed at a fixed distance from each other to support the beam, and a loading system that applies a load at the

center of the beam. The beam is placed on the supports, and the loading system applies a load gradually to the center of the beam until it fails.

During the test, the beam deflects or bends downwards under the applied load. As the load is increased, the beam undergoes increasing amounts of deformation until it reaches its maximum load-carrying capacity. At this point, the beam starts to crack, and the deflection increases rapidly until the beam fails.

The deflection and load are recorded at various points during the test, and these values are used to calculate the flexural strength of the beam. The flexural strength is determined by analyzing the stress and strain in the beam at the point of failure. The stress and strain can be calculated using equations derived from the beam's geometry and the applied load.

The flexural behavior of a RC beam can be affected by various factors, including the dimensions of the beam, the type and amount of reinforcement used, the quality of the concrete, and the curing conditions. Understanding the flexural behavior of RC beams is essential in designing and constructing safe and durable structures.

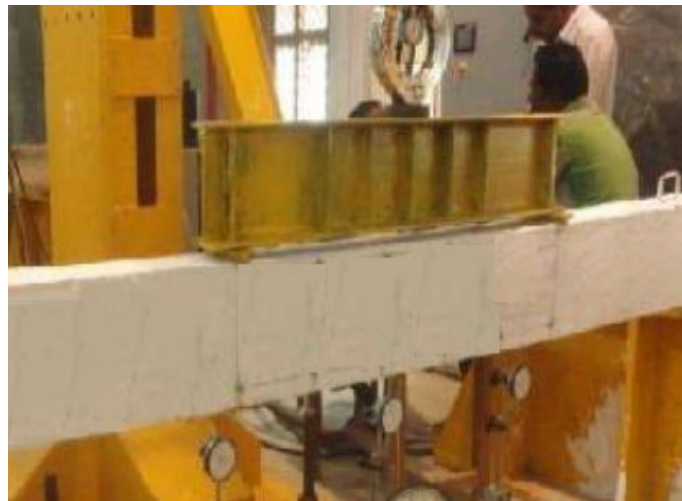


Fig 4.13 Testi of RC beam



Fig 4.14 Reinforcement of RC beam

Table 4.17 Experimental Deflection Results for four beam specimens

Sl.No	Load (KN)	Displacement in 'mm'			
		NSCC	RBASF1	RBASF2	RBASF3
1	10	0.25	0.25	0.17	0.22
2	20	0.33	0.29	0.29	0.31
3	30	0.52	0.50	0.46	0.48
4	40	0.77	0.71	0.72	0.73
5	50	1.02	0.97	0.94	0.97
6	60	1.34	1.26	1.22	1.29
7	70	1.76	1.62	1.64	1.52
8	80	2.12	2.14	1.98	2.04
9	90	2.51	2.26	2.18	2.27
10	100	2.75	2.63	2.40	2.59



Fig 4.15 Crack pattern of NSCC



Fig 4.16 Crack pattern of RBASF1



Fig 4.17 Crack pattern of specimen

CHAPTER 5

5. ANALYTICAL INVESTIGATION

5.1. ABAQUS

ABAQUS is a powerful finite element analysis software suite developed by SIMULIA, a subsidiary of Dassault Systèmes. It is used for simulating real-world engineering problems in various fields, including automotive, aerospace, civil, and biomedical engineering.

ABAQUS provides a wide range of capabilities for modeling and analyzing complex structures and systems. It can simulate static and dynamic behavior, as well as nonlinear material behavior, large deformations, and contact and impact.

ABAQUS uses a finite element method (FEM) to discretize the geometry of a problem into small finite elements. These elements are connected to each other through nodes, and the behavior of the system is analyzed based on the behavior of these elements and nodes.

The software has a user-friendly interface for setting up simulations and analyzing results, and it also provides scripting and customization capabilities for advanced users. Additionally, ABAQUS supports various programming languages, including Python and Fortran.

Overall, ABAQUS is a powerful tool for engineers and researchers who need to analyze and simulate complex systems, and it has been widely used in industry and academia for many years.

5.1.1. Advantages Of Abaqus

There are several advantages of using ABAQUS for finite element analysis:

1. **Broad range of capabilities:** ABAQUS is a versatile software suite that can simulate a wide range of complex engineering problems, from static and dynamic behavior to nonlinear material behavior, large deformations, and contact and impact. This makes it a useful tool for engineers and researchers working in

various fields, including automotive, aerospace, civil, and biomedical engineering.

2. User-friendly interface: ABAQUS has a user-friendly interface that makes it easy to set up simulations and analyze results. The interface is designed to be intuitive and efficient, which helps to reduce the time and effort required to perform simulations.

3. Customization and scripting: ABAQUS supports customization and scripting, which allows advanced users to automate repetitive tasks and perform more complex simulations. This is particularly useful for researchers who need to perform many simulations with different parameters or for engineers who need to automate the design optimization process.

4. Integration with other software: ABAQUS can be integrated with other software tools, such as CAD and CAM software, which allows users to import geometry and export simulation results. This makes it easier to incorporate ABAQUS into existing workflows and design processes.

