

BUCKLING BEHAVIOUR OF CONCRETE ENCASED CASTELLATED COLUMN WITH LACINGS

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

Submitted by,

ARUN SHAJIN C (Reg No: 41380001)



**DEPARTMENT OF CIVIL ENGINEERING
SCHOOL OF BUILDING AND ENVIRONMENT**

**SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600119

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SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

Accredited with 'A' grade by NAAC
Jeppiyaar Nagar, Rajiv Gandhi Salai, Chennai - 600 119.

Phone: 044 - 2450 3150 / 3151 / 3152 / 3154 / 3155 Fax: 044 - 2450 2344
www.sathyabama.ac.in



DEPARTMENT OF CIVIL ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of **ARUN SHAJIN C (Reg No: 41380001)** who carried out the project entitled **“BUCKLING BEHAVIOUR OF CONCRETE ENCASED CASTELLATED COLUMN WITH LACINGS”** under my supervision from December 2023 to May 2023.

Internal Guide

(Dr.C. Manoj Kumaar)

Head of the Department

(Dr.S.Packialakshmi)

Submitted for Viva voce Examination held on 05/05/2023

Internal Examiner

External Examiner

DECLARATION

I **ARUN SHAJIN C (41380001)** , here by declare that the Project Report entitled “**BUCKLING BEHAVIOUR OF CONCRETE ENCASED CASTELLATED COLUMN WITH LACINGS**”,done under the guidance of **Dr. C. Manoj Kumaar** is submitted in partial fulfillment of the requirements for the award of Master of Engineering degree in Structural Engineering.

DATE : 05-05-2023

PLACE: Chennai

A handwritten signature in blue ink, reading "C. Arun Shajin", is shown within a light gray rectangular box.

SIGNATURE OF THE CANDIDATE

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ABSTRACT

Castellated columns are structural members that are created by breaking a rolled column along the center-line by flame after that rejoining the equivalent halves by welding such that for better structural strength against axial loading, the total column depth is increased by around 50 percent. The implementation of these institutional members will also contribute to significant economies of material value. The main objectives of this study are to study the enhancement of the load-carrying capacity of castellated columns with encasement of the columns by Concrete and lacing reinforcement, and serviceability of the confined castellated columns

The Castellated columns with concrete and Lacing Reinforcement improve compactness and local buckling (web and flange local buckling), as a result of steel section encasement. This study presents axial load test results for four specimens Castellated columns section encasement by concrete with laced reinforcement6 castellated columns are fabricated and analyses, 1 normal I-Section castellated column and 1 Castellated column encasing by concrete without reinforcement and 4 columns encased by different concrete thickness with laced reinforcement are manufacture and analyses

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CHAPTER 1

INTRODUCTION

1.1. GENERAL

Steel is a widely used material in construction due to its high strength, durability, and versatility. It is often used in the construction of buildings, bridges, tunnels, and other infrastructure. Steel is an alloy of iron and carbon, with small amounts of other elements added to improve its properties. It is a strong and rigid material that can be easily shaped into various forms, making it ideal for use in construction. Steel structures can be prefabricated off-site and assembled on-site, which can reduce construction time and cost. One of the most significant advantages of steel in construction is its strength-to-weight ratio. Steel is much lighter than other materials like concrete and masonry while still providing the same strength and durability. This makes it an excellent choice for structures where weight is a concern, such as high-rise buildings and long-span bridges. Steel is also a highly ductile material, meaning it can be deformed without breaking. This makes it ideal for resisting extreme loads like earthquakes and high winds. Additionally, steel is resistant to fire, which makes it an ideal choice for buildings that require high fire resistance. Structural steel is steel construction material which fabricated with a specific shape and chemical composition to suit a project's applicable specifications. Depending on each project's applicable specifications, the steel sections might have various shapes, sizes and gauges made by hot or cold rolling, others are made by welding together flat or bent plates. Common shapes include the I-beam, HSS, Channels, Angles and Plate Overall, steel is a versatile and reliable material that offers numerous benefits for construction projects. Its high strength, durability, and flexibility make it an excellent choice for a wide range of applications, from small buildings to large-scale infrastructure projects.

1.1.1. Cold-Formed Steel (Cfs)

Cold-formed steel (CFS) is a type of steel used in construction that is formed at room temperature, unlike hot-rolled steel that is formed at high

temperatures. CFS is made by rolling or pressing steel sheets or strips into various shapes and sizes, such as studs, tracks, channels, angles, and other profiles.

CFS is used in construction for various applications, including walls, roofs, floors, and structural framing. It is a lightweight, durable, and cost-effective material that offers numerous benefits over other construction materials like wood, concrete, and masonry.

CFS is its high strength-to-weight ratio. CFS structures can be designed to carry loads that are much higher than those of wood structures while using less material. CFS is also highly durable and resistant to fire, pests, and rot, making it an ideal choice for structures that require high fire resistance and durability.

Advantage of CFS is its flexibility and ease of installation. CFS components can be easily cut and shaped on-site, which allows for quick and efficient installation. Additionally, CFS is compatible with a wide range of building materials, making it a versatile option for construction projects. Each piece of CFS contains a minimum of 25 percent recycled content, is 100 percent recyclable at the end of its lifespan, and emits no volatile organic compounds — it's an exceptionally sustainable building material.

Overall, CFS is a popular material for construction due to its strength, durability, cost-effectiveness, and versatility. It is used in a wide range of applications and has become a preferred choice for residential, commercial, and industrial construction projects.

1.1.2. Castellated Column

A castellated column is a type of structural steel column that has been cut and reconfigured to create a larger effective cross-sectional area. The column is made by cutting the web of an I-shaped beam in a pattern of alternating rectangular openings and then welding the cut sections back together to form a column with a "castellated" appearance.

The cut and welded sections of the column create a series of internal cells or chambers that can be used to run utilities, such as electrical wiring, plumbing, and HVAC ductwork. The open cells also reduce the weight of the column

without compromising its structural integrity, making it an ideal choice for structures that require high load-bearing capacity while minimizing weight.

Castellated columns are commonly used in commercial and industrial buildings where large, open spaces are required. They can span longer distances and support heavier loads than traditional columns, which can result in significant cost savings. The open cells also allow for easy access to utilities, reducing the need for additional installation and maintenance costs.

Castellated columns offer a unique combination of strength, weight reduction, and utility access that makes them a popular choice for construction projects where space and cost are critical factors.

1.1.3. History of castellated column

The history of castellated columns dates back to the early 20th century, when they were first used in the construction of the Tower Bridge in London. The engineer responsible for the design, Sir John Wolfe Barry, wanted to create a bridge that was both strong and lightweight. He came up with the idea of using castellated beams, which are similar to castellated columns but used for horizontal members, to achieve this goal.

Castellated beams were made by cutting an I-shaped beam along its web, leaving a series of rectangular openings, and then welding the two halves of the beam back together. The resulting beam was stronger and more rigid than a solid beam of the same weight, as the open cells reduced the weight while maintaining the same overall cross-sectional area.

Inspired by the success of castellated beams, engineers began to experiment with using a similar approach for vertical members, which led to the development of castellated columns. The first known use of castellated columns was in the construction of the New York Life Insurance Building in 1928.

The history of castellated columns dates back to the early 20th century when a British engineer named Robert Halpin first proposed the concept in 1908. Halpin's idea was to cut and reconfigure I-shaped steel beams to create a column with a larger effective cross-sectional area while reducing its weight.

However, it was not until the 1950s that the castellated column gained popularity in construction. The United States steel corporation developed the concept further, making it commercially viable and introducing it to the construction industry. The castellated columns were initially used in the construction of the Trussed Steel Tower, an observation tower in the United States, in 1956.

Since then, castellated columns have become a popular choice in the construction industry, particularly in commercial and industrial buildings where large, open spaces are required. They are used to support heavier loads, span longer distances, and reduce construction costs while maintaining the required strength and structural integrity.

Over time, the design of castellated columns has been refined, with different patterns of cut-outs and different shapes being developed. The concept has also been applied to other structural elements, such as beams and girders, expanding its use in construction projects. Today, castellated columns remain an essential component in the construction industry, offering a unique combination of strength, weight reduction, and utility access. Castellated columns have also been used in the construction of notable buildings, such as the Empire State Building and the Willis Tower (formerly known as the Sears Tower) in Chicago.

1.1.4. Advantage and disadvantage of castellated column

1.1.4.1. Advantage of castellated column

- **Reduced weight:** Castellated columns have a lower weight than solid columns, which can lead to lower construction costs and improved structural efficiency. This can also lead to easier transportation and installation of the columns
- **Increased load-bearing capacity:** The internal cells created by the cut and welded sections of a castellated column provide additional strength and stiffness, enabling the column to support heavier loads than traditional solid columns. This can lead to more efficient use of the available floor space in a building.

