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Experimental and Analytical Study on Concrete Infilled Light Gauge Steel Sections

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CHAPTER NO.-1

INTRODUCTION

1.1 Introduction to Cold-form Steel Section

The use of cold-formed steel members in building construction began in the 1850s in both the United States and Great Britain. In the 1920s and 1930s, acceptance of cold-formed steel as a construction material was still limited because there was no adequate design standard and limited information on material use in building codes. One of the first documented uses of cold-formed steel as a building material is the Virginia Baptist Hospital, constructed around 1925 in Lynchburg, Virginia. The walls were load bearing masonry, but the floor system was framed with double back-to-back cold-formed steel lipped channels. According to Chuck Greene, P.E of Nolen Frisa Associates, the joists were adequate to carry the initial loads and spans, based on current analysis techniques. Greene engineered a recent renovation to the structure and said that for the most part, the joists are still performing well. A site observation during this renovation confirmed that these joists from the roaring twenties are still supporting loads, over 80 years later. In the 1940s, Lustron Homes built and sold almost 2500 steel-framed homes, with the framing, finishes, cabinets and furniture made from cold-formed steel. The requirement for the lighter, stronger, durable and economical structural materials, techniques and sections for constructions grows day by day. This constantly increasing demand lead to the testing and experimenting of new composite sections which are stronger and durable than the conventional concrete sections.

Steel is an alloy of iron and carbon that is widely used in construction and other various applications due to its hardness and tensile strength. Structural steel is generally divided into hot-rolled sections and cold-formed sections. These two types of steel sections are distinguished by the method of forming in their manufacturing process. Hot-rolled steel sections are formed under high temperature up to 1400^{o}C in blast furnace or electric arc furnace, while the cold-formed steel sections are manufactured in room temperature. The difference of the manufacturing process makes the properties of hot rolled and cold-formed steel vary in strength, structural performance, and failure mode. Cold formed steel sections are press folded steel sections which are moulded under the high pressure and under cold stateof a high capacity moulding iron. It is also theoretically and experimentally proven that the cold formed sections provide increased strength than the hot rolled sections of the same size and grade. They can be useful in construction practices

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due to theirstrength, ductility, stiffness, energy absorption capacity, easy construction procedure and overall economy. The thickness of these sheets ranges from 0.0147inch (0.373mm) to about ¼ inch (6.35mm). Cold-formed steel sections tend to be more sensitive to local buckling than the hot rolled sections. The manufacturing and transportation of these members is easy and durable than most of the construction materials. They possess high strength to weight ratio than many of the building and structural materials. The cold formed steel sections are durable, and they last for long time due to high resistance to corrosion. They are recyclable and reusable products which require very less energy, time and expenses to remold them to the required shape and size. These Sections can be classified into open sections, closed sections, built up sections. Generally, these sections are available for use as basic building materials for assembly at the site or they can be prefabricated panels or frames. The yield strength of steel sheets used in forming cold-formed sections is at least 280[5] N/mm^2.



Fig:1.1 Cold formed Light Gauge Steel Section

These are thin sheets of steel products which are extensively used in building industry and range from purlins to roof sheeting and floor decking. These building materials encompass columns, beams, joists, studs, floor decking, built-up sections and other components. Generally, these are available for use as basic building elements for assembly at site or as prefabricated frames or panels. These steel members have been used in many bridges, coaches, highway products, transmission towers and transmission poles etc.

- **Properties of Light Gauge Steel System**

Build ability: The use of pre-fabricated and preassembled steel components reduces site works, reduces material waste and improves quality.

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Speed: This system requires a shorter construction period compared to that for a conventional system.

Strong but Lightweight: Steel has one of the highest strength-to-weight ratios of any construction material. These results in savings in the foundation required and the lightness also makes for easier on-site handling.

Safety: Steel's inherent strength and noncombustible qualities enable light steel frame houses to resist such devastating events as fires, earthquakes, and hurricanes. Homes can be designed to meet the highest seismic and wind load specifications in any part of the country.

Quality: A better quality finished house that is durable and low in maintenance.

Easy to Remodel: Remodeling can be easily accomplished. Non-load bearing walls can be readily relocated, removed or altered.

Design Flexibility: Because of its strength, steel can span longer lengths, offering larger open spaces and increased design flexibility without requiring intermediate columns or load bearing walls.

Recyclable: All steel products are recyclable.

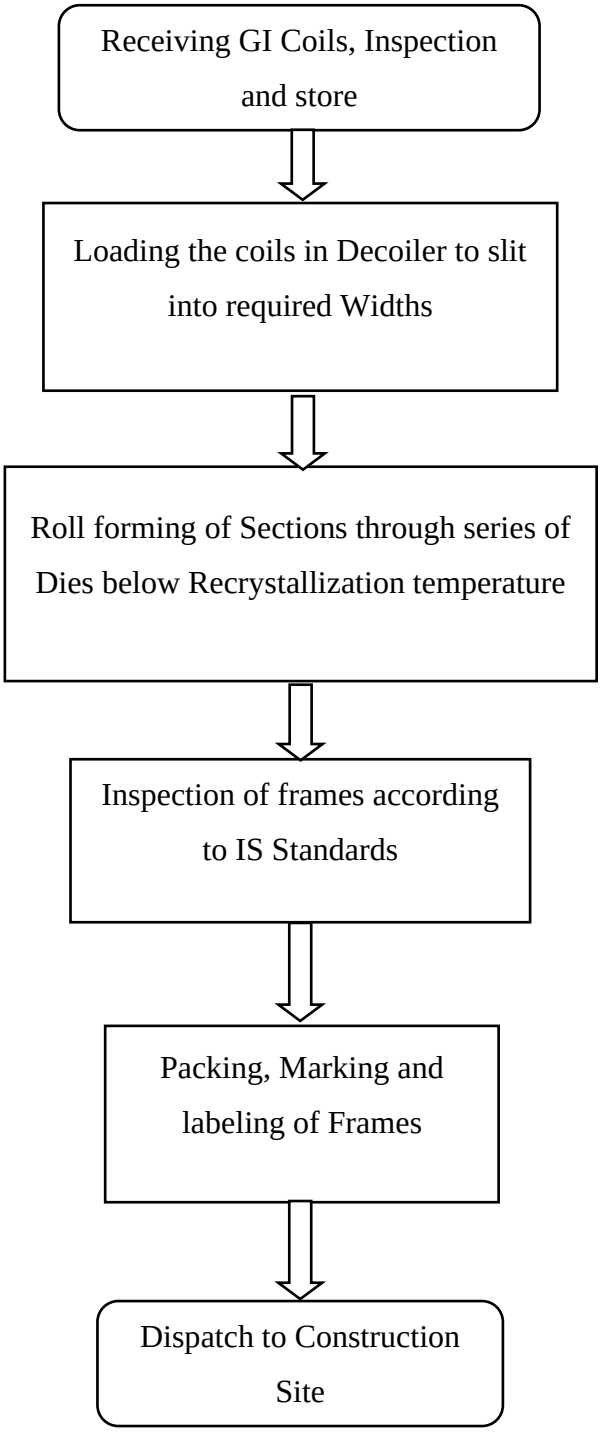
Although the cold rolled products were developed during the First World War, their extensive use worldwide has grown only during the last 20 years because of their versatility and suitability for a range of lighter load bearing applications.[2] In the past, cold-formed steel sections were used as secondary structural members, for example, roof purlin and side rail for wall cladding. Thin-walled behavior limits the structural performance of cold-formed steel sections by premature buckling and instability. Over the past two decades, the increasing application of cold-formed steel in construction industry has brought massive researches in progress to ensure the stability and reliability of the constructed steel structures. As the industry demand grows gradually, many research studies were done to minimize the safety issue and promoted the use of cold-formed steel members as primary structural members, for example, roof truss, beam, and column member. The research includes the investigation of buckling properties of cold-formed steel members, failure mode of the members, and strength and stiffness of the cold-formed steel member. These research studies provide the latest models and contribute important information to the design guidelines of British Standard 5950 Part 5 and Eurocode BS EN 1993 Part 1.3 and Part 1.8[7]. The situation is obvious in the United States of America which accelerated by the development of research institutes such as American Iron and Steel Institute (AISI)[7]. Cold formed steel construction has been used for highly pleasing designs in practically every sector of building construction.

Manufacturing of cold formed steel sections is done with the steel coils of 1.0 to 1.25 m width, slit longitudinally to the correct width appropriate to the section required and then feed them into a series of roll forms to the required shapes. These steel rolls containing male and female dies, are arranged in pairs,

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moving in opposite direction so that as the sheet is fed through them its shape is gradually altered to the required profile[4]. The sections are formed with the required width. In view of the use of very thin steel sheet sections, (generally in the 1 mm - 3 mm range), attention must be paid to buckling of these elements as they can buckle leading to the failure of the members. The techniques of eliminating lateral buckling in practice, by providing lateral braces or by attachment to floors can be done to prevent the buckling.



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Figure 1.2 Flowchart for Manufacturing of Cold form steel

The local buckling behavior of concrete in-filled sections is enhanced by the pressure of concrete in-fill when compared to hollow box-sections. For hollow sections the walls are hinged along the corners and the local buckling may involve the corners too whereas for concrete in–filled sections, the walls are fixed along the corners and they remain straight. This effect allows using an increased wall slenderness and higher steel quality.[5] In addition, the presence of the steel box-section produces an increase of concrete strength due to the confinement effect.

The design of Cold – Formed steel section is done by using I.S. 801-1975[3]. This results in uneconomic design as in W.S.M. full section is not utilized. So, to utilize the full cross – section of the section and to maintain economy, it is required to revise Indian Standard Code and in S.I. System.

- **Connections**

The behavior of connections is extremely important in structural design, influencing both the structural efficiency and cost. Due to the comparative thinness of the material, connection technology plays an important role in the development of structures formed using cold formed sections. The conventional methods of connections, such as bolting, and arc-welding are of course available but are generally less appropriate & the new special techniques are more suited to thin material in the face of tremendous pressure on the construction industry to reduce cost, improve quality and build faster. Light duty connection methods such as spot welding, self-pierced riveting and screwing are the new fastening technologies.