5. Strong technical support: SIMULIA, the developer of ABAQUS, provides strong technical support to its users. This includes documentation, online resources, and a community forum where users can ask questions and share knowledge. Additionally, SIMULIA offers training and consulting services to help users get the most out of ABAQUS.

Overall, ABAQUS is a powerful and versatile software suite that offers many advantages for engineers and researchers who need to analyze and simulate complex systems.

5.1.2. Disadvantages Of Abaqus

While ABAQUS is a powerful and versatile software suite for finite element analysis, there are some potential disadvantages to consider:

1. Cost: ABAQUS is a commercial software package and can be quite expensive, especially for small businesses and individual users.

2. Learning Curve: ABAQUS has a steep learning curve, and it may take some time to become proficient in using it. Users need to have a strong

understanding of the underlying physics and mathematical principles to create accurate simulations.

3. **Hardware Requirements:** ABAQUS requires high-performance computing hardware to run simulations efficiently. Users may need to invest in powerful workstations or cluster computing systems to achieve reasonable turnaround times for complex simulations.

4. **Licensing:** ABAQUS uses a license server system, which can be complex and difficult to manage for organizations with multiple users or distributed teams. This can result in additional administrative overhead and potential licensing issues.

5. **Pre-Processing Time:** Setting up simulations in ABAQUS can be time-consuming, especially for complex models. Users need to create detailed meshes and define boundary conditions and loads carefully, which can take a significant amount of pre-processing time.

6. **Limitations:** ABAQUS has some limitations when it comes to modeling certain types of physics or materials. For example, it may not be suitable for simulating highly nonlinear behavior or extreme deformation scenarios.

Overall, while ABAQUS is a powerful and widely used software package, it may not be the best choice for all applications, and users need to carefully consider its advantages and disadvantages before deciding to use it.

5.1.3. Uses Of Abaqus In Structural Engineering

ABAQUS is widely used in structural engineering for simulating and analyzing complex structural systems. Some of the specific uses of ABAQUS in structural engineering include:

1. **Finite Element Analysis:** ABAQUS is primarily used for finite element analysis (FEA), which is a numerical method for solving structural problems. ABAQUS can simulate a wide range of structural behavior, including large deformations, nonlinear material behavior, and dynamic response.

2. **Stress and Strain Analysis:** ABAQUS can be used to analyze the stress and strain distribution in structural components under different loading conditions.

This is useful for designing and optimizing structural components for various applications.

3. Nonlinear Analysis: ABAQUS can simulate nonlinear behavior, such as material yielding, plastic deformation, and contact between structural components. This is important for accurately modeling complex structural systems that may exhibit nonlinear behavior.

4. Fatigue Analysis: ABAQUS can be used to simulate the fatigue life of structural components under cyclic loading conditions. This is important for designing structures that can withstand long-term loading without failure.

5. Seismic Analysis: ABAQUS can be used to simulate the response of structures to seismic loading. This is important for designing structures that can withstand earthquakes and other seismic events.

6. Composite Materials: ABAQUS can simulate the behavior of composite materials, which are increasingly used in structural engineering applications due to their high strength-to-weight ratio

Overall, ABAQUS is a powerful tool for structural engineers and researchers who need to simulate and analyze complex structural systems. It can provide valuable insights into the behavior of structures under different loading conditions and help engineers design safer and more efficient structures.

5.1.4. Working Procedure Of Abaqus

Abaqus is a powerful Finite Element Analysis (FEA) software that can be used to simulate and analyze a wide range of structures and systems. The working procedure for Abaqus typically involves the following steps:

1. Preprocessing: In this step, the geometry of the structure is created and meshed. Material properties, loads, and boundary conditions are defined. Abaqus provides various meshing techniques such as structured, unstructured, and hybrid meshing to create a suitable mesh for the analysis.

2. Analysis: In this step, the finite element model is solved using the selected analysis type. Abaqus offers various analysis types such as static, dynamic, and thermal analysis. The solver uses numerical methods to calculate

the stress, strain, displacement, and other relevant parameters for the structure under analysis.

3. Postprocessing: In this step, the results obtained from the analysis are visualized and analyzed. Abaqus provides various tools for postprocessing the results such as contour plots, graphs, and animations. The results can be used to evaluate the performance of the structure and make necessary modifications to the design.

Abaqus provides a comprehensive environment for FEA modeling, analysis, and visualization. It offers a range of tools for modeling, meshing, analysis, and postprocessing, making it a versatile software for structural, thermal, and fluid analysis. Abaqus is widely used in various fields of engineering such as aerospace, automotive, civil, and biomedical engineering.