- Improved utility access: The open cells in castellated columns can be used to run utilities such as electrical wiring, plumbing, and HVAC ductwork, reducing the need for additional installation and maintenance costs. This can also help with the overall design and aesthetics of the building.
- Enhanced design flexibility: The unique castellated appearance of the columns can add a distinctive design element to a building, enhancing its visual appeal. The use of castellated columns can allow for more creative and complex architectural designs
- Reduced material usage: The use of castellated columns can reduce the amount of material required for a building, leading to cost savings and reduced environmental impact.

1.1.4.2. Disadvantage of castellated column

- Complicated fabrication: The process of cutting and welding the web of an I-shaped beam to create a castellated column is more complicated than fabricating a solid column, which can lead to higher production costs.
- Potential for buckling: The open cells in castellated columns can lead to a reduction in the column's buckling resistance, which can be a concern in tall structures or structures subject to high wind loads.
- Limited availability: Castellated columns may not be readily available from all suppliers, which can limit their use in certain construction projects.
- Higher fire risk: The open cells in castellated columns can provide a path for fire to spread, increasing the risk of fire damage to the structure.
- Structural complexity: Castellated columns can introduce structural complexity to a building, which can make the design and construction process more challenging. This can lead to increased costs and longer construction times.

1.1.5. Composite column

A composite column is a structural column made by combining two or more materials to create a stronger, more efficient column than either material alone could provide. Typically, composite columns consist of a steel or concrete core surrounded by a layer of concrete, steel, or other materials. The steel or concrete core of a composite column is designed to carry most of the load, while the outer layer provides additional strength, stiffness, and durability. By combining materials, composite columns can provide several advantages over traditional columns made of a single material.

One of the significant advantages of composite columns is their higher load-carrying capacity. They can support more significant loads than traditional columns due to the combination of materials and their enhanced structural efficiency. Additionally, composite columns can span longer distances without intermediate supports, making them ideal for large open spaces. Another advantage of composite columns is their fire resistance. Steel and concrete are both fire-resistant materials, and the combination of the two can provide even higher fire resistance. This makes composite columns an ideal choice for buildings that require high fire resistance, such as commercial and industrial structures.

Composite columns also offer improved durability and resistance to corrosion, making them a suitable choice for structures in harsh environments, such as marine structures or industrial buildings. Overall, composite columns are a versatile and efficient solution for structural applications in construction. They offer higher load-carrying capacity, improved fire resistance, and increased durability and corrosion resistance, making them an ideal choice for a wide range of construction projects.

1.1.6. Advantage and disadvantage of composite column

1.1.6.1. Advantage of composite column

- Increased strength and load-bearing capacity: Composite columns consist of a steel section encased in concrete, which results in a column that can support heavier loads than a steel-only column.

The concrete also provides additional stiffness and strength, reducing the risk of column buckling and increasing overall structural capacity.

- Improved fire resistance: The concrete encasement of a composite column provides increased fire resistance compared to a steel-only column. The concrete protects the steel from heat, preventing it from reaching the temperature at which it can weaken or fail.
- Reduced column size and weight: The increased strength and load-bearing capacity of composite columns allow for smaller column sizes and lighter weight, which can lead to cost savings in material and construction.
- Improved design flexibility: Composite columns can be designed to match the architectural requirements of a building. They can be cast in various shapes and sizes, making them suitable for use in a wide range of building designs.
- Reduced construction time: Composite columns can be prefabricated off-site, reducing construction time and minimizing disruption to the building site.

1.1.6.2. Disadvantage of composite column

- Higher initial cost: Composite columns typically have a higher initial cost than traditional steel-only columns due to the additional cost of the concrete encasement and fabrication.
- Corrosion protection: The steel section of a composite column must be adequately protected from corrosion, which can require additional coatings or other protection measures.
- Limited adjustability: Once the concrete is poured around the steel section of a composite column, adjustments to the column's length or position become difficult or impossible. This can limit the adjustability of the column during construction.
- Structural complexity: Composite columns can introduce structural complexity to a building, which can make the design and construction process more challenging. This can lead to increased costs and longer construction times.

- Handling and installation: Composite columns are typically heavier and more cumbersome to handle and install than traditional steel-only columns, which can require specialized equipment and increase construction costs.

1.2. OBJECTIVES

- To study the performance and buckling behavior of cold formed steel castellated column.
- To determine the load carrying capacity of the column.
- To examine the Castellated cold formed steel columns encased with concrete and reinforcement lacings to improve the capacity of the column as well as reduce the deflections of that columns.
- To examine the lateral deformation (buckling loading) loading of cold formed steel castellated column.
- To study the load deflection and load strain behavior.
- To develop model column in Abaqus Software.
- To compare the analytical result and experimental result.
- To study the buckling behavior of castellated columns members and the critical load capacity of the section.
- To study the maximum load carrying capacity of the column.

1.3. SCOPE

The scope of the present investigation includes:

- The Castellated columns with concrete and Lacing Reinforcement improve compactness and local buckling (web and flange local buckling), as a result of steel section encasement
- Develop the analytical model for predicting the buckling behaviour and maximum load carrying capacity of the castellated column encased with concrete and reinforcement lacings.
- Compare the bucking behaviour of the reinforcement concrete column and cold formed steel castellated column with concte.

1.4. NEED FOR STUDY

- To study the influence of cold formed steel and castellated column.
- To increase the strength of the castellated column by encasing with concrete.
- To analysis and study the load carrying capacity of cold formed steel castellated column encase by concrete and cold formed steel castellated column encasing by concrete with reinforcement lacing.

CHAPTER 2

LITERATURE REVIEW

1.5. LITERATURE REVIEW

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 the use of alternative cementitious materials to improve the fresh and hardened properties of SCC. Various fresh and mechanical properties were analyzed. Flexural strength obtained was slightly higher. The binary and ternary mix contains blends of Portland cement, silica fume and fly ash. Hence the result shows that better fresh properties and hardened properties are obtained with various cementitious blends used as a partial replacement.

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) experimented on the split tensile strength properties of SCC. It was observed experimentally that more than 4 % weight of TiO₂ causes a reduction in the split tensile strength because of the production of the crystalline. They also conducted for the SCC mixes with the optimum dosage of TiO₂ and low volume Flyash.

Adel Gorjinia Khoshkenari et al (2012) carried investigation to establish the best use of recycled aggregates of size 0-2mm in concrete mix producing standard properties of strength and workability. The study revealed that the use of RCA caused a decrease in splitting and compressive strength than used to normal aggregates. It was found that the use of silica fume can improve the strength properties of RCA.

Bibhuti Bhusan Mukharjee & Sudhirkumar V Barai (2014) studied the mechanical behaviour of concrete containing recycled aggregates and nano-silica. He understood that the full replacement of natural coarse aggregate with recycled aggregates had a major influence on the hardened state properties. It was also found that the nano-silica considerably increased the compressive strength and microstructure 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.

KazimTurk 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) For partial replacement up to 50%, no remarkable reduction in compressive strength of concrete is found compared with the first-class brick aggregate concrete, and By recycling, it is possible to make concrete with higher strength compared with the in-situ strength of concrete.

Tarek Uddin Mohammed et al (2017) No significant difference was found in load-displacement behaviour of the reinforced concrete beams made with recycled aggregate and virgin brick aggregates, In comparison with virgin brick aggregate, utilization of recycled brick aggregate in concrete does not reduce the cracking moment as well as ultimate moment capacity of reinforced concrete Beams

Fernando Lopez Gayarre et al (2019) This work studies concrete made with recycled brick aggregates (RBA) to substitute both the fine and coarse fractions of the natural aggregates for the manufacturing of prestressed joists Concrete with 35% of RBA shows acceptable shrinkage values for structural purposes, but the decrease of the elasticity modulus may require further study.

Pei Ge et al (2021) In this test, the volume fraction of RBA, sand/cement and water/ cement ratio were considered; when the volume fraction of RBA is between 44% and 47%, and the total volume fraction of RBA and sand is about 70%, the compressive strength of RBAC reaches the maximum. Mix proportion design method of RBAC based on aggregate skeleton theory was established. Compared with ACI 211.2 and ACI 211.6, the mix proportion design method proposed in this paper is to mix more RA and less sand and cement in concrete mix proportion under the condition of ensuring concrete strength and slump, which is beneficial to protect the environment.

BoWang et al. (2021) provided a comprehensive review of the RA and RCA about their history, manufacturing process and their material properties etc. The methods for improving RAC mechanical properties and long-term performance are also summarized. 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) A quantitative relationship was represented between the content of old attached mortar and the performance of RA at the material level. The difference in properties of Recycled aggregate and Natural Aggregate are due to the presence of the old mortar present in RA. The performance of RA is not only improved by removing the existing mortar on RA but also by controlling the water-cement ratio, and adjusting the aggregate moisture content like this simple and economical method can be also employed to get a better quality of RA. The presence of the adhering mortars in the RA was the main reason why the quality is poor than that of the NA.

Kho PinVerian et al. (2018) The quality of RCA depends on the feature of the original aggregate and the condition of demolished concrete. The difference in properties of RCA when compared to Natural Aggregate it is due to the presence of existing mortar on the surface of recycled aggregate. Several ways to improve the quality of concrete containing RCA have been mentioned in this literature.