Our project involves experimentally testing the composite section of cold formed light gauge steel with the infill of plain cement concrete (PCC) and steel fibre reinforced concrete (SFRC). A steel-concrete composite column is a compression member, comprising either a concrete encased hot-rolled steel section or a concrete filled tubular section of hot-rolled steel and is generally used as a load-bearing member in a composite framed structure. There is no requirement to provide additional reinforcing steel for composite concrete filled tubular sections, except for requirements of fire resistance. The local buckling behavior of concrete-filled box sections is enhanced by the pressure of concrete in-fill when compared to hollow box-sections. Composite columns are structural members subjected to compression and bending, made of concrete and structural steel. Analysis of structures using finite element method is an alternate method to predict the behavior of structures. Finite element analysis (FEA) is a computer simulation technique used in engineering analysis. In this study, buckling analysis was adopted to analyze the behavior of in-filled composite column under concentric loading using ANSYS Workbench v14.5 software.

- **ANSYS Workbench v14.5**

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ANSYS Civil gives designers the ability to assess the influence of this range of variables in a virtual environment. Thus, engineers can advance through the design and materials selection process quickly and efficiently.

1.2 Problem Statement

1. By observation there seems to be lack of utilization of light gauge steel framing in residential construction.
2. The problem is that builders may not be taking advantages of materials that may improve the quality of their construction.
3. The major part of construction industry now a day is focused on economic growth rather than the research.

1.3 Objectives of the Project

The aim of this work is to study of composite columns and beams when subjected to compression and flexural testing. The study focuses on the following:

1. To study the buckling behavior of hollow column, PCC in-filled column and SFRC infilled column subjected to loading.
2. To study the flexural behavior of light gauge steel hollow, PCC and SFRC in-filled beams under simply supported conditions under concentric loading.
3. To compare the experimental results with analytical results by ANSYS Workbench v14.5 software.

1.4 Scope of the Project

1. Improvement in structural integrity
2. Light weight composite section
3. Improvement in Aesthetics
4. Reduction in dead load

1.5 Advantages of Cold Formed Steel Sections

Generally, cold-formed steel sections have several advantages over hot rolled steel sections and timber trusses. The main advantages are listed as follows:

1. **No Insect and Fungal Infection**

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The problems such as rot and decomposition due to insect and fungal infections are eliminated. Therefore, the material curing and maintenance costs, which are necessary for timber, could be eliminated as well.

2. Consistency and Accuracy of Profile

The nature of manufacturing process of cold rolling includes the ability of the desired profile to be maintained and repeated for as long as required with minimum tolerances. The consistency and accuracy of the profile can easily be achieved using computer control system. The quality of the section can be efficiently controlled in the factory and does not depend on environmental factor as in the case of timber.

3. Versatility of Profile Shape

Almost any desired cross-sectional shapes can be produced by cold rolling, such as T-section, Z-section, dam section, and hat section. The size, length, shape, and thickness can easily be met as the production can automatically be controlled in the production line.

4. Corrosion Resistance by Pre-galvanization or Pre-coating

The steel material may be pre-galvanized or pre-coated with materials such as zinchi-ten to enhance its corrosion resistance and attractive surface finish. The coating gives the truss attractive silver finish and avoids the messy requirement of painting the frames on site.

5. Variety of Connection and Jointing Methods

All conventional methods of connecting components such as riveting, bolting, welding, screwing, and adhesives material are suitable for cold-formed section. A pointed long screw about 10 mm long and 5 mm in diameter was used in this study since it is the fastest and easiest way available in the local market.

6. Speedy in Construction and Easy to Erect

Generally, steel construction has eliminated the curing time which is inevitable in concrete construction. The use of cold-formed steel section has a better advantage than hot-rolled steel since it can be cut and erected with very light machine and need only one or the most, two workers to install it.

7. Increases in Yield Strength Due to Cold Forming

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The cold forming process introduces local work hardening in the strip being formed near the formed corners. This local work hardening may result in an increment of ultimate yield strength of about 25% from its expected design strength.

8. Minimum Use of Material

Since the material used can be very thin in comparison with the lowest thickness limit of hot rolled steel sections, it therefore allows the material usage for a given strength or stiffness requirement to be much less than that of the smallest hot rolled sections. The material thickness, or even the cross-sectional geometries, could be controlled to achieve the structural features with minimum material weight.

9. Lower in Production Cost and Higher in Profit

In cold rolled process, the manufacturing costs involve the purchasing of the rolling machine and the steel strip coils. The cost of the machine can be easily recovered in the continuous mass production of the section. The cold formed steel roof truss system, which is in great demand and not enough supply locally can be considered as having a good potential as a construction material. Therefore, the investment required is relatively lower and the return back is sooner than most of other construction materials.

10. Fire Resistance

Steel framing is non-combustible and will not add fuel to a fire. It improves fire safety compliance with local codes and regulations. Steel framing offers code-approved increases in allowable floor area and/or allowable building heights, compared to conventional wood framing. One-third of all fires start in wall cavities. Actual case studies show steel houses perform extremely well in-house fires, and experience little or no damage to the structural framing.

11. Environmental Compatibility

Steel offers builders an environmentally friendly alternative to wood. There is little waste when steel framing materials are used. Builders can reduce their disposal costs and divert material from local landfills. Building an average wood-frame home generates approximately 50 cubic feet of landfill waste. A comparable steel-frame home generates about 1.5 cubic feet of waste.

12. Pollution Control

The Healthy House Institute recommends steel framing to support good indoor air quality. Homeowners sensitive to chemicals, and those susceptible to asthma, are exposed to fewer toxins in a steel-framed home. The American Lung Association encourages the use of steel framing with its Healthy House program. Steel resists mould spores that can lead to chronic illness. No pesticides or toxins are required to protect steel

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framing from termites or vermin. No emissions from resins, adhesives or chemicals normally used for wood construction occur with steel.

13. Recyclability

Steel is 100% recyclable and considered to be a green building material. Steel framing materials contain, on average, 67% recycled steel. Steel can be a significant factor in the LEED certification process. It takes 25 old-growth trees to build a 2,500 square-foot home, compared with 7 recycled automobiles for the same home with steel framing. 60 million tons of steel scrap is recycled each year – more than paper, aluminium, glass and plastic combined.

14. Lightning Resistance

Steel buildings are lightning resistant because steel framing provides multiple conductive paths directly to the ground. A steel frame reduces the likelihood of explosions, secondary fires or personal injury. Steel skyscrapers have provided occupants with safe offices and residences for decades.

15. Earthquakes and Hurricanes

Steel framing can be engineered to meet the highest seismic and wind loads prescribed by building codes. Steel has the highest strength-to-weight ratio of any framing material a lighter structure with stronger connections results in less damage from seismic forces. Steel's strength and resiliency help it to survive earthquakes. With a steel structure, there is a smaller probability of wind damage due to stronger (screwed vs. nailed) connections. For generations, we have relied on the strength and durability of steel in our commercial buildings, hospitals and schools.

Compared with other materials such as timber and concrete, the following qualities can be realized for cold-formed steel structural members.

1. Lightness
2. High strength and stiffness
3. Ease of prefabrication and mass production
4. Fast and easy erection and installation
5. Substantial elimination of delays due to weather
6. More accurate detailing
7. Non-shrinking and non-creeping at ambient temperatures
8. Formwork unneeded
9. Termite-proof and rot proof

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10. Uniform quality

11. Economy in transportation and handling

1.6 Limitations

1. Skilled workmen required for forming of these sections

2. Curing of these sections for small sectional areas is not possible due risks involving steel being corroded.

3. The joints of these sections must be proper and rigid that fixed beam can be erected.

4. There should not be any voids in the in-filled concrete in these sections as they may only weaken the sections.

5. These sections must be casted carefully and under strict supervision as the higher the compression higher is the strength of section achieved

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CHAPTER 2

LITERATURE REVIEW

2.1 General

This chapter presents a review of relevant literatures to bring out the background of the study undertaken in this project. The research contributions which have a direct relevance are treated in greater detail. Some of the historical works which have contributed greatly to the understanding of the cold form steel tube sections are also described. First, a brief review of the historical background is presented. The concepts of composite beam and column, their necessary advantages and applications, related to work carried out in this thesis, are then discussed. The amount of the literature on the subject has been increasing rapidly in the recent years. Several of this is available in the proceedings of the conferences which are very helpful for understanding the recent developments in cold form steel structural framing.

2.2 Previous Literature

2.2.1Ariel Hanaor[1](1999)

The author presented paper on the use of cold-formed sections as composite beams in slab systems offers high flexibility in design and several advantages. Among these advantages are the enabling of shallow overall slab depth, easy adaptation to irregular geometries, freedom in design of cross-sections and ready availability of materials and sections. The main problem in implementation of the designs is ensuring adequate shear transfer between the concrete slab and the cold-formed beam section, whose thickness is often too small for welding of conventional shear studs. The paper presents designs and test results for several technologies involving cold-formed sections in composite construction, including self-drilling screwed cold-formed shear connectors, and built-up sections bolted to precast concrete planks. The tests include extensive push-out tests of numerous types of connectors, as well as full-scale composite element tests. Results indicate that design of shear connectors can in most cases be conservatively based on codes of practice for the design of cold-formed connections. Full-scale tests indicate high ductility and capacity which exceeds design assumptions.

2.2.2 A. Jayaraman[2](2015)

The author studied the light – gauge steel and its evolution as a building material in the 1930’s and reached large scale usage only after the Second World War. In comparison with conventional steel construction, where standard hot rolled shapes are used, the cold formed light gauge steel structures are relatively new development. This paper presents a study on behaviour and

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economical of cold formed steel (CFS) built up channel section using different codes. This paper provides an experimental investigation for the bending strength of Cold – Formed light gauge steel plain (stiffened) rectangular sections. The test specimens were brake pressed from high strength structural steel sheets. In addition, the test strengths were compared with the design strengths calculated using the Indian Standard and Euro Codes Specification for Cold –Formed steel structures. Flexural members are linear members in which axial forces act to cause elongation (stretch). The theoretical data are calculated using Indian Standard code IS 801-1975 and the section properties of the specimens are obtained using IS 811-1975. The specimens are designed under uniformly distributed loading with simply supported condition. The research project aims to provide which code of practice given more economical, high bending strength, more load carrying capacity and high flexural strength. The studies reveal that the theoretical investigations limit state methods (SI method) have high bending strength, high load caring capacity, maximum deflection and minimum local buckling& distortional buckling compare to the other codes.

2.2.3 Balaji A Raju[3](2013)

Author studied the pre-engineered steel buildings used in the construction of industrial buildings. Very short erection time and higher strength to weight ratio are the major advantages of these systems. Some of the components like slabs and walls in PEB construction are still done on-site. This paper addresses this limitation through development of a composite panel using cold form steel section. The panel is experimentally analyzed for flexure and the results hence obtained are also simulated using finite element method.