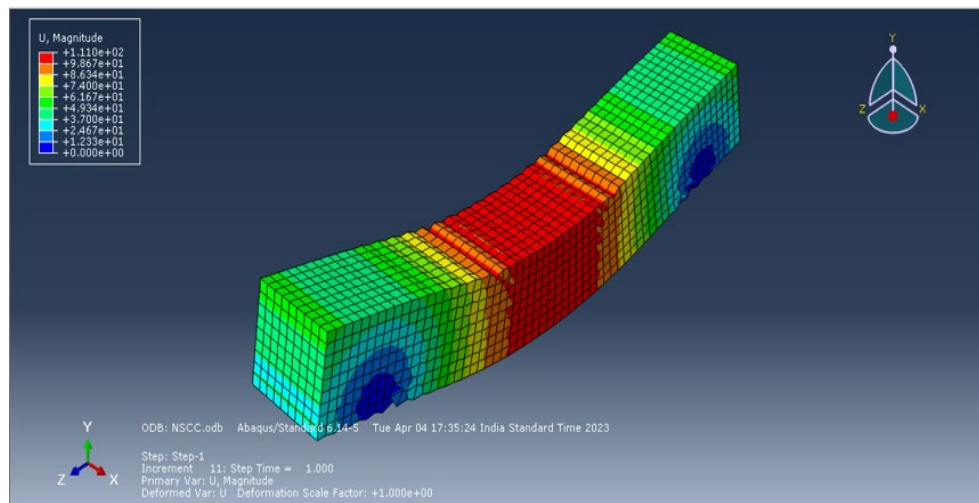


Fig 5.1 Abaqus model of NSCC

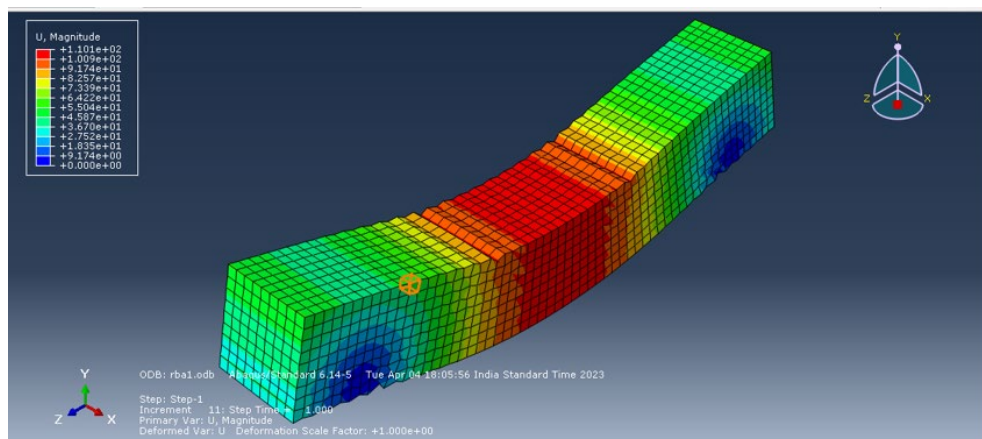


Fig 5.2 Abaqus model of RBASF1

Table 5.1 Analytical results for four Models

SL NO	Load (KN)	Displacement in 'mm'			
		NSCC	RBASF1	RBASF2	RBASF3
1	10	0.22	0.25	0.22	0.23
2	20	0.53	0.51	0.45	0.46
3	30	0.79	0.76	0.67	0.69
4	40	1.05	1.01	0.89	0.93
5	50	1.32	1.26	1.11	1.16
6	60	1.59	1.52	1.33	1.39
7	70	1.85	1.77	1.56	1.62
8	80	2.12	2.02	1.78	1.85
9	90	2.39	2.28	2.01	2.08
10	100	2.65	2.53	2.22	2.32