HuiGuo et al (2018) The increase in recycled aggregate decreases results in poor durability. The durability is improved by using pozzolanic materials either as a surface coating or mixed with the concrete. The CO₂ treatment enhances the properties of recycled aggregate and the durability of concrete. The durability depends on adhered mortar and it is inversely proportional.

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.

1.6. SUMMARY

After studying the various literature involving SCC much wide range of materials in various proportions has been done. In most of the work, cement has been replaced with industrial by products like fly ash, GGBS, silica fume, lime powder, etc. Some works were done by using manufactured aggregates in partial replacement of natural aggregates. Though many works have been done by the use of recycled aggregates in SCC there is no visibility of the use of the RBA. So, I decided to use such materials in this project with the addition of steel fibers in SCC.

CHAPTER 3

METHODOLOGY

3.1 FLOWCHART

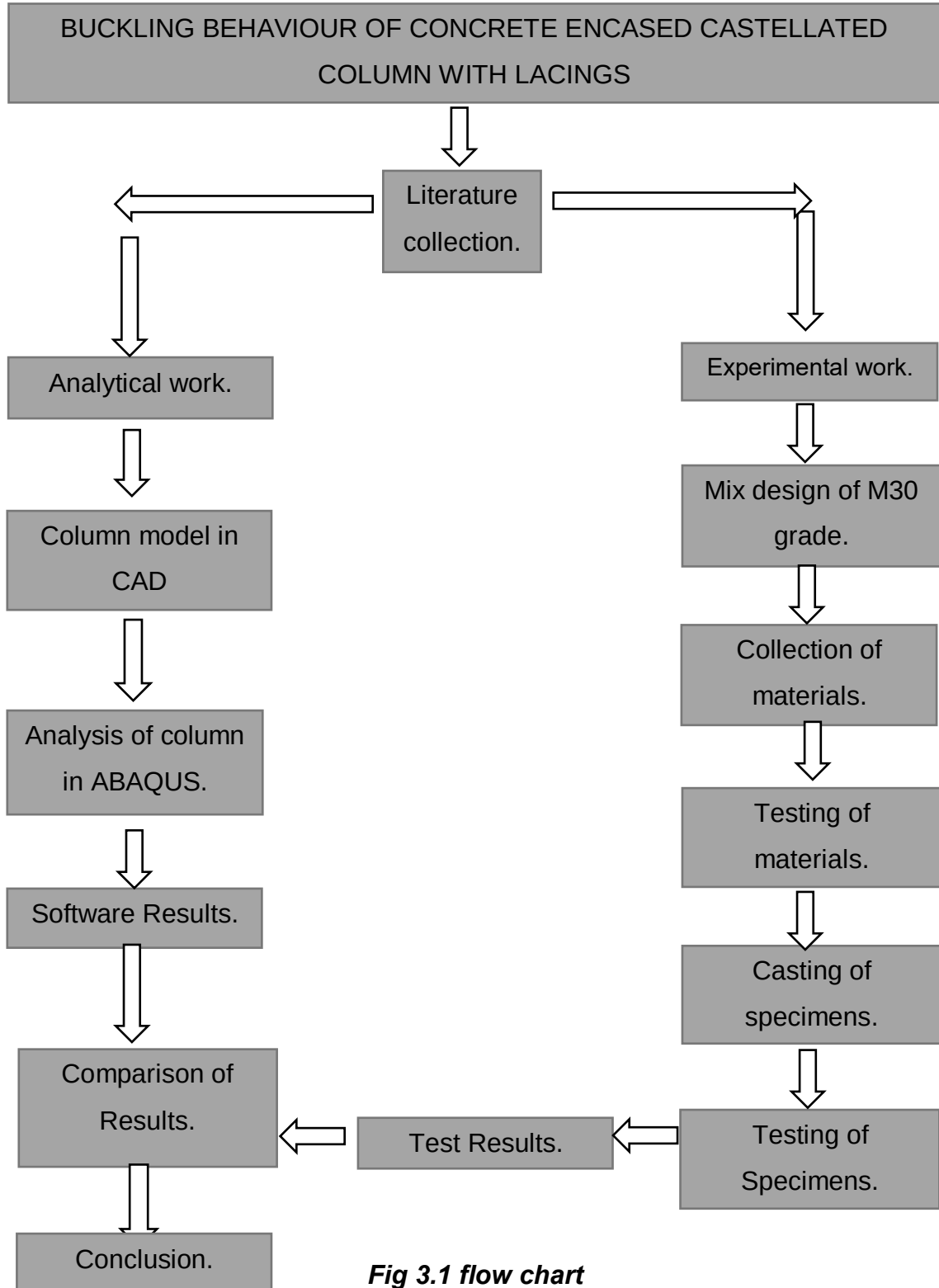


Fig 3.1 flow chart

3.2 MATERIALS

3.2.1 Cold rolled sheet

Cold-rolled sheet, also known as cold-rolled steel, is a type of metal sheet that is produced by rolling steel at low temperatures. The process of cold rolling involves passing a hot-rolled steel sheet through a series of rollers at room temperature, which reduces the thickness and improves the surface finish of the steel sheet. This process also increases the strength and hardness of the steel by introducing strain hardening. Cold-rolled sheet is commonly used in a wide range of applications, including automotive parts, appliances, construction materials, and electrical equipment. It is often preferred over hot-rolled steel for applications where surface quality and dimensional accuracy are critical. Cold-rolled sheet is available in a variety of grades, thicknesses, and widths to meet the specific needs of different applications.

3.2.1.1 Properties of Cold rolled sheet

- **Strength:** Cold-rolled sheet has high strength-to-weight ratio and is often used in applications where strength is important. The strength of cold-rolled sheet is influenced by factors such as the thickness and chemical composition of the steel.
- **Ductility:** Cold-rolled sheet has high ductility, which means it can be bent or shaped without cracking or breaking. This makes it a versatile material for a wide range of applications.
- **Toughness:** Cold-rolled sheet is tough, which means it can resist impact and withstand high levels of stress without fracturing. This makes it a durable material for structures and machinery that are exposed to high loads and other challenging conditions.
- **Surface finish:** Cold-rolled sheet has a smooth and uniform surface finish that is free from defects such as surface roughness, scale, and rust. This makes it an ideal material for applications where appearance is important, such as in automotive and appliance manufacturing.

- Corrosion resistance: Cold-rolled sheet can be coated with materials such as zinc or paint to improve its resistance to corrosion. This makes it a good choice for outdoor applications where exposure to the elements is a concern.
- Magnetic properties: Cold-rolled sheet has magnetic properties, which makes it a popular choice for applications that require magnetic properties, such as in motors and transformers.

3.2.2 Cement

Cement is a powdery substance made from a mixture of materials such as limestone, clay, shale, sand, and iron ore. It is the primary binding agent used in the construction industry for making concrete, mortar, and other construction materials. Cement is produced by heating the raw materials at a high temperature in a kiln and then grinding the resulting clinker into a fine powder. Different types of cement are available, with varying properties and strengths, such as Portland cement, blended cement, and specialty cement. Cement is used in various applications, such as building foundations, walls, floors, bridges, and highways, due to its excellent compressive strength, durability, and resistance to moisture and fire. However, cement production is known to have a significant environmental impact due to the energy consumption and emissions associated with the manufacturing process, as well as the use of raw materials. Efforts are being made to reduce the environmental impact of cement production through the development of sustainable and eco-friendly alternatives.

Ordinary Portland cement (OPC) of 53 grade conforming to IS: 8112 has been used in the present investigation. This is the most common cement used in general concrete construction.

3.2.2.1 Properties of Cement

- Fineness: Cement particles are typically very fine, with a particle size distribution ranging from 1 to 100 microns. The fineness of cement affects its rate of hydration and strength development.
- Cement sets and hardens due to a chemical reaction with water, known as hydration. The setting time of cement refers to the time

it takes for the cement to harden after it is mixed with water. The setting time of cement can be adjusted by altering the chemical composition of the cement.

- **Compressive strength:** The compressive strength of cement refers to its ability to resist deformation under compressive loads. The compressive strength of cement is a critical factor in determining its suitability for various construction applications.
- **Heat of hydration:** The heat of hydration of cement refers to the amount of heat that is released during the chemical reaction between cement and water. The heat of hydration can be an important factor in determining the suitability of cement for use in large concrete structures.
- **Soundness:** The soundness of cement refers to its ability to retain its volume after it has set and hardened. Cement that undergoes significant volume changes during setting and hardening can lead to cracking and other structural problems.
- **Specific gravity:** The specific gravity of cement is a measure of its density compared to water. The specific gravity of cement can vary depending on its chemical composition and the conditions under which it was produced.