2.2.4 Bong-Ho Cho[4](2017)

Author and his coauthors presented paper that proposes a new steel concrete composite beam that has a similar shape to the conventional steel wide flange beam, but whose lower flange has a tubular shape with infilled concrete. It has openings in the web for perfect integration between concrete and steel materials, and the tubular lower flange is reinforced with steel rebars to enhance its flexural strength. The bending capacity of the new composite beam was investigated by performing a two-point loading test on seven specimens, which can be categorized mainly into two types, non-composite and fully composite specimens. The load versus displacement curves were plotted for all the specimens and their failure modes were identified. Theoretical equations were proposed to estimate the flexural strength of the new composite beam members, and their accuracy was examined by comparing the predictions of the equations with the test results.

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2.2.5 M.Shanmuga Priya[9] (2014)

Author analyzed the comparison of experimental results with numerical analysis using ANSYS on the buckling behavior of medium height light gauge steel rectangular hollow column and in-filled column with plain cement concrete and steel fiber reinforced concrete subjected to concentric and eccentric loads. The numerical simulations are compared with experimental results collected from the literature and the reliability of the proposed finite element model is discussed.

2.2.6 Nimmy Thomas[10]

Author studied was made to assess the flexural capacity of Composite Beams using Truss beams under two-point loading with span 2m. Beam consist of top and bottom chord with cold formed light gauge steel plate (width 100 mm and thickness varying from 1.5mm to 2mm) and light gauge angle section welded at the ends of the plate. Top and bottom chord members were connected by steel rods of diameter 8mm making inclined connections with horizontal using Fe 250 grade steel at both faces of angles. Truss was filled with M25 concrete to form a Composite Beam. A comparative study was made between truss beam and composite beam to assess the ultimate load carrying capacity, Flexural strength, Ultimate Deflection, displacement ductility. Tests were conducted on truss beams and composite beams for different thickness. From the result it was observed that for truss beams as the thickness varied from 1.5mm to 2mm load carrying capacity increased by 1.08 times but when the same truss beam encased by concrete load carrying capacity raised by 2.26 times. When concrete was encased, and thickness was increased load carrying capacity increased by 2.6 times. As the thickness increases from 1.5 to 2mm displacement ductility factor increased by 4.8% for truss beam but when concrete is encased displacement ductility factor get increased by 76.47%. Flexural strength of composite beam is 2.46 times more than truss beam when the thickness of light gauge cold formed steel plate is 2mm and when the thickness of light gauge cold formed steel plate is 1.5mm Flexural strength of composite beam is 2.27 times more than the flexural strength of truss beam. A marginal increase in load carrying capacity, flexural strength, displacement ductility occurs after encasing concrete.

2.2.7 Numburi R. Dharma Krishna[11]

Author has studied cold formed steel are manufactured from thin steel sheet at a very low temperature. The thin sheets of steel are rolled or compressed to desired sections. The thickness of these steel products generally ranges from 0.3mm to 6mm approximately. Due to its thickness they are weak when compared to hot roll steel products. So, they are infilled with concrete or other high strength materials. In this research, rectangular cold formed steel sections were considered and was

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infilled with concrete in which coarse aggregate is replaced with construction waste (broken tiles). In this paper, the first stage deals with the optimum percentage replacement of broken tiles which is replaced at 10%, 15%, and 20% weight of coarse aggregate. The optimum percentage replacement is then infilled to rectangular cold formed steel sections and the flexural properties for the same is studied using ANSYS software.

2.2.8 Prakash M. Mohite[12](2015)

Author compared the cold formed steel are nowadays used for building construction especially non-load bearing partition, curved walls, etc. due to its flexural strength and good appearance. The cold formed steel enhances the mean yield stress by 15% to 30% as compared to hot rolled steel. In this paper detailed parametric and comparative study of cold formed steel sections by different codes is carried out for prediction of flexural strength of beams. Various codes predict different strength. The flexural strength of cold formed steel beam is carried out and presented using CUFSM software which uses Direct Strength Method for prediction of flexural strength and this flexural strength is compared with IS 801-1975 and experimental results.

2.2.9 Prof. JothiBaskar[13](2016)

Author studied Cold form steel is also called as light gauge steel sections. In this paper, the investigation made on the C channel section to calculate the buckling load using experimentally and theoretically. The C channel section is formed by channel section with lip was tested as under axial compression. The Finite strip method is developed by CUFSM software. The buckling load value was taken from GBTUL software. The column strength determined by Direct Strength Method based on AISI-S100:2007. The load carrying capacity of column compared with numerical, theoretical and experimental results.

2.2.10 Satalingappa P. Deshamukh[14](2013)

Author experimented theCold-formed structural members steel in this form is more easily delivered from the steel mill to the manufacturing plant where it is usually cold rolled into open and closed section members. The present experimental study is on the effect of infilled Normal Concrete and Geopolymer concrete only at the joints in cold formed tubular sections and which may increase the load carrying capacity of the joints. In present study strength of the joint is increased by infilling different grades of concrete in the tubular specimens the joints with single number of bolts at the connection. This work presents number of experimental tests have been carried out on cold formed tubular tension members fastened with bolts, to calculate the failure capacity and increase in strength

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of the member and also to trace the entire load versus Strain/Elongation so that the behavior of the connection is examined and also MATLAB used for calculation of maximum loads for various thickness.

2.2.11 S. Saravanan[15] (2014)

Author experimented work thatin recent years, for earthquake prone areas, lightweight structures are used to reduce the effect of lateral forces due to earthquakes. In latest trends, the usage of cold formed steel structures (CFS) with Cement bonded particle board (CBPB) as an infill and it is recommended in all earthquake prone areas. In partially infilled structures, column with short gap will behave as short column during earthquake and attract larger forces due to in-plane stiffness of the infills and can damage the column seriously due to excessive shear forces, which is known as captive column effect. Since it is complex to consider the contribution of strength and stiffness of these partial infills, the structure is analyzed and designed as bare frames. On the other hand, the real behavior of partial infilled structures during earthquake is like captive columns. One of the major failures of structure during earthquake is due to captive column effect. Several literatures and research papers have been published in the area of captive column effect and its remedy in RCC frame. A detail study is required for understanding the captive column effect *i*n cold formed steel columns under lateral loading as in the case of RCC framed structures. An experimental investigation is conducted in single bay two storied cold formed steel bare frame and cold formed steel frame with CBPB as partial infill in bottom story to study the behavior of captive column effect. This study clearly indicates that, the bare frame deflected uniformly which shows the lateral forces are distributed over the full height whereas in the frame with partial infill, the short column has attracted excessive shear forces resulting in failure Proving Captive Column Effect. This study clearly indicates that the columns in lightweight structures with partial infill also behave as a short column and can be seriously damaged during an earthquake.

2.2.12 Mohammed Sakr1, Bothaina Osama1(3 june 2022)

Composite members made from a mix of steel and concrete enjoy the merits of both materials [1], specifically the high ductility and tensile strength of steel, the high compressive strength of concrete and its capability to stop the local buckling of steel tube. Additionally, the steel tube provides confinement mechanism for the concrete. Composite columns have become increasingly popular in a variety of engineering constructions, particularly highrise buildings and long-span bridges [2]. The most common steel–concrete composite member is the concrete filled steel tube (CFST) column. The structural performance of CFST members has been the subject of numerous experimental and analytical research [3–5]. Relevant design specifications have been established in various nations and areas as a result of these findings to better guide the design of CFST members and structures.

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2.2.13 Zhenshan Wang (3 aug 2022)

To enhance the local buckling resistance of thin-walled steel pipes and enhance their fire and corrosion resistance, a new spirally stiffened thin-walled square concrete-filled steel tubular laminated composite member with transverse ribs is proposed. Through the four forms of combined members for eccentric pressure testing, it was found that: ordinary thin-walled steel pipe concrete drum buckling is more severe; with spiral ribs, the buckling is limited between the stiffening ribs; and the deformation is significantly reduced. By addressing the problem of cooperative work between the inner and outer structural layers of new components, it was found that, after setting constraints such as steel bars, the integrity of the two can be ensured, and the stress performance is significantly improved; compared to ordinary steel pipe concrete, the load-carrying capacity is 17.9% higher, and the deformation capacity is roughly equivalent. Spiral ribs as a new form of spatial restraint, in addition to increasing the local bending stiffness, manifest an overall restraint role in limiting lateral deformation of the steel pipe, whereas the role of vertical stiffness is insignificant.

2.3 Summary of Literature

It is found that lot of work is done on concrete filled cold form section & found to be most economical & speedy construction technique to complete the construction within deadline with optimization on expenditure. And much of literature is available on the experimental testing and results of compressive strength of concrete infilled column sections and concrete infilled beam sections. While the main study is focused on the testing of these columns no particular literature guides through the process to be adopted for the curing process of these composite sections.

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CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 MATERIAL

The conventional concrete grade of strength M25 is used, the strength of the concrete should be sufficient to avoid cracks due to bearing and restrict the wrapping of elements of the sections.

3.1.1 Cement:

In this experiment 53 grade ordinary Portland cement (OPC) with brand name Birla Super was used for all concrete mixes. The cement used was fresh and without any lumps.

3.1.2Fine aggregate

Fine aggregate is natural sand which has been sieved and washed. Their particle size varies from 0.075mm to 0.425mm.

3.1.3 Coarse aggregate

The particle size of these aggregates is larger than the size of fine aggregates. The Crushed stone aggregate were collected from the local quarry. They vary from 4.75mm to 20mm. Coarse aggregate used in the experimentation was of 10 mm down size. These aggregates tend to improve the quality and bond characteristics and generally results in a higher flexural strength of concrete.

3.1.4Cold formed steel section:

These are the products made by rolling or pressing thin gauges of steel sheet. In Indian market, these are named as CR tubes also known as cold rolled. They come in 6m length and in various thickness ranging from 0.0147in. [0.373mm] to about ¼ in. [6.35mm]. In this research cross section of cold-formed steel were taken as 50 mm x 50 mm, 2.5mm thickness and 700 mm long sections and 60 mm x 40 mm, 2.5 mm thickness and 700 mm long sections and 50 mm x 25 mm, 2.5mm thickness and 700 mm long sections.