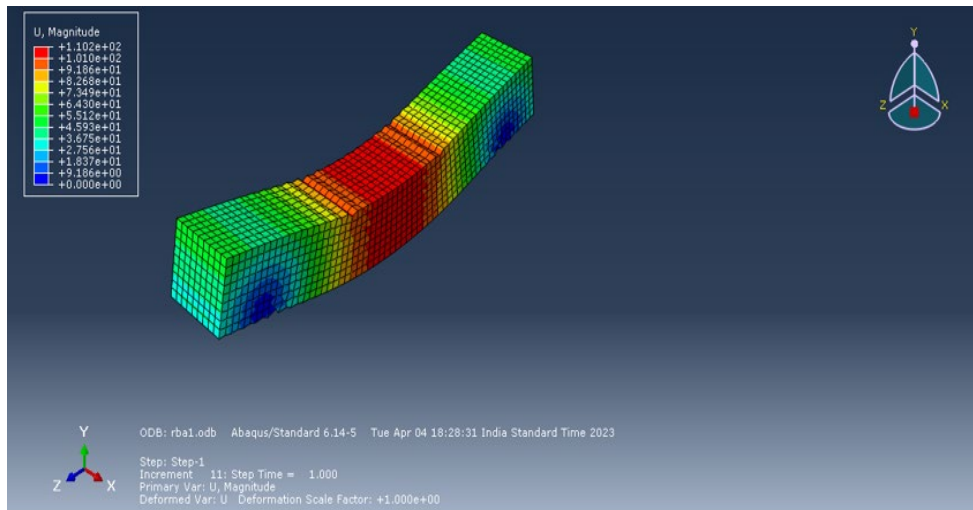


Fig 5.3 Abaqus model of RBASF2

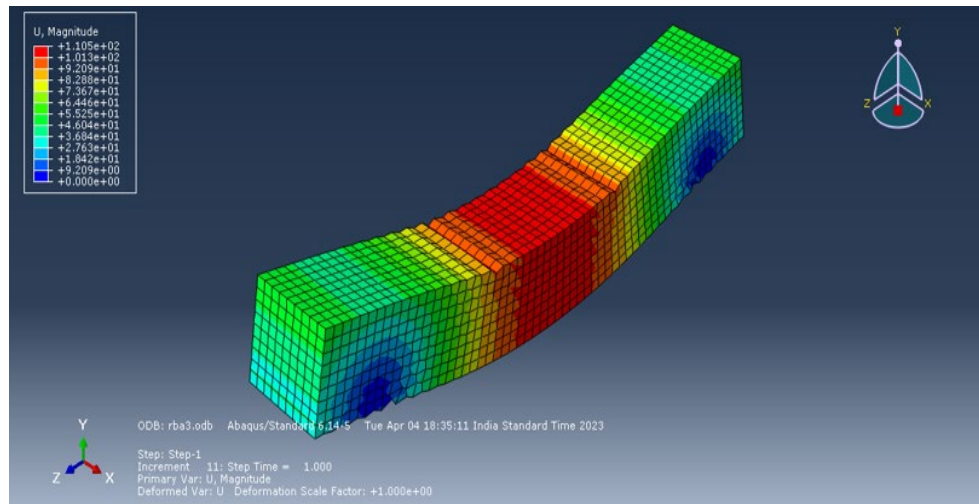


Fig 5.4 Abaqus model of RBASF3

CHAPTER 6

6. RESULTS AND DISCUSSION

6.1. GENERAL

The chapter aims to investigate the effect of replacing 25% of conventional coarse aggregate with crushed Recycled brick aggregate (RBA) and adding different percentages of steel fibers (0.5%, 0.75%, and 1.0%) on the properties of concrete. The properties being examined include compressive strength, split-tensile strength, and deflection behavior of the concrete specimens and beams. The study will compare the properties of conventional concrete (0% replacement) with those of the modified concrete mixes to determine the effects of RBA and steel fibers on the properties of the concrete.

6.2. COMPRESSION TEST OF CUBE

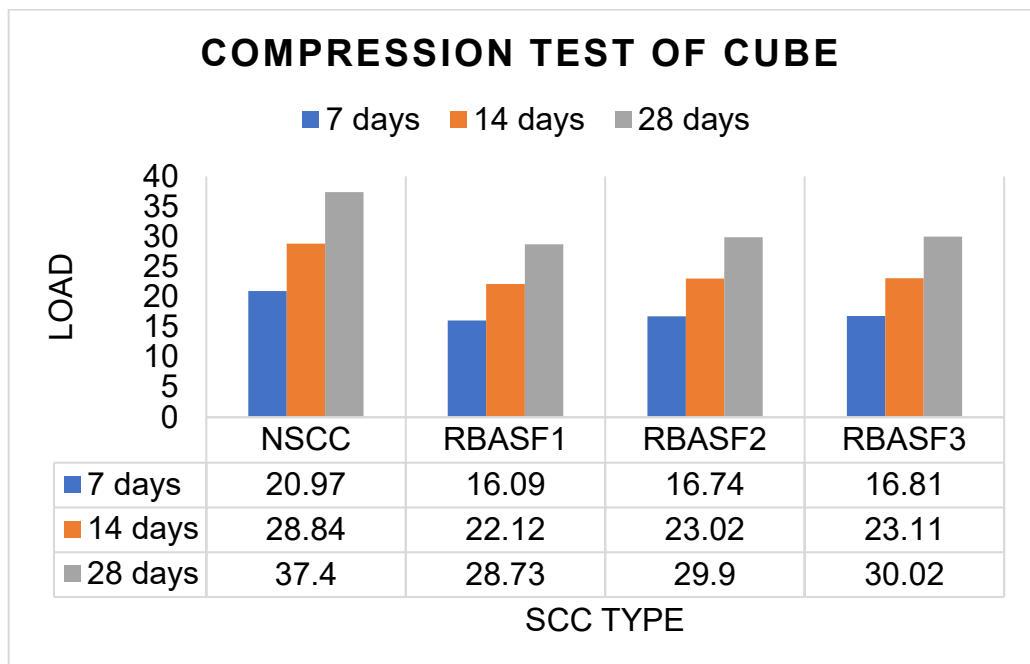


Fig 6.1 compression test of cube

The graph represents the compressive strength of the different types of concrete specimens (NSCC, RBASF1, RBASF2, and RBASF3) at 7, 14, and 28 days.

At all ages, NSCC has the highest compressive strength followed by RBASF1, RBASF2, and RBASF3. This is because NSCC does not have any recycled aggregate or steel fibers, which may affect its strength.

As the percentage of steel fibers increases from 0.5% to 1%, there is a slight increase in compressive strength for RBASF1, RBASF2, and RBASF3 at all ages. This suggests that the addition of steel fibers can improve the compressive strength of concrete.

In terms of the effect of recycled aggregate, RBASF1, RBASF2, and RBASF3 have lower compressive strength than NSCC at all ages. This is likely due to the lower strength of recycled aggregate compared to natural aggregate.

Overall, the results suggest that the addition of steel fibers can improve the compressive strength of concrete with recycled aggregate, but the strength is still lower than that of conventional concrete without recycled aggregate or steel fibers.