3.2.3 Fine Aggregate:

Fine aggregate for concrete, also known as sand, is a granular material that is typically smaller than 4.75 millimeters in diameter. It is commonly used in the construction industry as a component of concrete, mortar, and other construction materials. Fine aggregate is typically made from natural or manufactured sources, such as river sand, crushed stone, or industrial byproducts. The properties of the fine aggregate, such as particle size distribution, shape, texture, and cleanliness, can affect the workability, strength, and durability of the concrete. The use of high-quality fine aggregate with well-graded particle sizes and low levels of impurities can improve the quality and performance of the concrete. Fine aggregate is usually combined with coarse aggregate, such as gravel or crushed stone, and cement to produce concrete.

that can be used in a wide range of construction applications, including building foundations, walls, floors, and pavements.

Good quality easily locally available M sand will be used. Generally fines are classified based on size, that is below 4.75mm is regarded as fine aggregate

3.2.3.1 Properties of fine aggregate

- Particle shape: M-sand particles have a cubical shape with sharp edges and corners, which makes it ideal for use in concrete mixtures. This shape also provides better workability and cohesiveness.
- Particle size distribution: M-sand particles have a uniform particle size distribution, which means the size of the particles is consistent. This helps in producing high-quality concrete with consistent strength and durability.
- Density: M-sand has a density of around 1.75 - 1.9 g/cm³, which is similar to that of river sand. This makes it easy to handle and transport.
- Water absorption: M-sand has a low water absorption rate of around 1-2%, which means it can retain the required amount of water for the curing process of concrete.
- Fineness modulus: M-sand has a fineness modulus of around 2.3-3.1, which is within the desirable range for producing high-quality concrete.
- Abrasion resistance: M-sand has high abrasion resistance, which makes it a durable material for use in concrete mixtures.
- Compressive strength: M-sand has good compressive strength, which is important for producing high-quality concrete that can withstand high loads and stresses.

3.2.4 Coarse Aggregate:

Coarse aggregate is an essential component of concrete, which is used in a wide range of construction applications, such as building foundations,

columns, beams, and pavements. The main function of coarse aggregate in concrete is to provide structural support and strength to the concrete. Coarse aggregate is typically made from natural or manufactured sources, such as crushed stone, gravel, or recycled concrete. The properties of the coarse aggregate, such as particle size distribution, shape, texture, and strength, can affect the workability, strength, and durability of the concrete. The use of high-quality coarse aggregate with well-graded particle sizes and low levels of impurities can improve the quality and performance of the concrete. Generally, the size of the coarse aggregate used in concrete ranges from 10 mm to 40 mm, depending on the specific application. The amount of coarse aggregate used in concrete is typically determined by the strength and durability requirements of the structure being constructed. Too much or too little coarse aggregate can negatively impact the properties of the concrete. The proper proportioning of coarse aggregate in concrete is essential to ensure that the concrete achieves the desired strength, durability, and workability for the specific application.

Crushed angular metal of 20mm size from local source will be used as Coarse aggregate. In General Coarse Aggregate used for concrete is blast out of quarries and crushed or broken to a size of less than 20mm. This we make use in Conventional concrete preparation. These aggregates are made use in SCC.

3.2.4.1 Properties of Coarse aggregate

- Density: The density of coarse aggregate is typically between 1,000 and 2,000 kg/m³, which is higher than that of fine aggregates (i.e. sand). This density helps to create concrete with higher strength and durability.
- Particle size distribution: Coarse aggregates are typically graded to a certain range of sizes, which can range from 5mm to several centimeters. The size and distribution of particles in the aggregate mix can affect the strength and workability of the concrete.
- Shape: Coarse aggregates can have different shapes, such as angular, rounded, or irregular. Angular aggregates provide more

interlocking between the particles, which can result in better strength and stiffness. Rounded aggregates have less interlocking, but they can provide better workability and reduce the risk of cracking.

- **Crushing value:** This is a measure of the resistance of the coarse aggregate to crushing under a compressive load. The crushing value can indicate the strength and durability of the aggregate and its suitability for use in concrete.
- **Abrasion resistance:** Coarse aggregates can be subject to abrasion, which can cause them to wear down over time. A higher abrasion resistance can indicate a more durable and long-lasting aggregate.
- **Porosity:** Coarse aggregates can have different porosities, which can affect the amount of water that the concrete mix can hold. A low porosity can result in a stronger and more durable concrete.
- **Specific gravity:** The specific gravity of the coarse aggregate can indicate the strength and durability of the aggregate. A higher specific gravity can indicate a stronger and more durable aggregate.

3.2.5 Water:

Potable water is used for mixing and curing of concrete as per IS 456-2005

3.3 TEST ON MATERIALS

3.3.1 Test for Cement

3.3.1.1 Fines test on cement

Fineness test on cement is performed to measure the particle size of cement. The test helps to determine the size of cement particles and their distribution. The following are the steps involved in the fineness test on cement:

- Take a representative sample of cement, about 100 gm, and weigh it accurately.

- Pour the cement sample on a standard 90 µm IS sieve, which is placed on top of a sieve shaker.
- Shake the sieve shaker for a minimum of 10 minutes.
- After 10 minutes, weigh the residue left on the sieve.
- Calculate the percentage of residue on the sieve as follows:

$$\text{Residue \%} = (\text{Weight of residue} / \text{Original weight of cement sample}) \times 100$$
- Determine the fineness of the cement using the following formula:

$$\text{Fineness} = 100 - \text{Residue \%}$$

The fineness of cement is expressed as a percentage of the residue remaining on the 90 µm sieve. According to the Indian Standards, the fineness of cement should not be less than 90% for ordinary Portland cement and not less than 80% for rapid hardening cement. The fineness test on cement is essential because the particle size of cement can affect the rate of hydration, strength, and setting time of cement. A finer cement with a smaller particle size will hydrate faster, resulting in higher early strength development, while a coarser cement with a larger particle size will hydrate slower, resulting in lower early strength development but higher ultimate strength.

3.3.1.2. Initial Setting time

The initial setting time of cement is the time taken by cement paste to reach a specified degree of stiffness that the paste ceases to be workable. This means that the cement paste loses its plasticity and can no longer be molded or shaped. The initial setting time is determined by using a Vicat apparatus, which is a device used for measuring the setting time of cement.

The test for initial setting time involves the following steps:

- Take a clean, dry, and non-porous Vicat apparatus and fill it with cement paste prepared by adding 0.85 times the water required for standard consistency.
- Lower the plunger gently on the surface of the paste and quickly release it. The plunger will penetrate into the paste, and the depth of penetration will be recorded.

- Repeat the above step at regular intervals of time until the plunger fails to make an impression.
- The time elapsed between the addition of water to cement and the time at which the needle fails to penetrate the cement paste to a depth of 5 mm is known as the initial setting time of cement.

The initial setting time of cement varies according to the type of cement and the conditions under which it is stored and used. Generally, the initial setting time of ordinary Portland cement is around 30 minutes to 6 hours, depending on factors such as temperature, humidity, and water-cement ratio. The initial setting time is an important factor in determining the handling and curing time of concrete, as it indicates the time available for finishing operations such as troweling and placing reinforcement.

3.3.1.3 Final Setting Time

The final setting time of cement is the time taken by cement paste to harden sufficiently and attain a state of complete rigidity. This means that the cement paste has fully set and hardened, and can no longer be disturbed or moved. The final setting time is determined by using a Vicat apparatus, which is a device used for measuring the setting time of cement.

The test for final setting time involves the following steps:

- Take a clean, dry, and non-porous Vicat apparatus and fill it with cement paste prepared by adding 0.85 times the water required for standard consistency.
- Lower the plunger gently on the surface of the paste and let it rest for 1 minute.
- After 1 minute, gently lower the plunger on the surface of the paste. If the plunger makes an indentation, the test is continued at intervals of 30 minutes until the plunger fails to make an indentation.
- The time elapsed between the addition of water to cement and the time at which the needle fails to penetrate the cement paste to a depth of 1 mm is known as the final setting time of cement.

The final setting time of cement varies according to the type of cement and the conditions under which it is stored and used. Generally, the final setting time of ordinary Portland cement is around 6 to 10 hours, depending on factors such as temperature, humidity, and water-cement ratio. The final setting time is an important factor in determining the handling and curing time of concrete, as it indicates when the concrete can be safely removed from the formwork and subjected to loads or traffic.

3.3.1.4 Specific gravity of cement

The specific gravity of cement is the ratio of the mass of a given volume of cement to the mass of an equal volume of water at a specified temperature. It is an important physical property of cement that affects its strength, durability, and other engineering properties.

The specific gravity of cement is typically measured at 27°C (81°F) using a pycnometer, which is a glass container with a known volume. The following are the general steps to determine the specific gravity of cement using a pycnometer:

- Clean the pycnometer and dry it thoroughly.
- Fill the pycnometer with distilled water up to the mark.
- Weigh the pycnometer along with the water.
- Empty the pycnometer and dry it thoroughly.
- Fill the pycnometer with cement up to the mark.
- Weigh the pycnometer along with the cement.
- Calculate the specific gravity of cement using the following formula:
$$\text{Specific Gravity of Cement} = \frac{\text{Mass of Cement}}{(\text{Mass of Pycnometer} + \text{Mass of Cement} - \text{Mass of Pycnometer with Water})}$$

The specific gravity of cement varies depending on the type of cement, but it typically ranges from 3.1 to 3.16. The high specific gravity of cement indicates that it is a dense material, which can improve the strength and durability of concrete made with it.