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Figure No. 3.1 Cold Form Section

- **Properties of Cold Formed Tubular section:**

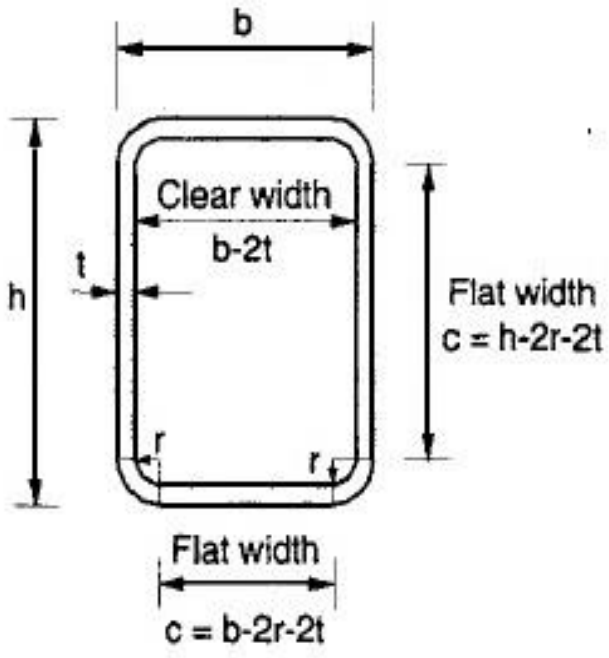


Figure no. 3.2 Cross-section of cold formed steel section

Where,

h - height of the section

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b - width of the section

t - thickness of the section

r -Radius section

Ixx and Iyy –is the moment of inertia about x and y axis

Some special characteristics associated with cold-formed tubes are listed below.

For Flexural Analysis of Beam and Buckling Analysis of Column following sections were used

Table No.1 Size of beam Sections

Sr.No.	Details	Size of Section	Length of Specimen	Type of Section
1	Section I	(60X40X3)mm	700 mm	Hollow
2		(60X40X3)mm	700 mm	PCC
3		(60X40X3)mm	700 mm	SFRC
4	Section II	(50X50X2.5)mm	700 mm	Hollow
5		(50X50X2.5)mm	700 mm	PCC
6		(50X50X2.5)mm	700 mm	SFRC
7	Section III	(25X50X2.5)mm	700 mm	Hollow
8		(25X50X2.5)mm	700 mm	PCC
9		(25X50X2.5)mm	700 mm	SFRC

Table Size of Column Sections **No.2**

Sr.No.	Details	Size of Section	Length of Specimen	Type of Section
1	Section I	(60X40X3)mm	500 mm	Hollow
2		(60X40X3)mm	500 mm	PCC
3		(60X40X3)mm	500 mm	SFRC
4	Section II	(50X50X2.5)mm	500 mm	Hollow
5		(50X50X2.5)mm	500 mm	PCC
6		(50X50X2.5)mm	500 mm	SFRC
7	Section III	(25X50X2.5)mm	500 mm	Hollow
8		(25X50X2.5)mm	500 mm	PCC
9		(25X50X2.5)mm	500 mm	SFRC

Table Properties of Cold Form Steel **No.3**

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SR.NO	PROPERTIES	VALUE
1	Modulus of elasticity, MPa	25000
2	Poisson's ratio	0.3
3	Density, kg/m3	2350

3.1.5Steel Fibres

Cold drawn steel wire fibres used to provide concrete with temperature and shrinkage crack control, enhanced flexural reinforcement, improved shear strength and increase the crack resistance of concrete. These steel macro-fibres will also improve impact, shatter and fatigue and abrasion resistance while increasing toughness of concrete.

3.1.6 Water

Ordinary potable water free from organic content, turbidity and salts was used for mixing throughout the investigation.

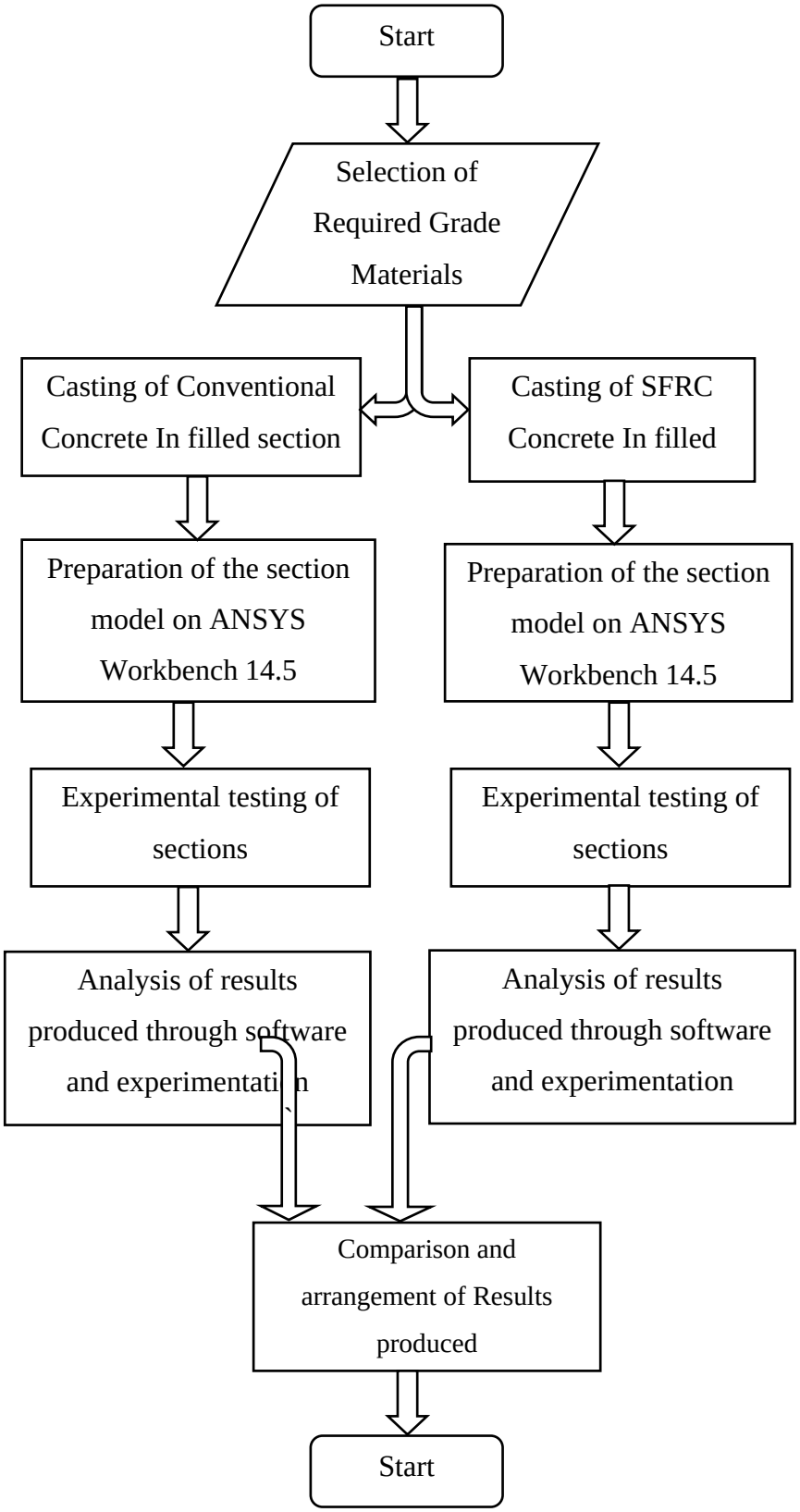
3.1.7 Polyethylene Glycol 400 (PEG 400)

Curing allows continuous hydration of cement and consequently continuous gain in the strength, once curing stops strength gain of the concrete also stops. Proper moisture conditions are critical because the hydration of the cement virtually ceases when the relative humidity within the capillaries drops below 80%. Proper curing of concrete structures is important to meet performance and durability requirements. In conventional curing this is achieved by external curing applied after mixing, placing and finishing. Self-curing or internal curing is a technique that can be used to provide additional moisture in concrete for more effective hydration of cement and reduced self-desiccation.

3.2 Flowchart

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3.3 Methodology adopted:

Experimental work includes casting of cold form steel tube by concrete with grade M25 as column sections and as beam sections. The casted Infilled cold form steel tube beam & hollow cold form tube beams along with the columns were tested on UTM. A member subjected to flexure (bending) results in bending stresses and the member undergoes deflection. Flexure test consists of subjecting a specimen beam of steel of standard size to single point load. All specimens were tested up to failure.

The column sections subjected to compression test result in compressive stresses to be induced in the sections and resulting in the buckling of the section. During the compression tests on the column sections an iron plate was inserted on the top and bottom of the section and the force was applied on the top most part of the section gradually.

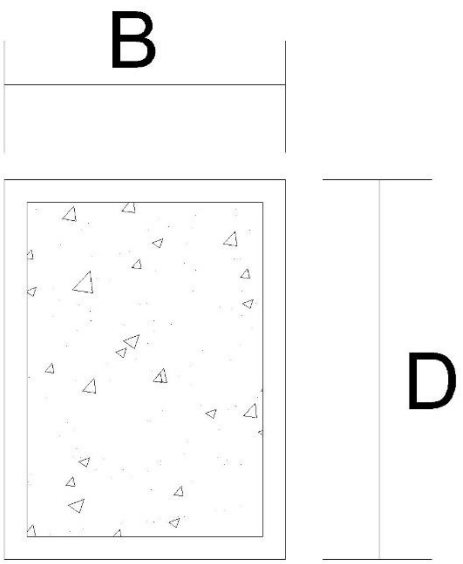


Figure No.3.3 Cross Section of Concrete Infilled Cold Formed Steel

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CHAPTER 4

EXPERIMENTATION

4.1 Requirements

The project work focuses on the primary analysis of the light cold formed concrete In-filled sections with in fill of plain cement concrete and specimen of steel fiber reinforced concrete. A total of 30 specimens were tested during the project duration.15 sections were tested under buckling analysis and were treated as columns while 15 sections were tested for their deflection as beam specimens with one-point loading system.24 sections were In-filled with concrete of which 12 sections were infilled with plain cement concrete and 12 sections were in-filled with steel fiber reinforced concrete. The same sections of the same size were analyzed in the ANSYS Workbench v14.5.

This research contains following four stages.

1. Procurement of the required materials along with the designated grades.
2. To prepare the concrete mix and test the respective specimens on the UTM and to record the results and observations.
3. To prepare models of cold formed steel infilled with concrete and in filled with steel fiber reinforced concrete and to find the flexural properties on ANSYS Workbench v14.5 software.
4. To compare the analytical results from the ANSYS software with the experimental results.

The flexural properties of cold formed steel hollow sections were analyzed by using ANSYS v14.5 software. Flexural properties like deformation, normal stress and strain were observed. During the analysis stage three cases were considered.

1. Analyzing cold form steel without any concrete infill.
2. Cold formed steel infilled with conventional plain cement concrete.
3. Cold formed steel infilled with steel fiber reinforced concrete.