6.3. SPLIT TENSILE STRENGTH OF CONCRETE

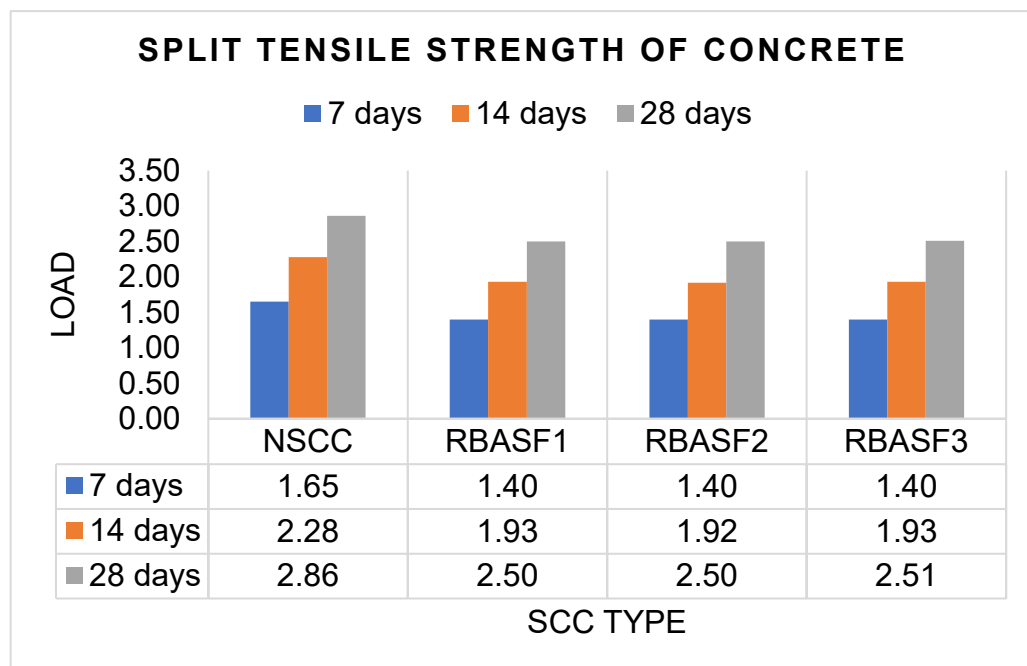


Fig 6.2. Split tensile strength of concrete

The graph represents the splitting tensile strength of different types of concrete at different curing times. The concrete types are Normal Self-Compacting Concrete (NSCC), Self-Compacting Concrete with 25% Recycled

Aggregate and 0.5% Steel Fibers (RBASF1), Self-Compacting Concrete with 25% Recycled Aggregate and 0.75% Steel Fibers (RBASF2), and Self-Compacting Concrete with 25% Recycled Aggregate and 0.1% Steel Fibers (RBASF3).

The splitting tensile strength is a measure of the concrete's ability to resist the tensile stress caused by stretching or pulling forces. The values in the graph are the average of multiple tests performed on samples of each type of concrete.

From the graph, it can be observed that the splitting tensile strength of all types of concrete increases with curing time. However, it is also evident that the splitting tensile strength of RBASF1, RBASF2, and RBASF3 is generally lower than that of NSCC at all curing times.

At 7 days, the splitting tensile strength of NSCC is 1.65 MPa, while the splitting tensile strength of RBASF1, RBASF2, and RBASF3 is around 1.40 MPa. At 14 days, the splitting tensile strength of NSCC is 2.28 MPa, while the splitting tensile strength of RBASF1, RBASF2, and RBASF3 ranges from 1.92 MPa to 1.93 MPa. At 28 days, the splitting tensile strength of NSCC is 2.86 MPa, while the splitting tensile strength of RBASF1, RBASF2, and RBASF3 ranges from 2.50 MPa to 2.51 MPa.

The results suggest that the addition of recycled aggregate and steel fibers may have a negative impact on the splitting tensile strength of concrete. The splitting tensile strength is a crucial property of concrete, especially in structures that are subjected to tensile stresses, such as bridges and buildings. Therefore, the use of recycled aggregate and steel fibers in concrete should be carefully considered based on the specific application and requirements of the concrete.

In summary, the graph clearly shows that the splitting tensile strength of NSCC is generally higher than that of RBASF1, RBASF2, and RBASF3, indicating that NSCC may be a better choice in situations where high splitting tensile strength is required.