3.3.2 Tests for Fine Aggregate

3.3.2.1. Sieve Analysis Test

Sieve analysis test is a commonly used method to determine the particle size distribution of fine aggregates. Here are the steps involved in performing a sieve analysis test for fine aggregate:

- Take a representative sample of the fine aggregate as per the standard specifications.
- Clean the sieves to be used for the test and stack them in order of decreasing sieve opening sizes, with the largest at the top and the smallest at the bottom.
- Weigh each sieve and record its weight.
- Pour the fine aggregate sample onto the top sieve of the stack.
- Place the lid on the top of the stack and shake it manually or mechanically for a minimum of 10 minutes.
- Weigh each sieve with the retained aggregate and record the weight.
- Calculate the percentage of the aggregate retained on each sieve by dividing the weight of the retained aggregate by the original weight of the sample and multiplying by 100.
- Calculate the cumulative percentage retained on each sieve by adding the percentages of the aggregate retained on that sieve and all sieves above it.
- Plot the results on a graph with particle size on the x-axis and cumulative percentage retained on the y-axis.
- Determine the fineness modulus of the fine aggregate by adding up the cumulative percentages retained on the sieves and dividing the sum by 100.

The results of the sieve analysis test can be used to evaluate the grading of the fine aggregate and ensure that it meets the standard specifications for use in concrete.

3.3.2.2. Water Absorption Test

Water absorption test is a commonly used method to determine the porosity of concrete or other construction materials. Here are the steps involved in performing a water absorption test:

- Dry the specimen to be tested in an oven at a temperature of 100-110°C until it reaches a constant weight.
- Allow the specimen to cool down to room temperature and weigh it (W1).
- Submerge the specimen in water for a specified duration (usually 24 hours) at a specified temperature (usually 25°C).
- After the specified duration, remove the specimen from the water and wipe off any excess water on its surface.
- Weigh the wet specimen immediately (W2).
- Calculate the water absorption of the specimen by using the formula:

$$\text{Water absorption} = [(W2 - W1)/W1] \times 100\%$$

The water absorption value obtained can be used to evaluate the porosity of the material and its ability to resist water penetration. The lower the water absorption value, the more impermeable and durable the material is likely to be.

3.3.2.3. *Specific Gravity Test*

The specific gravity test on fine aggregate is a commonly used method to determine the density of fine aggregate particles. Here are the steps involved in performing the specific gravity test on fine aggregate:

- Take a representative sample of the fine aggregate as per the standard specifications.
- Clean the pycnometer or specific gravity flask to be used for the test and dry it in an oven at a temperature of 100-110°C until it reaches a constant weight.
- Fill the pycnometer or specific gravity flask with a known mass of distilled water and weigh it (W1).
- Empty the water from the pycnometer or specific gravity flask and fill it with the fine aggregate sample.
- Weigh the pycnometer or specific gravity flask with the fine aggregate sample (W2).
- Fill the pycnometer or specific gravity flask with distilled water until the fine aggregate is completely covered.
- Weigh the pycnometer or specific gravity flask with the water and the fine aggregate sample (W3).

- Calculate the specific gravity of the fine aggregate using the formula:

$$\text{Specific gravity} = [(W_2 - W_1) / (W_3 - W_1)] \times (1 + (\text{water density} / \text{aggregate density}))$$

where water density is the density of distilled water at the test temperature, and aggregate density is the density of the fine aggregate particles. The specific gravity value obtained can be used to evaluate the quality of the fine aggregate and ensure that it meets the standard specifications for use in concrete. A higher specific gravity value indicates that the fine aggregate particles are denser and may have a lower porosity, which can improve the strength and durability of the concrete.

3.3.3 Test for Coarse aggregate

3.3.3.1. Impact Test

The impact test on coarse aggregate is a test that measures the resistance of the aggregate to impact. The test is performed to evaluate the toughness and durability of the aggregate, which can affect the ability of the concrete to resist wear and tear. The test is carried out by subjecting the aggregate to a standard impact of 15 blows of a metal hammer falling from a height of 380 mm. The aggregate is placed in a cylindrical steel container of 500 mm diameter and 700 mm height. The container is then placed in the apparatus and the hammer is allowed to fall freely on the aggregate. After the 15 blows are delivered, the aggregate is sieved through a set of sieves to determine the percentage of material passing through each sieve. The impact value is calculated as the percentage of material passing through the 2.36mm sieve after 15 blows. The higher the impact value, the tougher the aggregate. The impact test is used to evaluate the suitability of the coarse aggregate for use in concrete. The results of the test can be used to select aggregates that have good toughness and durability, which can help to ensure that the concrete has good resistance to wear and tear.

3.3.3.2 Sieve Analysis test

The sieve analysis test for coarse aggregate is a basic test that is performed to determine the particle size distribution of the coarse aggregate. This test is important because the particle size distribution can affect the

workability and strength of the concrete. To perform the test, a representative sample of the coarse aggregate is collected and washed to remove any dust or fine particles. The aggregate is then dried in an oven and weighed. The dried aggregate is then sieved through a set of sieves of different sizes, with the largest sieve on top and the smallest on the bottom. The sieves are stacked in descending order, and the aggregate is placed on the top sieve. The sieves are then placed in a mechanical shaker, which is set to shake for a specific amount of time. After shaking, the amount of aggregate retained on each sieve is weighed, and the percentage of the total weight of the aggregate is calculated. The particle size distribution curve is then plotted, which shows the percentage of aggregate passing through each sieve size. The curve can be used to determine the maximum size of the aggregate, the grading of the aggregate, and the suitability of the aggregate for use in concrete. The sieve analysis test for coarse aggregate is an important test that can help to ensure that the concrete has the desired strength and workability. The results of the test can be used to select aggregates that are appropriate for specific applications, such as high-strength concrete or concrete with good workability.

3.3.3.3 Specific gravity test

The specific gravity test for coarse aggregate is a simple and quick test that is used to determine the specific gravity of coarse aggregate particles. The specific gravity of an aggregate is a measure of its density compared to the density of water, and it is an important property of aggregates used in concrete because it can affect the strength and workability of the concrete. To perform the specific gravity test, a representative sample of the coarse aggregate is first weighed in air and then weighed while completely submerged in water. The weight of the sample in air is divided by the difference between the weight in air and the weight in water to obtain the specific gravity of the aggregate. Another method to perform the specific gravity test is by using the pycnometer method. In this method, a known volume of water is placed in a pycnometer, and the empty pycnometer is weighed. Then, a known weight of the dry coarse aggregate is added to the pycnometer, and the pycnometer is filled to a known volume with water. The weight of the pycnometer, aggregate, and water is then determined, and the specific gravity of the aggregate is calculated. The specific

gravity test is important because it can help to ensure that the concrete has the desired strength and workability. The results of the test can be used to select aggregates that are appropriate for specific applications, such as high-strength concrete or concrete with good workability.

3.3.3.4 Water Absorption Test

The water absorption test for coarse aggregate is used to determine the amount of water that an aggregate will absorb when immersed in water for a specified period. This test is important because the water absorption of coarse aggregates can affect the workability and durability of concrete. To perform the water absorption test, a dry sample of the coarse aggregate is weighed and then immersed in water for a period of 24 hours. After 24 hours, the aggregate is removed from the water, the surface water is removed using a towel, and the aggregate is weighed again. The difference between the initial weight and the weight after immersion in water is the amount of water that the aggregate has absorbed. The water absorption test is important because aggregates with high water absorption can affect the workability and durability of concrete. For example, if a coarse aggregate has a high water absorption, it can increase the amount of water needed in the concrete mix, which can reduce the strength of the concrete. Additionally, if the aggregate is exposed to freeze-thaw cycles, the water absorbed by the aggregate can freeze and expand, causing the aggregate to crack and reduce the durability of the concrete.

3.4 SAMPLES AND SPECIMEN DETAILS

The number of cubes, cylinder, conventional RCC column and cold formed steel castellated column with reinforcement lacings are listed below.