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Figure.4.1 Universal Testing Machine

The test setup required for axial deformation testing of the concrete in-filled light gauge steel hollow section is shown in Figure 4.1. The steel plate with 40 mm thickness was placed over the either side of the specimen.[4]Thus, entire load is applied on the concrete core, not on the steel. To maintain the equilibrium condition, the steel plate was provided at the bottom of the column section.[4] The load will apply on the concrete core to estimate the withstand capability of the ultimate load with universal testing machine (UTM). The process was repeated for various concrete in-filled steel hollow sections with infill of conventional plain cement concrete and steel fiber reinforced concrete. The material compressive strength of the steel hollow section was obtained by having two steel plates on either side of the steel to have the uniform distribution of the forces.[4]

Thus, the load was applied on the specimen with:

1. Concrete core in the Plain Cement Concrete (PCC) in-filled column
2. Concrete core in the Steel Fiber Reinforced Cement Concrete (SFRC) in-filled column
3. Cold formed Steel.

- **ANSYS**

ANSYS is the most advanced, comprehensive and reputable finite element analysis and design software package available for the structural engineering projects. It combines the state-of-the art general purpose structural analysis features of ANSYS (ISO-9001) with high-end civil engineering-specific structural analysis capabilities of Civil FEM, making it a unique and powerful tool for a wide range of civil engineering projects. ANSYS is the finite element software used by 90 of the TOP100 engineering firms in the world with 30 years of constant growing (NASDAQ ANSS).

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- ANSYS pre, post and solving capabilities, adds more than 400 new features and specific utilities for the Civil engineering field.
- ANSYS goal is to be a technological leader and different product with unique capabilities that is able to change the construction/civil engineering design and technological process.
- It means a new culture in this industry
- Product according new/emerging advanced high-end customer needs.

4.2Test Setup:

Flexural test on PCC and SFRC concrete infilled light gauge steel beam.

- Aim: To determine the flexure strength (Modulus of rupture) of beam.
- Equipment:

  Tamping rod (weight 2 kg, 40 cm. long and shall have a running face 25 mm – sq.), Universal Testing Machine, attachment of one point-loading for UTM,

  c-clamp, spade, trowels.
- Materials:

  Cement, Fine aggregate, Coarse aggregates, water, Coldform Steel Section etc.
- Procedure:

1. Measure the materials by weight balance. Prepare concrete by taking water cement ratio 0.45, Apply oil to the inner faces of the beam mold.
2. Fill the mold with fresh concrete in layers. Stroke of tamping rod shall be well distributed.
3. Test specimens which are stored in water at a temperature of 24+- 3 shall be tested immediately on removal from water test the specimen after 3,7 and 28 days.
4. The specimen shall then be placed in the machine in such a manner that the load shall be applied to the uppermost surface of the beam. The specimen shall be supported on 38 mm dia. Roller with 600 mm span for 150 mm size specimen.
5. The load shall be applied through single roller mounted at the center point of the supporting span that is spaced at 200 mm. The loading arrangement employed for the test. The axis of the specimen shall be carefully aligned with the axis of loading device.
6. The load is applied without shock at a rate of 4 KN/minute for specimen. The load shall be increased until the specimen fails, and the maximum load applied to the specimen during the test shall be recorded.
7. If the line of rupture occurs in the center, the modulus of rupture is given by

   $fcr = PL/(bd^2)$

- Buckling test on PCC and SFRC concrete infilled light gauge steel beam:

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- Aim: To determine the buckling load of column
- Procedure: -

1. Dimension of test piece is measured at three different places along its height/length to determine the average cross-section area.
2. Ends of the specimen should be plane for that the ends are tested on a bearing plate.
3. The specimen is placed centrally between the two compression plates, such that the center of moving head is vertically above the center of specimen.
4. Load is applied on the specimen by moving the movable head.
5. Load is applied until the specimen fails.

4.3 Mix Design:

STIPULATIONS FOR PROPORTIONING

a)	Grade designation	:	M25
b)	Type of cement	:	OPC 53 grade
c)	Maximum nominal size of aggregate	:	10mm
d)	Minimum cement content	:	320 kg/m^3
e)	Maximum water-cement ratio	:	0.45
f)	Workability	:	100mm (slump)
g)	Exposure condition	:	Mild
h)	Method of concrete placing	:	By Hand
i)	Degree of supervision	:	Good
j)	Type of aggregate	:	Angular
k)	Maximum cement content	:	450 kg/m^3
l)	Self-curing agent	:	Polyethylene Glycol PEG400

TEST DATA FOR MATERIALS

a)	Cement used	:	OPC 53 grade
b)	Specific gravity of cement	:	3.15
c)	Self-curing agent	:	Polyethylene Glycol PEG400
d)	Specific gravity of :		
	1) Coarse aggregate	:	2.78
	2) Fine aggregate	:	2.66
e)	Water absorption :		

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1) Coarse aggregate : 0.5%
2) Fine aggregate : 1%

f) Free (surface) moisture :

1) Coarse aggregate : Nil
2) Fine aggregate : Nil

g) Sieve analysis :

1) Coarse aggregate : Zone III
2) Fine aggregate : Conforming to grading Zone I of Table 4 of IS 383

TARGET STRENGTH FOR MIX PROPORTIONING

$f'_{ck} = f_{ck} + 1.65\ s$

where ,

f'_{ck} = target average compressive strength at 28 days,

f_{ck} = characteristic compressive strength at 28 days, and

s = standard deviation

From Table 1,

Standard deviation, s = 4 N/mm^2

Therefore, target strength = 25 + 1.65 x 4 = 31.6 N/mm^2

SELECTION OF WATER-CEMENT RATIO

From Table 5 of IS 456,

Maximum water-cement ratio = 0.45

SELECTION OF WATER CONTENT

From Table 2,

Maximum water content = 186 liter (for 25 to 50 mm slump range)

Estimated water content for 100 mm slump = 186 + [(6/100) x 186] = 197.1 liter

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CALCULATION OF CEMENT CONTENT

Water-cement ratio = 0.45

Cement content = 197.1/0.45 = 438.1 kg/m^3

From Table 5 of IS 456,

Minimum cement content for mild exposure condition = 320 kg/m^3

438.1 kg/m^3 > 320 kg/m^3, hence OK.

PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT

From Table 3,

Volume of coarse aggregate = 0.64

Volume of fine aggregate = 1-0.64 = 0.36

MIX CALCULATIONS

The mix calculations per unit volume of concrete shall be as follows :

a) Volume of concrete = 1 m^3

b) Volume of cement = (Mass of cement)/(Specific gravity of cement) x 1/1000
= 438.1/3.15 x 1/1000
= 0.139 m^3

c) Volume of water = (Mass of water)/(Specific gravity of water) x 1/1000
= 197.1/1 x 1/1000
= 0.197 m^3

d) Volume of self-curing agent
(2 % by weight of cement) = (Mass of self-curing agent)/(Specific gravity of That agent) x 1/1000
= 0.2628/1.11 x 1/1000
= 0.00023 m^3

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e) Volume of all in aggregate = [a - (b + c + d)]

= [1 - (0.139 + 0.197 + 0.00023)]

= 0.664 m^3

f) Mass of coarse aggregate = e x volume of coarse aggregate x specific gravity of Coarse aggregate x 1000

= 0.664 x 0.64 x 2.78 x 1000

= 1182.6 kg

g) Mass of fine aggregate = e x volume of fine aggregate x specific gravity of fine aggregate x 1000

= 0.664 x 0.36 x 2.66 x 1000

= 636.7 kg

MIX PROPORTIONS

Cement = 438 kg

Water = 197.1 kg

Fine aggregate = 636.7 kg

Coarse aggregate = 1182.6 kg

Self-curing agent = 0.2628 kg

Water-cement ratio = 0.45

Table No.4 Mix design for conventional concrete of grade M25

Proportion	Water (Kg)	Cement (Kg)	Fine agg. (Kg)	Coarse agg. (Kg)
Per m^3	197.1	438	636.7	1182.6
Ratio	0.45	1	1.45	2.7

Table No.5 Mix design for different percentage replacements for SFRC

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%	Water (Kg)	Cement (Kg)	Fine agg. (Kg)	Coarse agg. (Kg)	SFRC (Kg)	PEG 400 (Kg)
2	197.1	438	636.7	1182.6	8.76	0.263

Table No.6 Properties of Concrete Mix

SR.NO	PROPERTIES	VALUE
1	Grade of concrete	M25
2	Specific gravity of cement	3.15
3	Specific gravity of fine aggregate	2.66
4	Specific gravity coarse aggregate	2.78

4.4 Procedure:

- **Casting of Cold Form Steel Tube:**

A plastic cover was provided on one side of the sections to support the wet concrete. The cold form steel rectangular tube having yield stress (F_y) 280 N/mm^2 taken from IS 1079:1973. The concrete was casted vertically into the steel hollow section in three layers in single batch to achieve consistency in the results. One batch was casted for the PCC infilled sections and second batch for the SFRC infilled sections. Each layer was compacted by a table vibrator & tamping was done by steel rod. The specimen was placed in cool place without any interruption and since PEG 400 was used as self-curing agent internal curing was achieved and there was no need for external curing of the sections.

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Figure No. 4.2 Weighing of Material



Figure No. 4.3 Casting Material

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Figure No. 4.4 Dry Mixing

4.5 Curing:

Curing allows continuous hydration of cement and consequently continuous gain in the strength, once curing stops strength gain of the concrete also stops. Proper moisture conditions are critical because the hydration of the cement virtually ceases when the relative humidity within the capillaries drops below 80%.[6]Proper curing of concrete structures is important to meet performance and durability requirements. In conventional curing this is achieved by external curing applied after mixing, placing and finishing. Self-curing or internal curing is a technique that can be used to provide additional moisture in concrete for more effective hydration of cement and reduced self-desiccation[8].