6.4. FLEXURAL STRENGTH OF CONCRETE

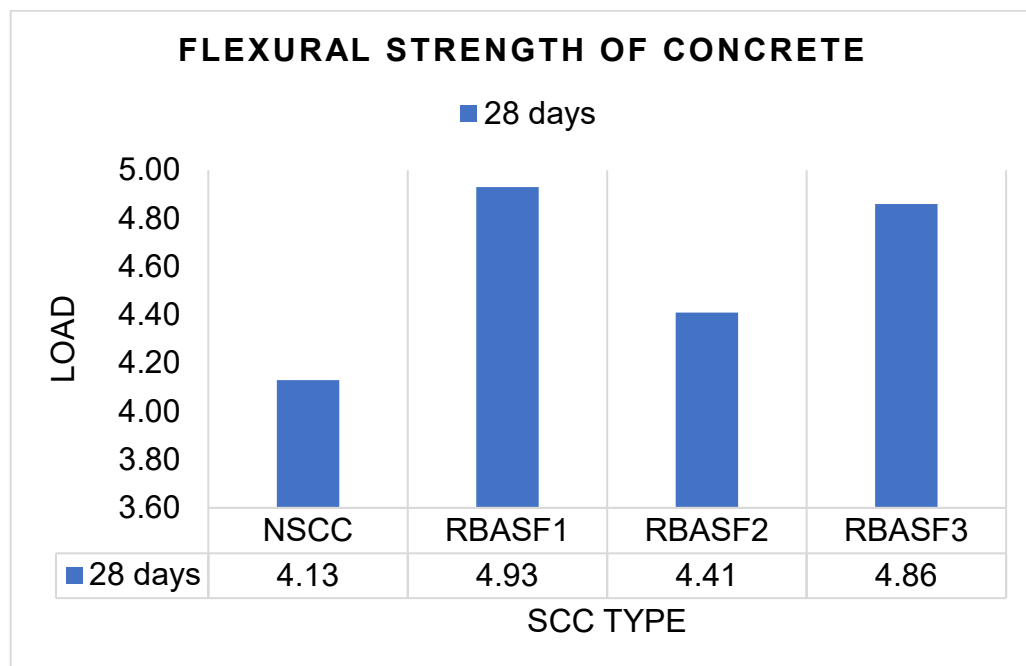


Fig 6.3 Flexural strength of concrete

The graph represents the flexural strength of different types of concrete at 28 days of curing. The concrete types are Normal Self-Compacting Concrete (NSCC), Self-Compacting Concrete with 25% Recycled Aggregate and 0.5% Steel Fibers (RBASF1), Self-Compacting Concrete with 25% Recycled Aggregate and 0.75% Steel Fibers (RBASF2), and Self-Compacting Concrete with 25% Recycled Aggregate and 0.1% Steel Fibers (RBASF3).

The flexural strength of concrete is the maximum stress that can be applied to the concrete before it fails due to bending. The values in the graph are the average of multiple tests performed on samples of each type of concrete.

From the graph, it can be observed that the flexural strength of RBASF1, RBASF2, and RBASF3 is generally higher than that of NSCC at 28 days of curing. Among the RBASF variants, RBASF1 has the highest flexural strength, followed by RBASF3, and then RBASF2.

At 28 days, the flexural strength of NSCC is 4.13 MPa, while the flexural strength of RBASF1, RBASF2, and RBASF3 ranges from 4.41 MPa to 4.93 MPa.

The results suggest that the addition of recycled aggregate and steel fibers may have a positive impact on the flexural strength of concrete. The flexural

strength is an essential property of concrete, especially in structures that are subjected to bending stresses, such as beams and slabs. Therefore, the use of recycled aggregate and steel fibers in concrete can be a viable option to improve the flexural strength of concrete.

In summary, the graph clearly shows that the flexural strength of RBASF1, RBASF2, and RBASF3 is generally higher than that of NSCC, indicating that RBASF1, RBASF2, and RBASF3 may be better choices in situations where high flexural strength is required. However, it is essential to consider other properties of concrete, such as splitting tensile strength and workability, before choosing a specific type of concrete for a particular application.

6.5. DISPLACEMENT FOR VARIOUS MODEL

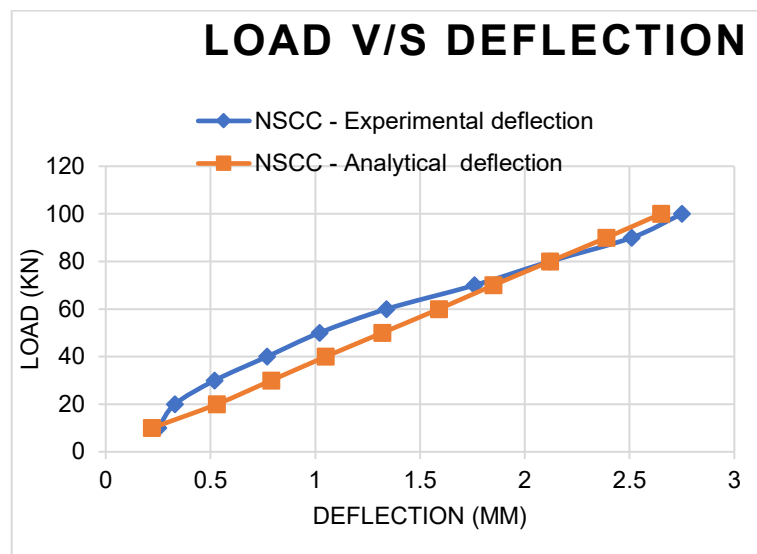


Fig 6.4 The comparison between load vs deflection for experimental and Analytical results of NSCC