- Cubes 9 nos
- Cylinder 9 nos
- Reinforcement concrete column 1 nos
- Castellated steel column encasing concrete 1 nos
- Castellated steel column encasing concrete with reinforcement 1 nos
- Cold rolled steel column encasing concrete 1 nos

3.4ANALYTICAL INVESTIGATION

3.5.1 Model

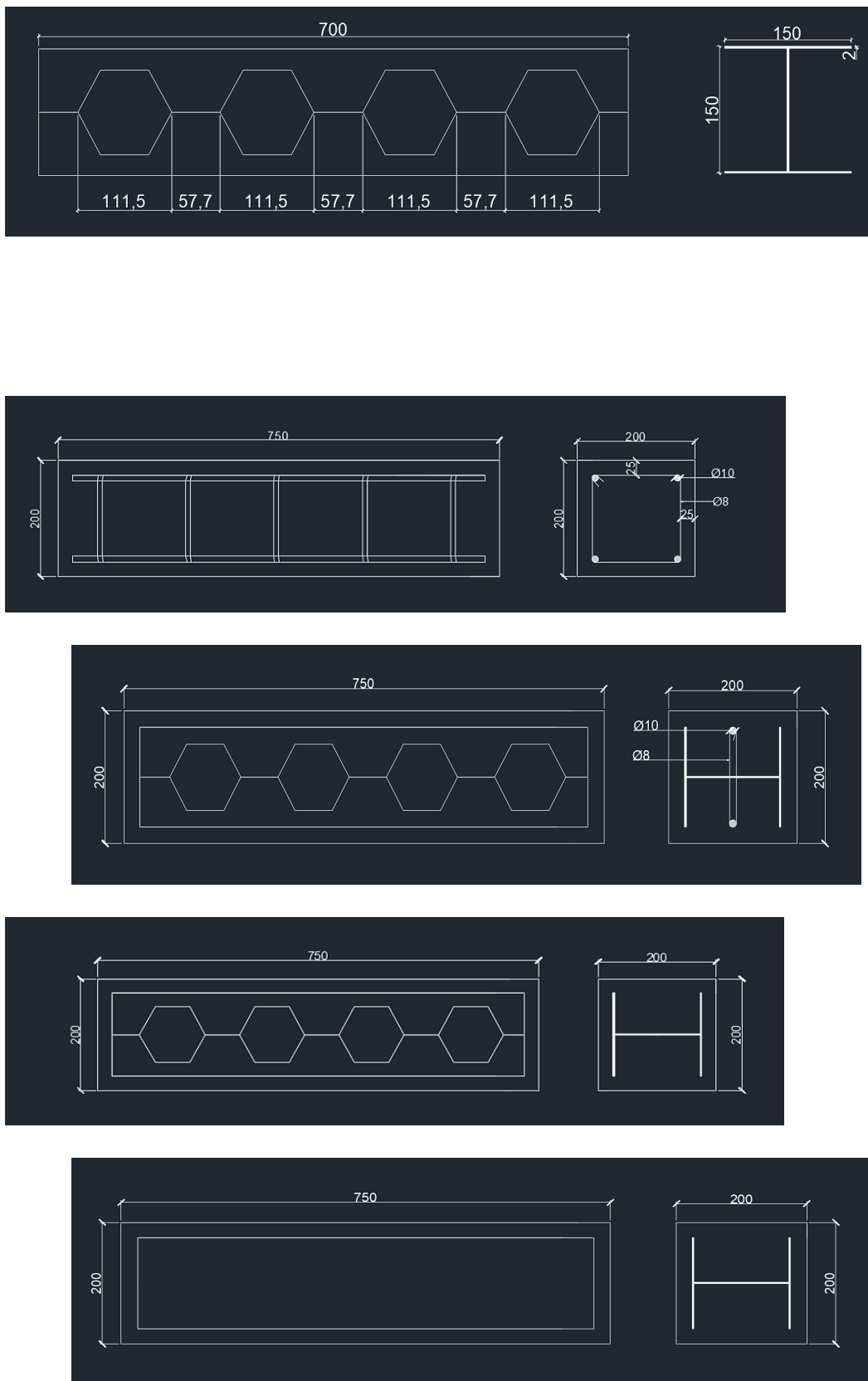


Fig 3.1 Castellated column model in CAD Software

3.5.2 Parameters

After a beam is modeled in CAD software the analysis part is carried over in the Abaqus software and find out which combination is optimum among the four combinations. Abaqus is a general-purpose, finite-element modeling package for numerically solving a wide variety of mechanical problems. These problems include static/dynamic, structural analysis, heat transfer, and fluid problems, as well as acoustic and electromagnetic problems.

3.6 EXPERIMENTAL INVESTIGATION

3.6.1 *Experimental setup*

With the aid of four LVDTs with a stroke of around 50 mm, the longitudinal stresses of the columns were determined. This Gauge Pattern measures axial strain precisely and keeps track of any unwelcome eccentricity when loading. The gauge duration was chosen to be equal to 1 m in order to deform the column away from stress concentration locations at the top and lower machine heads. All transducers were installed using pegs that were drilled into the centre of the columns in order to achieve the exact deformation of the column. Furthermore, stirrups and the centre of the longitudinal reinforcement are mounted with 10 mm long electrical tension gauges. The data was collected automatically using a data gathering technique.¹⁰⁴ Materials for Construction and Structural



Fig 3.2 Loading Frame

3.6.2 Test Procedure

3.6.2.1 Slump cone test for concrete

The slump cone test is a widely used test to determine the workability of fresh concrete. The following is a general procedure for conducting a slump cone test:

- Gather the necessary equipment, including a slump cone, a base plate, a tamping rod, and a measuring scale.
- Place the slump cone on the base plate and moisten the interior surface of the cone.

- Fill the cone with freshly mixed concrete in three equal layers, tamping each layer with 25 blows from the tamping rod.
- After the final layer has been tamped, strike off the excess concrete level with the top of the cone using a trowel.
- Lift the cone straight up in a smooth, steady motion, allowing the concrete to flow freely.
- Measure the distance between the top of the cone and the highest point of the concrete subsidence, which is the difference in height between the original height of the concrete in the cone and the height of the concrete after it settles. This is known as the slump.
- Record the slump value in millimeters.

The slump value indicates the consistency and workability of the concrete. A low slump value indicates a stiffer, less workable concrete, while a high slump value indicates a more fluid, workable concrete. The appropriate slump value will depend on the specific application and requirements of the concrete. It's important to note that the specific procedures for conducting a slump cone test may vary depending on the testing equipment, standards, and objectives of the test. It's recommended to consult the appropriate codes and standards and work with qualified personnel to ensure that the test is performed correctly and safely.

3.6.2.2. Test on the Harden Concrete

3.6.2.2.1 Compression Strength for cubes

Using compression testing on concrete cubes is a frequent and popular technique to find the concrete's compressive strength. Typically, concrete cubes are cast in a Size: 150 mm x 150 mm x 150 mm. In order to prevent cavities, the concrete is poured into the mould and manipulated. Moulds are removed after 24 hours, and test specimens are then submerged in water to cure. It is cured in a lab under carefully monitored circumstances for a predetermined amount of time, usually 28 days. The cubes are taken out of the curing tank and

are left to air dry. In a compression testing machine, the cubes are loaded compressively until they break. Up until the cube fails or achieves its maximum load capacity, the load is delivered at a consistent rate, typically 0.7 MPa/s. 28 days. The maximum load capacity is noted, then by dividing the maximum load by the compressive strength of the concrete.



Fig 3.3 Compression Test

Using compression testing on concrete cubes is a consistent and reliable way to find the concrete's compressive strength. The test findings are utilized to determine the effectiveness and longevity of concrete in diverse applications, as well as to confirm that concrete meets the necessary strength requirements. We may find any problems with the concrete and take corrective action to make sure the construction is secure and long-lasting by doing compression tests.

3.6.2.2.2 Split tensile strength of cylinder

One of the fundamental and crucial characteristics of concrete that significantly influences the size and degree of cracking in structures is its tensile

strength. Additionally, because concrete is brittle, it is very weak in tension. It is therefore not anticipated to resist the direct stress. As a result, cracks form in concrete when tensile forces are greater than its tensile strength.

In order to establish the load at which the concrete members may crack, it is important to determine the tensile strength of concrete. In addition, one approach for figuring out concrete's tensile strength is to split a concrete cylinder. The process is based on ASTM C496 (Standard Test Method of Cylindrical Concrete Specimen), a code that is similar to IS 5816 1999 and other codes.

After 7, 14, or 28 days of curing, or at any other specified age at which the tensile strength is to be determined, remove the wet specimen from the water. Next, wipe any remaining water off the specimen's surface. After that, mark diametrical lines on the specimen's two ends to make sure they are located along the same axial plane. Next, note the specimen's weight and dimensions. Set the required range for the compression testing device. Place the specimen and a plywood strip on the lower plate. Orient the specimen such that the vertical, centred lines on the ends are over the bottom plate. Place the second piece of plywood over the specimen. Lower the upper plate until it barely touches the plywood strip. Apply the load continuously without shock at a rate between 0.7 and 1.4 MPa/min (based on IS 5816 1999, 1.2 to 2.4 MPa/min). Lastly, record the breaking load (P).



Fig 3.4 Split Tensile Strength

CHAPTER 4

RESULTS AND DISCUSSION

4.1 TEST ON CEMENT

Specific gravity and standard consistency tests, as well as a setting time test, were performed on cement in accordance with IS: 1727-1967 and IS: 4031-1968, Parts 3, 4, respectively. The table below lists cement's physical characteristics.