4.6 Experimental Testing:

The cold form infilled and hollow specimen of length 500mm and 700mm and of cross sectional areas 60x40mm,50x50mm,25x50mm were simply supported on universal testing machine. Similarly, hollow and infilled beam of length 700mm and hollow and infilled column of length 500mm designed for same loading was simply supported on universal testing machine. A gradually load and a hydraulic jack were fixed on the frame to apply the force onto the test specimen. Flexural tests were carried out on 12 concrete filled steel composite beams, of M25 grade respectively and three hollow cold form steel beams. And similarly, for buckling testing 12 concrete in-filled steel column were used as well as six hollow cold form steel columns respectively. Deflection measured at the mid span of the specimen by universal testing machine directly by using digital gauges. The test set-up and instruments of the beam and column specimens as follows in figure 4.6

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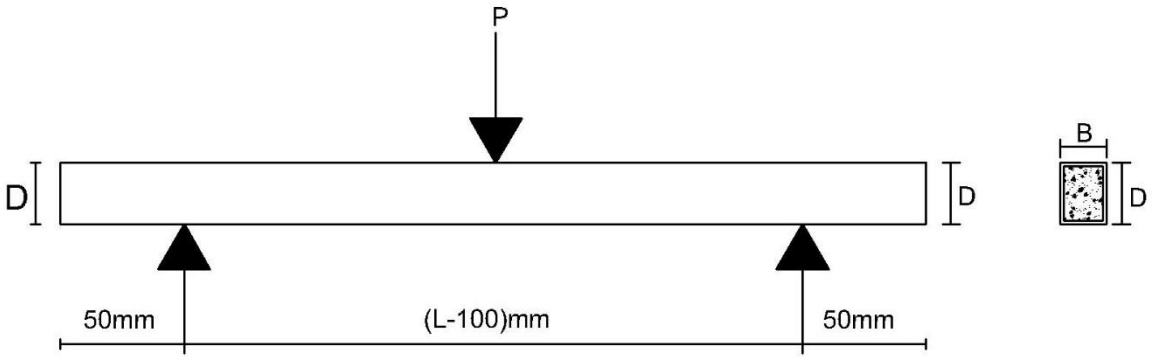


Figure No. 4.5 Loading Diagram of Beam Section



Figure No. 4.6 Testing of Beam Section On UTM

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Figure No. 4.7 Deflected Beam Section after Testing

A member subjected to flexure (bending) results in bending stresses and the member undergoes deflection. Flexure test consists of subjecting a specimen beam of steel of standard size to single point loads. The middle portion of the beam will have been subjected to pure bending (i.e. constant B.M. and zero S.F.). Both the cold form hollow & in-filled beam specimens are tested up to failure and deflections at the mid span recorded at frequent intervals. This experimental study was able to determine not only the maximum moment capacity of the specimens, but also to investigate the failure pattern up to and beyond the ultimate load.

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Figure No. 4.8 Testing of column section under UTM



Figure No. 4.9 Deflected column section after testing

4.7 Analytical Testing:

For beam section of size 25x50x700 the analysis was carried as shown below:

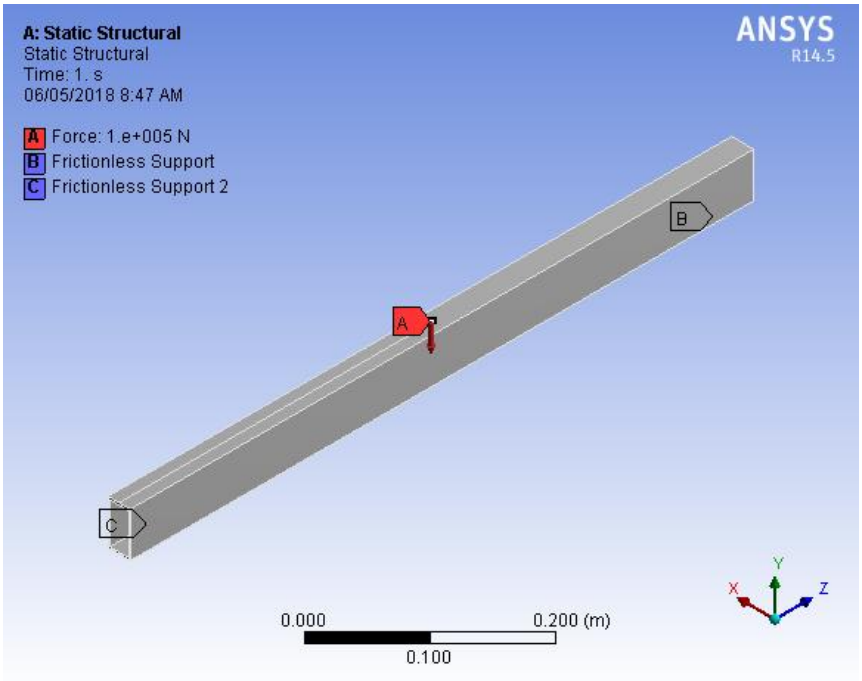


Figure No.4.10 Cold formed Steel beam of size 25x50x700 on ANSYS software

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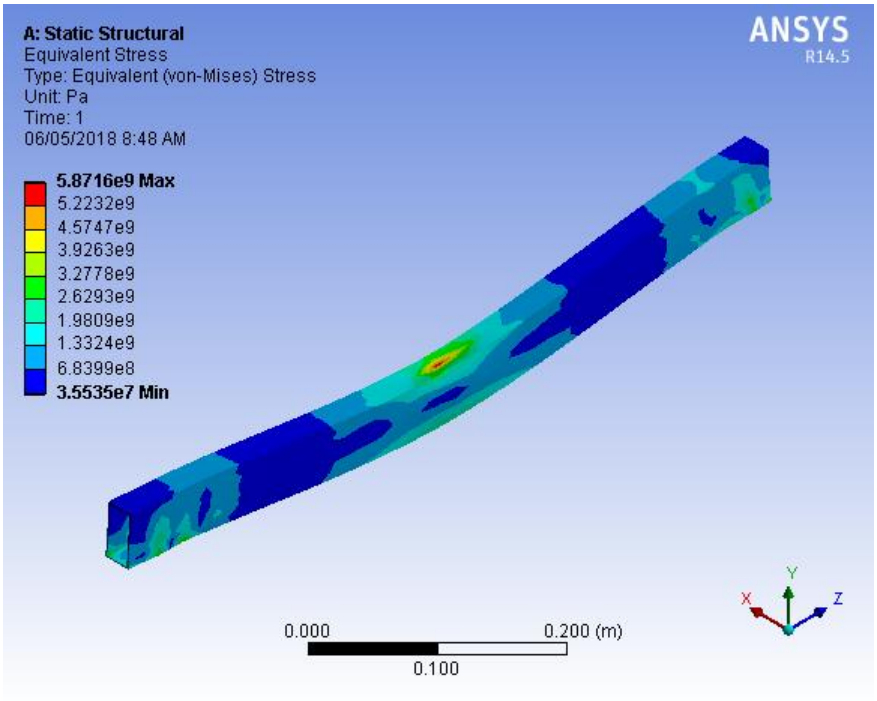


Figure No.4.11 Stress Diagram of Cold Formed Steel Beam of size 25x50x700on ANSYS Software

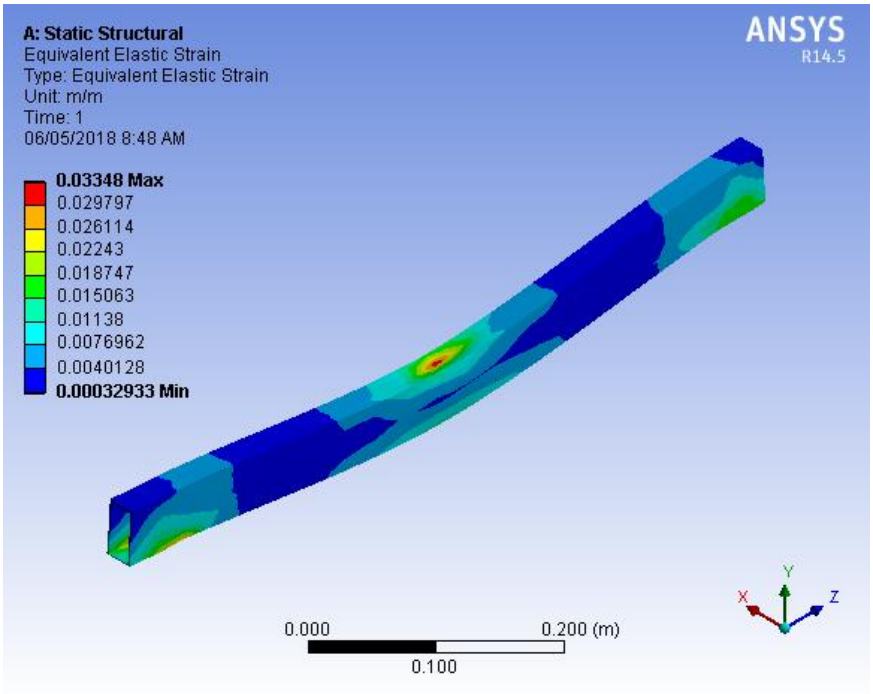


Figure No.4.12 Strain Diagram of Cold Formed Steel Beam of size 25x50x700on ANSYS Software

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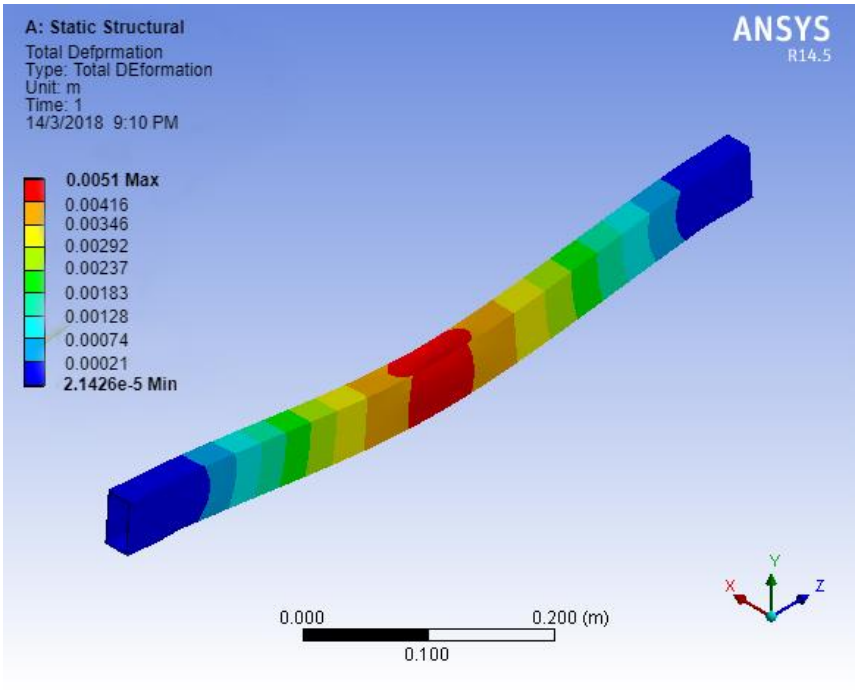


Figure No.4.13 Deflection Diagram of Cold Formed Steel Beam of size 25x50x700on ANSYS Software