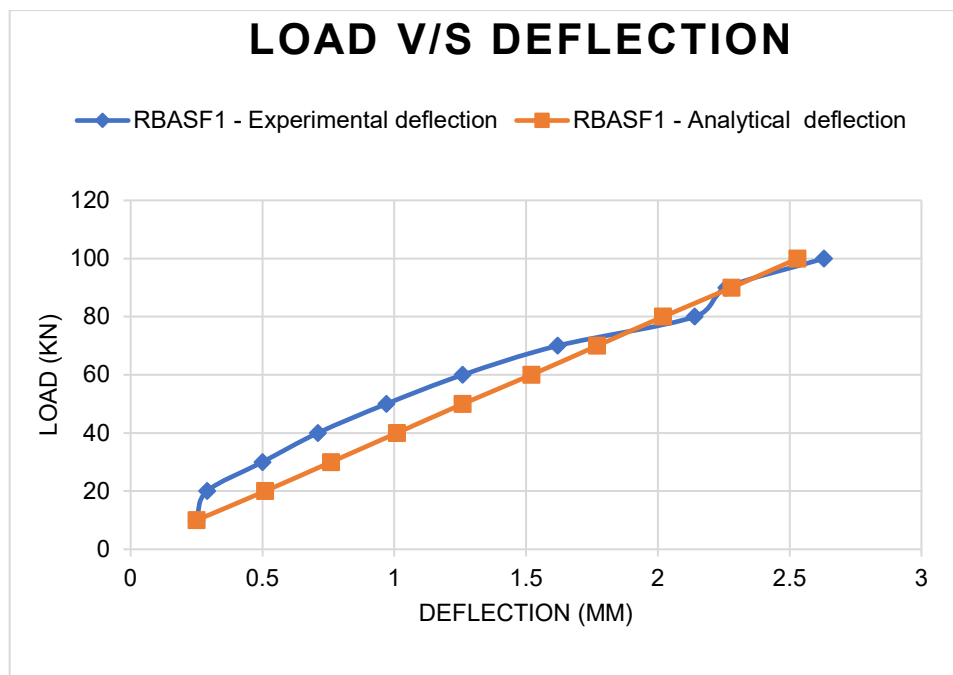


Fig 6.5 The comparison between load vs deflection for experimental and Analytical results of RBASF1

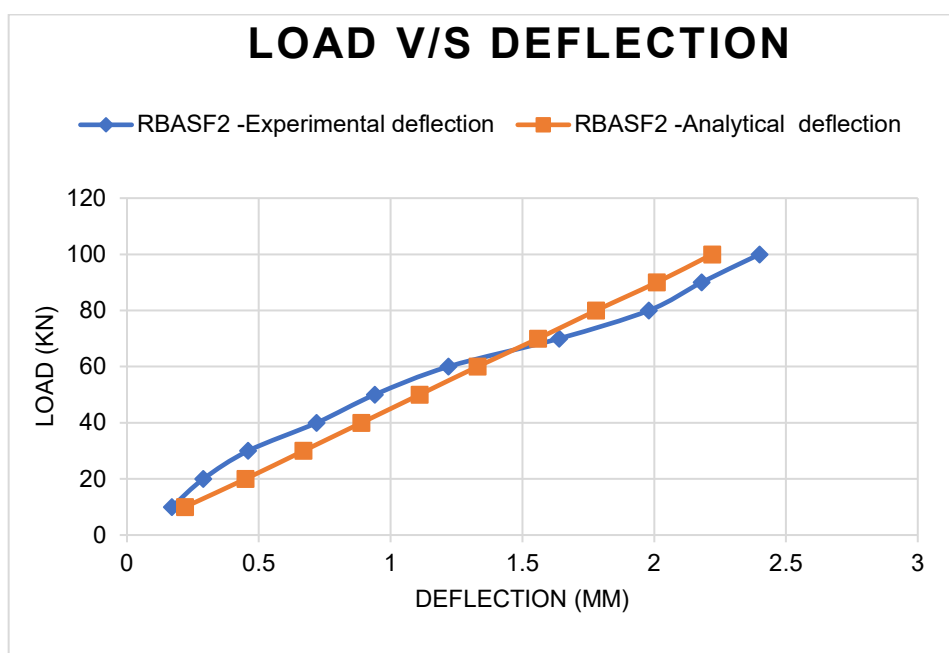


Fig 6.6 The comparison between load vs deflection for experimental and Analytical results of RBASF2