S.NO	PHYSICAL PROPERTY	RESULT
1	Initial setting time	48 minutes
	Finial setting time	275 minutes
2	Standard Consistency	32 percentage
3	Specific gravity	2.7

Table 4.1 Physical Properties Of Cement

4.2 TEST ON FINE AGGREGATE

A number of tests, including sieve analysis, specific gravity, bulk density, and water absorption, have been carried out on fine aggregate, and the results are shown and tabulated below.

S.NO	PHYSICAL PROPERTY	RESULT
1	Specific Gravity	2.5
2	Bulk Density	
	Loose	1620 Kg/m ³
	Compacted	1820 Kg/m ³
3	Water absorption	1.20

Table 4.2 Physical Properties Of Fine Aggregate

S.NO	Sieve size	Weight retained Kg	% of weight retained	Cumulative % of retained	% of passing	Permissible % passing as per IS 383
1	4.75mm	0.034	0.0034	0.034	3.40	96.60
2	2.36mm	0.028	0.0028	0.062	6.20	93.80
3	1.18mm	0.100	0.0100	0.162	16.20	83.80
4	600 μ	0.400	0.0400	0.562	56.20	43.80
5	300 μ	0.310	0.0310	0.872	87.20	12.80
6	150 μ	0.088	0.0088	0.960	96.00	4.00
7	Pan v	0.020	0.0020	0.980	98.00	2.00

Table 4.3 Sieve Analysis Of M Sand

4.3 TEST ON COARSE AGGREGATE

For Coarse aggregate the following test are performed and the results are tabulated

4.4.1 20mm Normal Aggregate

S.NO	Sieve size in mm	Weight retained Kg	Cumulative weight retained kg	Weight passing Kg	Weight passing %
1	25	0	0	5	100
2	20	0.320	0.320	4.68	93.6
3	16	3.086	3.406	1.594	31.88
4	12.5	1.342	4.748	0.252	5.04
5	10	0.162	4.91	0.09	1.8
6	4.75	0.022	4.932	0.068	1.36

Table 4.4 Sieve Analysis Of Coarse Aggregate

S.NO	PROPERTY	RESULTS
1	Specific Gravity	2.66
2	Bulk Density	1654 kg/m ³
3	Water absorption	1.0 %

Table 4.5 Physical Properties Of Coarse Aggregate

4.4 MIX PROPORTIONS

Mix Proportions for M30 grade concrete have been developed based on IS 10262: 2019 and the quantities of materials required for the study have been calculated . The water cement ratio of 0.43 has been set constant throughout the work.

4.5 TEST RESULT FOR HARDEN CONCRETE

4.5.1 Compression Test Result

S.NO	MIX	AVERAGE COMPRESSIVE STRENGTH IN N/MM ²		
		7 Days	14 Days	28 Days
1	M30 grade concrete	21.56	29.45	38.10

Table 4.6 Average Compressive Strength 7, 14, 28 Days

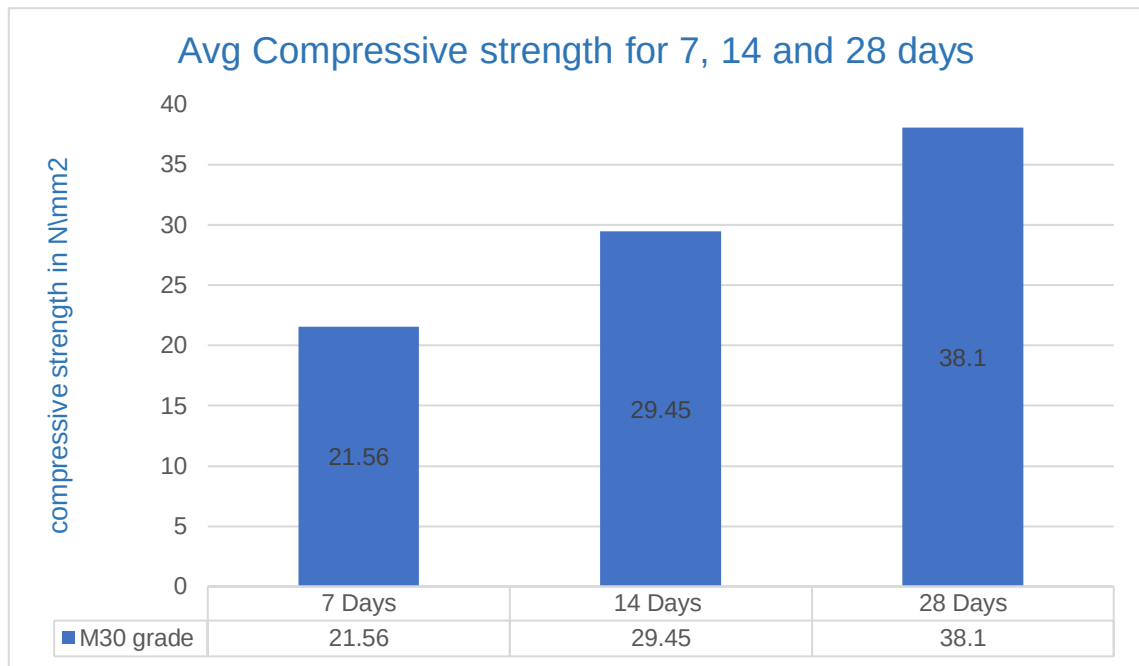


Fig 4.1 Average Compressive Strength 7,14and 28 Days

4.5.2 Split Tensile Results

S.NO	MIX	AVERAGE SPLIT TENSILE STRENGTH IN N/MM ²		
		7 Days	14 Days	28 Days
1	M30 grade	1.98	2.89	3.28

Table 4.7 Average Split Tensile Strength 7, 14 And 28 Days

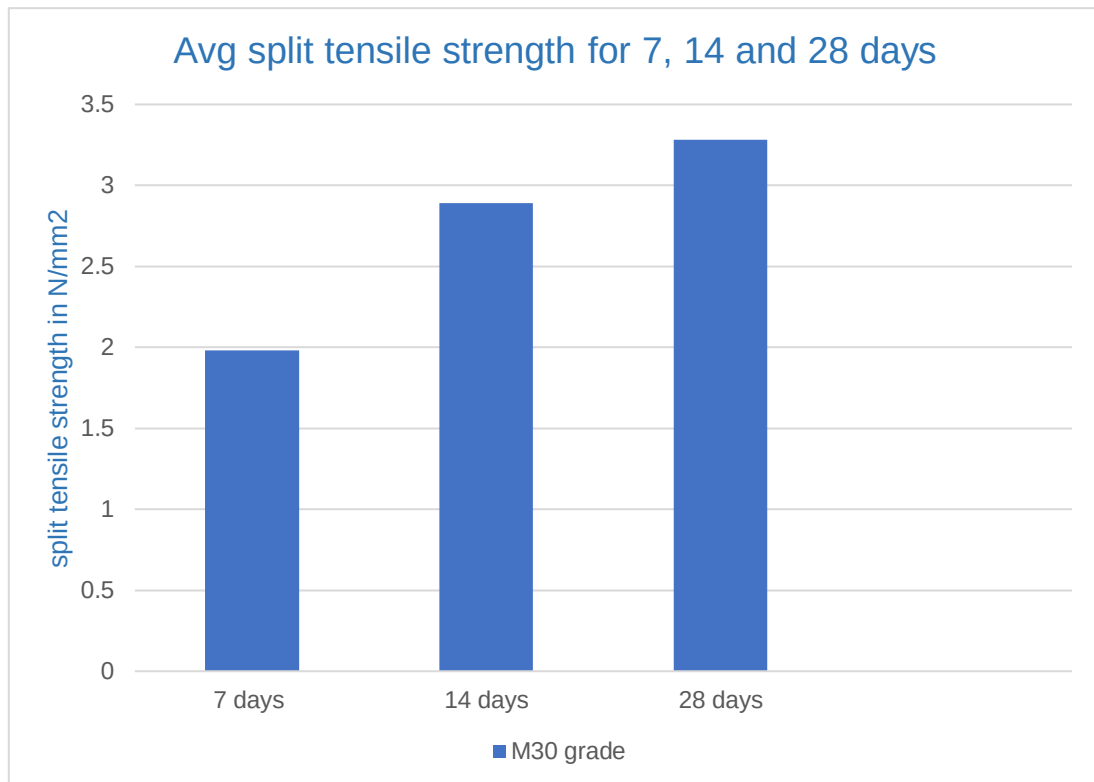


Fig 4.2 Average Split Tensile Strength 7,14 And 28 Days

4.5.3 Compression Test Result For Column

SL NO	LOAD	DISPLACEMENT IN MM			
		Conventional Rcc Column	CFS Castellaed Composite Column	CFS Castellated Composite Column With Reinforcement	CFS Composite Column
1	20	0.20	0.20	0.13	0.21
2	40	0.32	0.30	0.27	0.3
3	60	0.50	0.48	0.31	0.52
4	80	0.60	0.54	0.42	0.63
5	100	0.66	0.62	0.58	0.77
6	120	0.85	0.77	0.72	0.85
7	140	1.24	0.92	0.88	1.09
8	160	1.52	1.15	1.05	1.26

9	180	1.75	1.28	1.19	1.39
10	200	2.10	1.40	1.33	1.55

Table 4.8 Compression Test Result For Column

CHAPTER 5

ANALYTICAL INVESTIGATION

5.1 Abaqus

Abaqus is a powerful computer-aided engineering software suite developed by Dassault Systemes Simulia Corp. It is used for Finite Element Analysis (FEA) and Computational Fluid Dynamics (CFD) simulations in various industries such as aerospace, automotive, civil engineering, and biomechanics.