For the square beam section of size 50x50x700 analysis using ANSYS was carried out as shown in fig

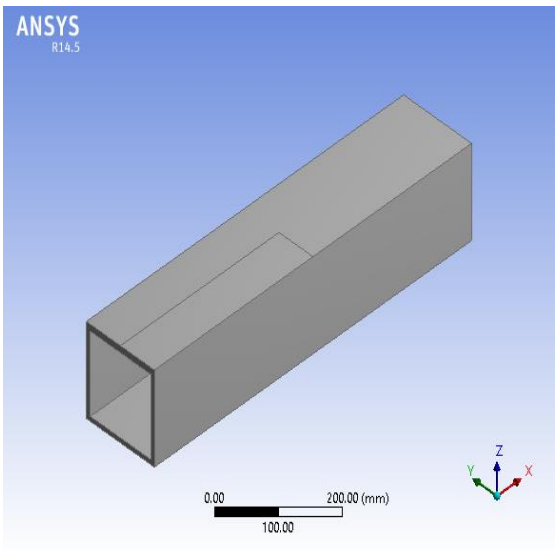


Figure No. 4.14 Cold formed Steel beam Of size 50x50x700 on ANSYS software

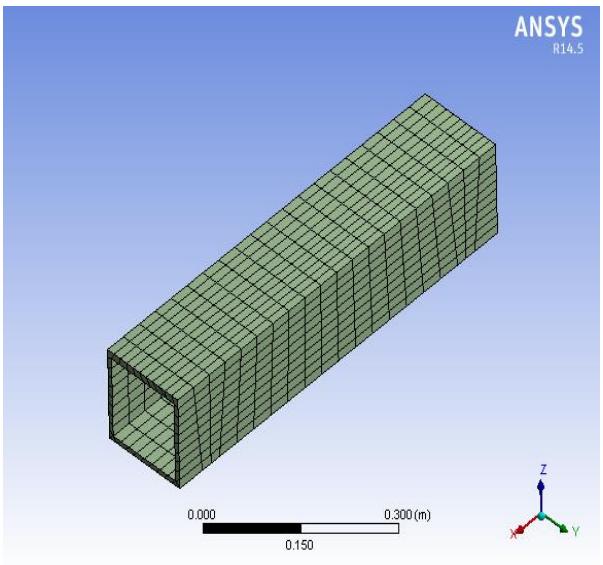


Figure No. 4.15 Meshing of Cold formed steel Beam of size 50x50x700 ANSYS Software

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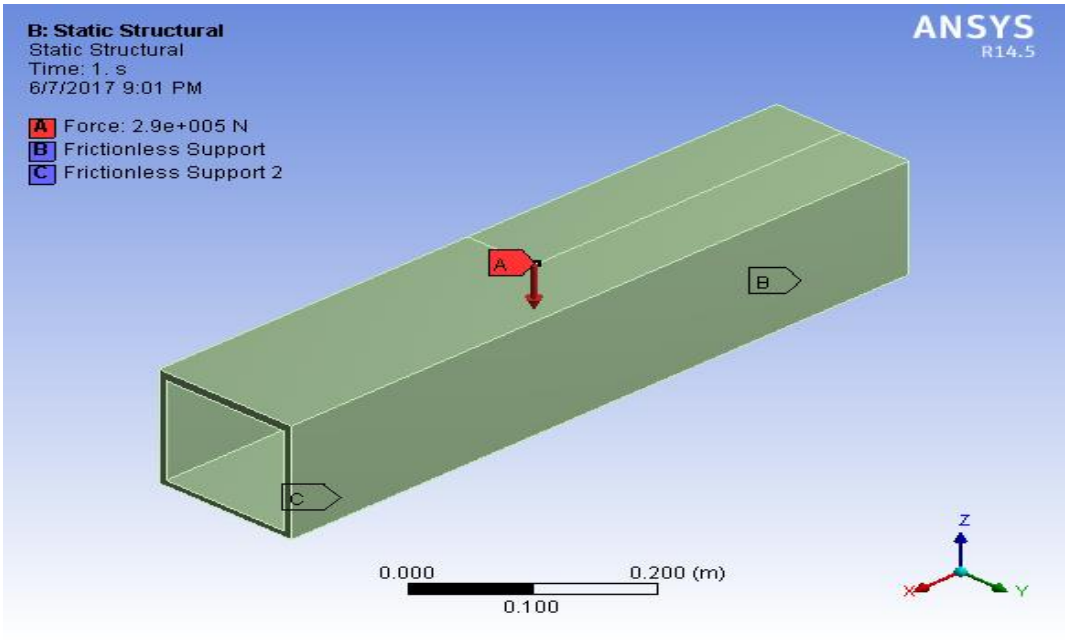


Figure No. 4.16 3D Loading Diagram of Cold Formed Steel Beam of size 50x50x700on ANSYS Software

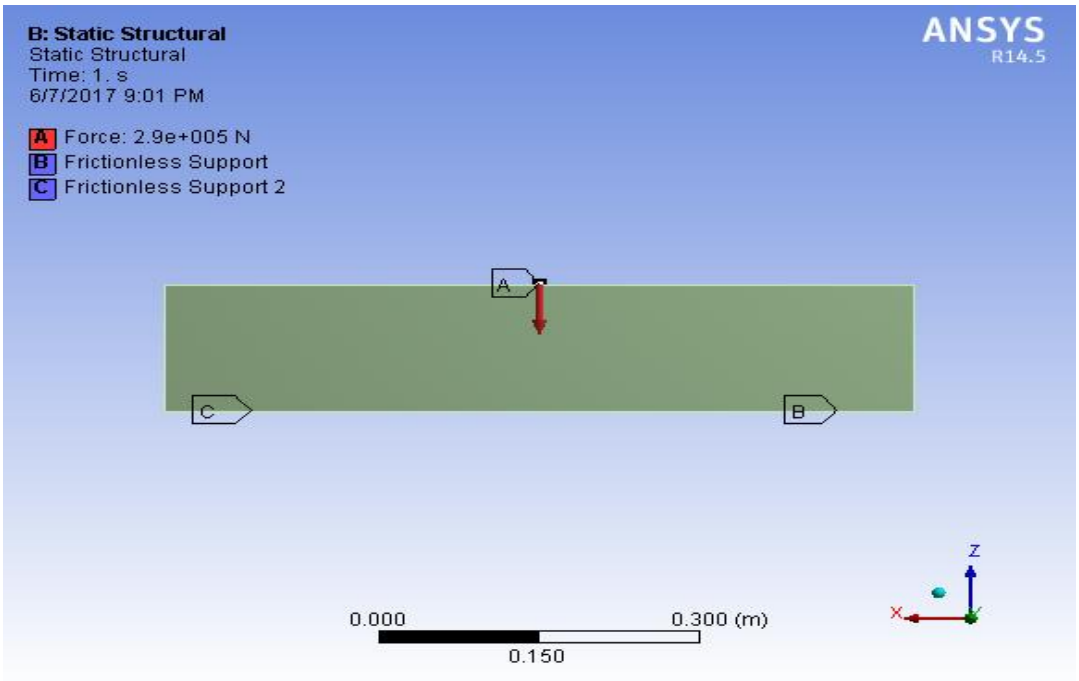


Figure No. 4.17 2D Loading Diagram of Cold Formed Steel Beam of size 50x50x700on ANSYS Software

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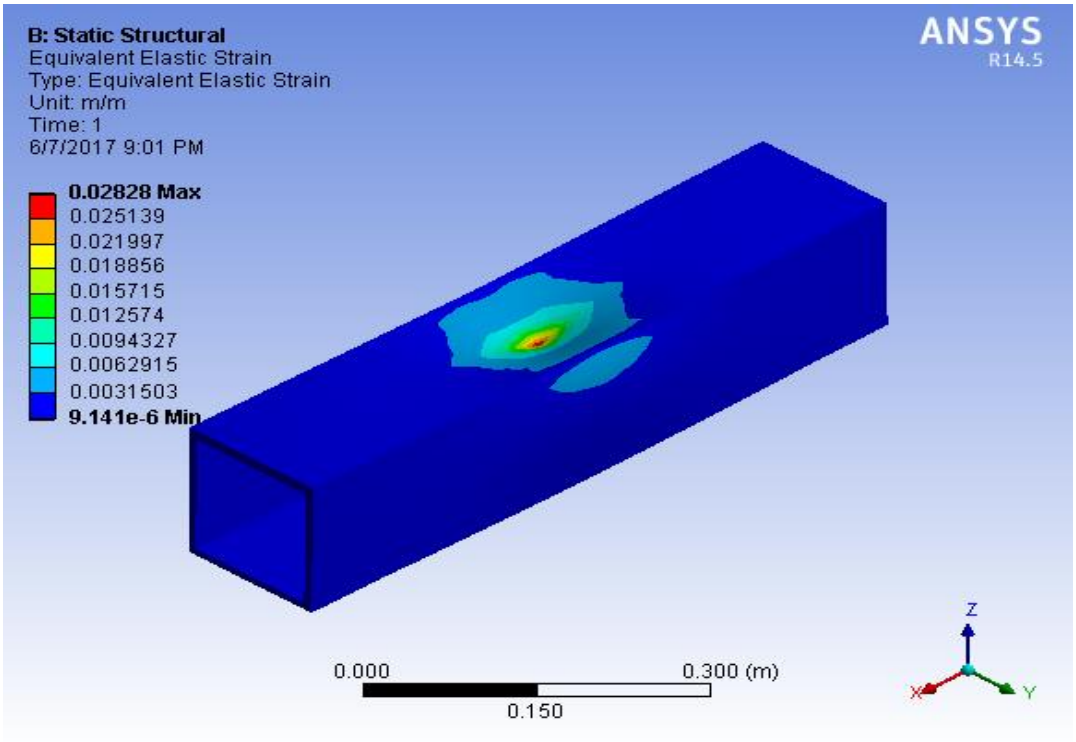


Figure No. 4.18 Strain Diagram of Cold Formed Steel Beam of size 50x50x700on ANSYS Software