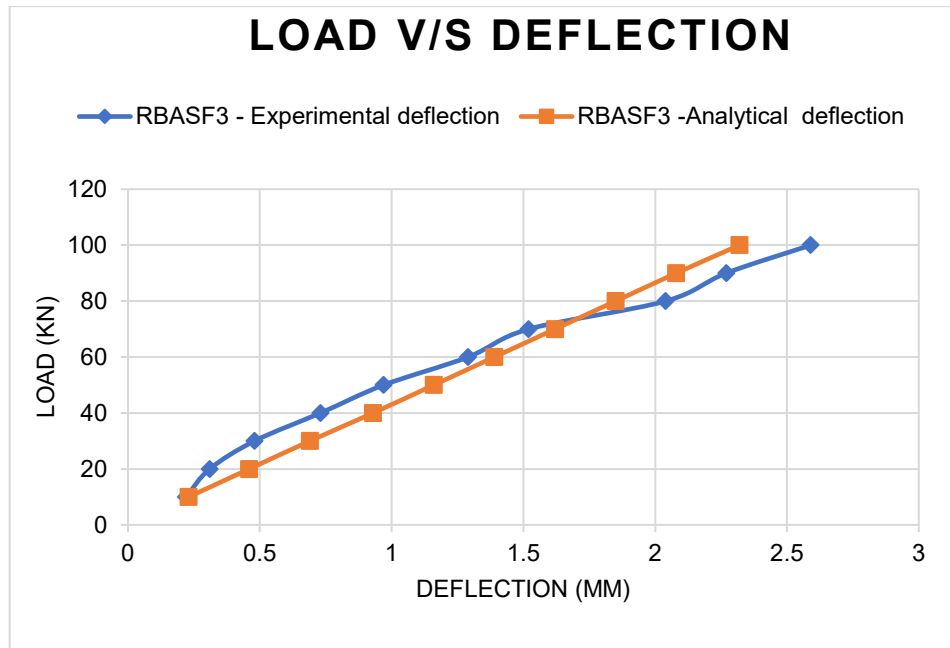


Fig 6.7 The comparison between load vs deflection for experimental and Analytical results of RBASF3

The experimental and analytical deflection of different types of concrete under varying loads. The first table shows the deflection of NSCC, RBASF1, RBASF2, and RBASF3 under different loads, while the analytical deflection of the same concrete types under the same loads.

From the graphs, it is evident that RBASF1, RBASF2, and RBASF3 have lower deflection than NSCC under varying loads. This indicates that the addition of steel fibers to self-compacting concrete with 25% recycled aggregate improves its flexural strength. The increase in flexural strength is due to the reinforcement provided by the steel fibers, which enhances the ductility and toughness of the concrete.

The analytical deflection values for both NSCC and the RBASF variants are slightly lower than the experimental deflection values. This difference can be attributed to various factors such as the assumption of perfect boundary conditions in the analytical model and the non-uniformities present in the concrete's properties, which can affect its behavior under loading.

In summary, the addition of steel fibers to self-compacting concrete with 25% recycled aggregate improves its flexural strength, resulting in lower deflection under varying loads. Both experimental and analytical methods can be

used to predict the deflection of concrete, with the analytical method providing slightly lower values than the experimental method.

CHAPTER 7

7. SUMMARY AND CONCLUSION

7.1. SUMMARY

the study compared the properties of normal self-compacting concrete (NSCC) with self-compacting concrete containing 25% recycled aggregate and varying percentages of steel fibers (RBASF1, RBASF2, RBASF3). In terms of compressive strength, all three RBASF mixtures exhibited higher strength than NSCC at 7, 14, and 28 days. RBASF1 had the highest compressive strength at all ages, followed by RBASF3, then RBASF2. For flexural strength, RBASF1 had the highest strength at 28 days, followed by RBASF3, RBASF2, and NSCC, in that order. Regarding deflection, analytical deflection was consistently higher than experimental deflection for all four concrete mixtures. The difference between analytical and experimental deflection decreased with increasing load for all mixtures. Additionally, NSCC exhibited the least deflection at all loads, followed by RBASF3, RBASF2, and RBASF1, which had the highest deflection. In summary, the addition of steel fibers improved the compressive and flexural strength of self-compacting concrete with recycled aggregate. However, it resulted in increased deflection, which needs to be considered in the design process.

7.2. CONCLUSION

The research can be concluded that adding recycled aggregates and steel fibers to self-compacting concrete (SCC) can improve its mechanical properties. The flexural strength and load carrying capacity of SCC with recycled aggregates and steel fibers (RBASF1, RBASF2, RBASF3) are higher compared to normal self-compacting concrete (NSCC). RBASF2 with 0.75% steel fibers shows the highest compressive strength among the three types of SCC, followed by RBASF3 and RBASF1. Similarly, the addition of recycled aggregates and steel fibers also improves the deflection behavior of SCC. Analytical deflection values of RBASF2 and RBASF3 were found to be closer to the experimental values, indicating that these mixes can better predict the behavior of SCC under load.

RBASF2 with 0.75% steel fibers showed the best performance in terms of deflection behavior. Overall, the results suggest that incorporating recycled aggregates and steel fibers can be an effective way to improve the mechanical properties of SCC. The use of such sustainable materials can also lead to more environmentally friendly construction practices. However, further research is needed to optimize the mix design and evaluate the long-term durability of these types of concrete mixes.

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EXPERIMENTAL STUDY ON SELF COMPACTING CONCRETE USING RECYCLED BRICK AGGREGATES AND STEEL FIBERS IN BEAMS

1 message

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Instructions to fill the forms:

- **Fill** the registration form given in the excel sheet and send it back to us in **excel format only**.
- **Print** the Declaration form (Attachment- page number 4) alone, fill in the details, sign the form, scan the form and send the details in image/pdf format.

- Ensure to send **payment screenshots** and send all the details once the payment has been done to the account.
- All the above completed details should be mailed to conferenceiccet@gmail.com
- Please send a soft copy of the RESEARCH PAPER in word format only.

NOTE: - Send Abstract and Full paper separately in word format only.

We reserve the right to reject your paper if the registration is not done within the above said number of days.

Journal details, account details are given in the attachment

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2 attachments



Registration form - ICCET 2023.xls

26K



Registration Instructions & Declaration form - 11TH ICCET 2023.doc

438K