Abaqus provides advanced features for modeling, meshing, analysis, and visualization. It can handle complex geometries, nonlinear material behavior, large deformations, and multiphysics problems. The software allows engineers and researchers to simulate the behavior of complex systems and structures under various conditions, such as mechanical loading, thermal loading, and fluid flow.

Abaqus has a user-friendly interface and supports various programming languages, such as Python and Fortran. It also provides extensive documentation and user support. The software is known for its accuracy, robustness, and scalability, and it has become a popular tool for product design, optimization, and research and development.

In addition to its standard features, Abaqus also offers specialized modules for specific industries and applications, such as Abaqus/CAE for simulation and modeling, Abaqus/Standard for static and dynamic analysis, Abaqus/Explicit for highly nonlinear and dynamic problems, and Abaqus/CFD for computational fluid dynamics.

5.1.1 Advantage of *abaqus*

Abaqus software offers several advantages for engineers and researchers involved in Finite Element Analysis (FEA) and Computational Fluid Dynamics (CFD) simulations. Some of the advantages of Abaqus software are:

- **Accuracy:** Abaqus software provides accurate solutions for complex problems involving nonlinear material behavior, large deformations, and multiphysics phenomena
- **Robustness:** The software is robust and can handle a wide range of simulations involving different types of loads, boundary conditions, and materials.
- **Customizability:** Abaqus software is highly customizable and allows users to create their own material models, elements, and user subroutines.
- **Scalability:** Abaqus software can be used for simulations ranging from simple, single-component models to complex, multi-component models.
- **User-friendly Interface:** The software has a user-friendly interface that makes it easy for engineers and researchers to perform simulations, analyze results, and create reports.
- **Comprehensive documentation:** Abaqus software comes with comprehensive documentation that includes theory manuals, user manuals, and verification and validation guides.
- **Technical support:** The software is supported by a dedicated technical support team that provides assistance with software installation, troubleshooting, and other issues.
- **Integration with other software:** Abaqus software can be integrated with other software tools, such as MATLAB, Python, and CAD software, to enhance the simulation capabilities and workflows.

5.1.2 ***Disadvantages Of Abaquas***

Here are a few potential disadvantages of using Abaqus software:

- **Cost:** Abaqus is a commercial software and can be expensive, especially for small businesses or individual users.

- Steep learning curve: Abaqus is a powerful software with a wide range of features, which can make it challenging to learn and master, especially for beginners.
- Hardware requirements: Abaqus is a resource-intensive software, and running simulations on large models or complex problems may require high-performance computing resources.
- Licensing limitations: Depending on the licensing agreement, the number of cores or processors available for parallel processing may be limited, which can impact simulation speed.
- Technical support: Although Abaqus has extensive documentation and user forums, getting timely and effective technical support can be a challenge, especially for users who are not experienced with the software.

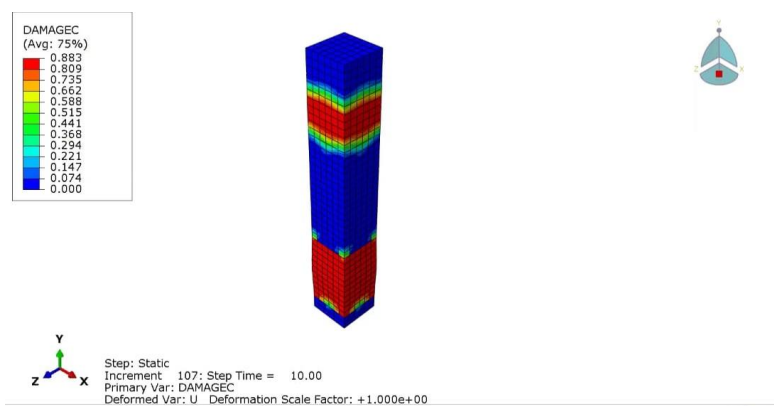
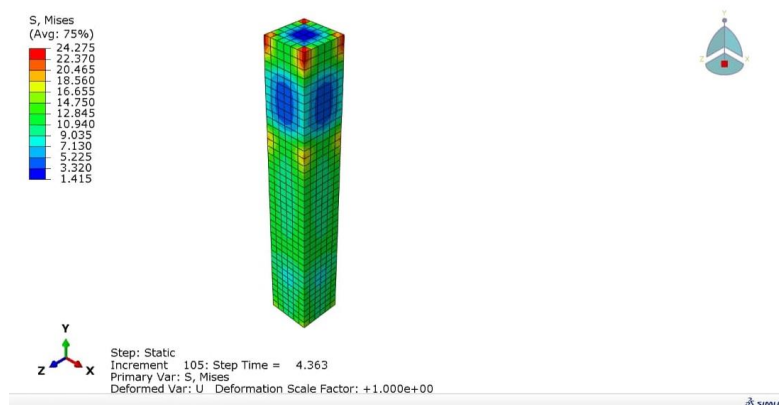
5.1.3 Application of Abaquas

Abaqus is a powerful finite element analysis software used for simulating and analyzing various types of engineering problems. Some common applications of Abaqus include:

- Structural Analysis: Abaqus can be used to analyze the behavior of structures under various loads and conditions, such as static and dynamic loads, temperature changes, and impact loads.
- Thermal Analysis: Abaqus can be used to simulate the thermal behavior of structures and systems, including heat transfer, thermal stress, and thermal expansion.
- Fluid-Structure Interaction: Abaqus can be used to simulate the interaction between fluids and structures, including the behavior of fluids in pipes and tanks, and the impact of fluid flow on structures.
- Electromagnetic Analysis: Abaqus can be used to simulate electromagnetic behavior, including electric and magnetic fields, and the interaction between electromagnetic fields and materials.

- **Composite Materials Analysis:** Abaqus can be used to simulate the behavior of composite materials, including their mechanical and thermal properties, and their response to different loading conditions.
- **Geotechnical Analysis:** Abaqus can be used to simulate the behavior of soil and rock structures, including their response to earthquakes, landslides, and other geological hazards.
- **Acoustic Analysis:** Abaqus can be used to simulate the behavior of acoustic waves and their interaction with structures, including noise reduction and vibration control.
- **Biomechanical Analysis:** Abaqus can be used to simulate the behavior of biological systems, including the mechanics of bones, muscles, and other tissues, and the interaction between biological systems and medical devices.

5.2 RESULT FROM ABAQUAS



5.3 DISPLACEMENT FOR FOUR MODELS

S.NO	LOAD (KN)	DISPLACEMENT IN MM			
		Conventional Rcc Column	CFS Castellaed Composite Column	CFS Castellated Composite Colum With Reinforcement	CFS Composite Column
1	20	0.23	0.25	0.20	0.23
2	40	0.5	0.4	0.35	0.46
3	60	0.78	0.55	0.48	0.66
4	80	1.02	0.70	0.59	0.88
5	100	1.25	0.82	0.70	1.05
6	120	1.59	0.93	0.95	1.33
7	140	1.77	1.22	1.02	1.56
8	160	1.93	1.55	1.24	1.70
9	180	2.09	1.72	1.38	1.95
10	200	2.37	2.1	1.75	2.04

Table 5.1 Software Test Result For Column

Both analytical and experimental data are compared to the deflection of all columns under varying loads. The required properties, boundary conditions, loading, meshing, etc. were provided when creating the beam models in the

Abaqus software, and the results were obtained. In the graph, which has load (KN) and deflection (mm) on opposite axes, these results are contrasted. When compared to other columns, the castellated concrete column with reinforcement have less deflection and high strength both experimentally and analytically.

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 SUMMARY

Lots of literature were studied and found the use of cold rolled sheet and castellated column in industry .and also studies physical properties and fabrication of castellated column and beam, .

The physical properties of all the materials used in concrete has been tested. The properties of harden concrete also investigated.in abaqus software models columns were developed. The experimental results were compared with finite element software result.

6.2 CONCLUSION

In this study we had investigated the buckling behavior of the cold formed steel castellated column at 3 different pattern tested.

Compare to the hot rolled sheet the cold formed steel have high strength and durability.

Castellated column have good binding property to compare the other composite columns.

From this investigation its is found castellated composite column are much more stronger than Reinforced concrete column

Compare to the reinforced concrete column castellated composite column have low deflection and high load carrying capacity.

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