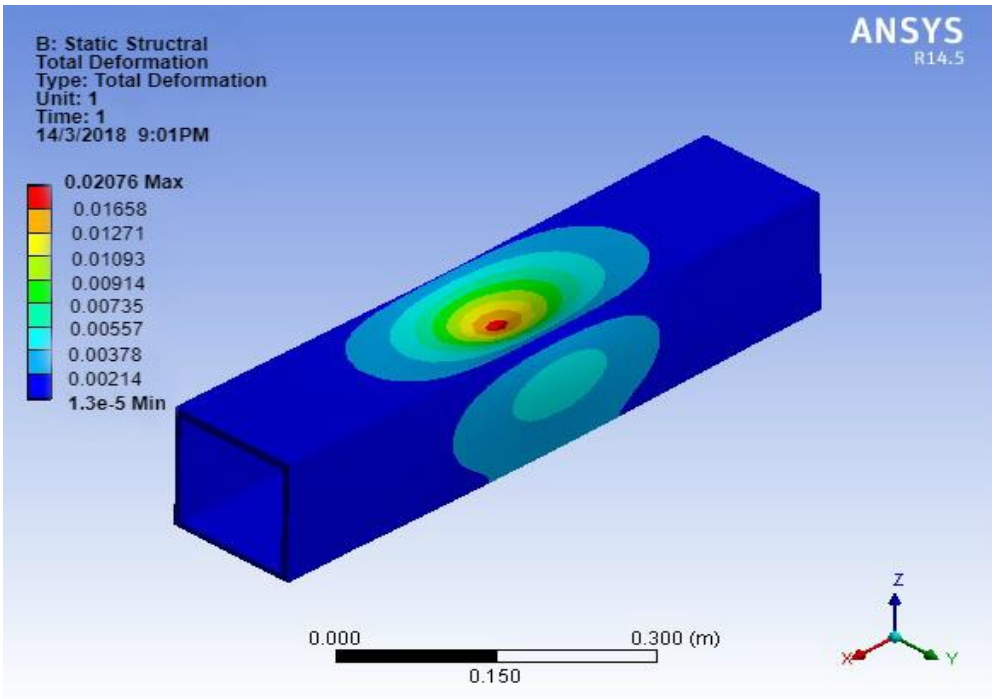


Figure No. 4.19 Deflection Diagram of Cold Formed Steel Beam of size 50x50x700on ANSYS Software.

For the rectangular beam section of size 60x40x700mm the analytical results are:

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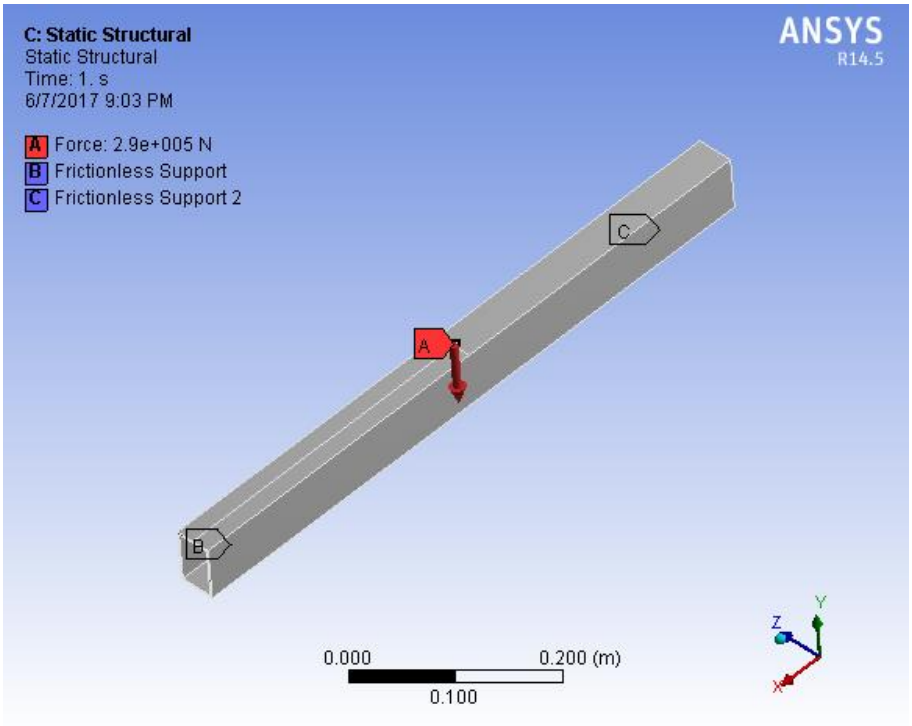


Figure No. 4.20 3D Loading Diagram of Cold Formed Steel Beam of size 60x40x700on ANSYS Software

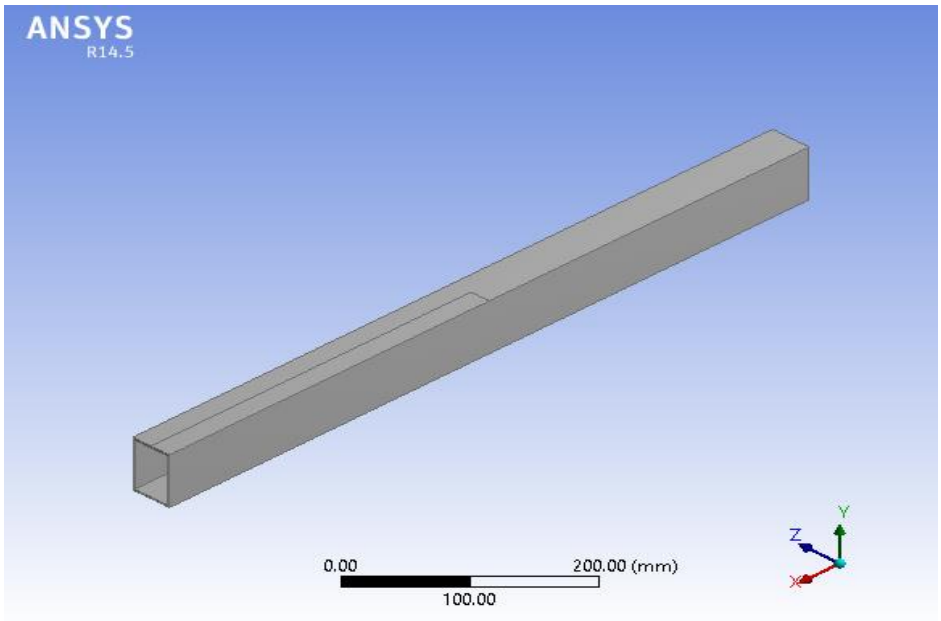


Figure No. 4.21 2D Loading Diagram of Cold Formed Steel Beam of size 60x40x700on ANSYS Software

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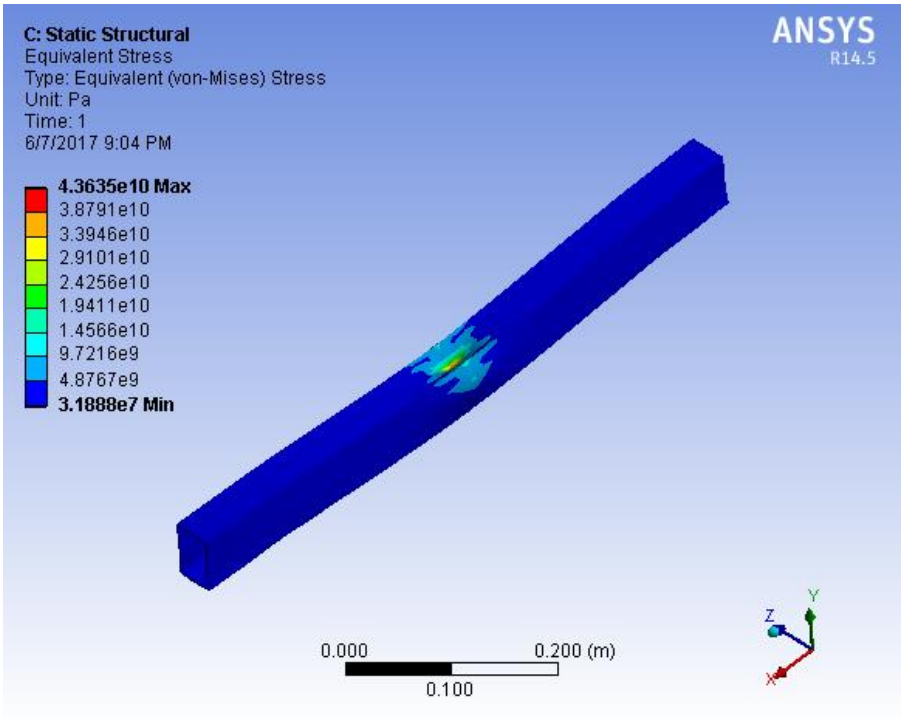


Figure No. 4.22 Stress Diagram of Cold Formed Steel Beam of size 60x40x700on ANSYS Software

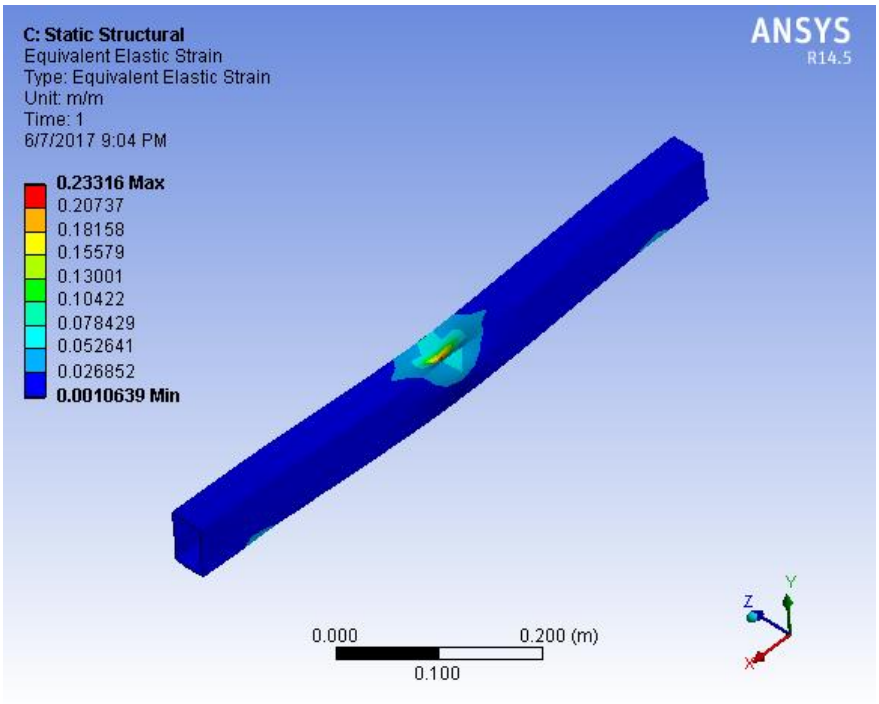


Figure No. 4.23 Strain Diagram of Cold Formed Steel Beam of size 60x40x700on ANSYS Software

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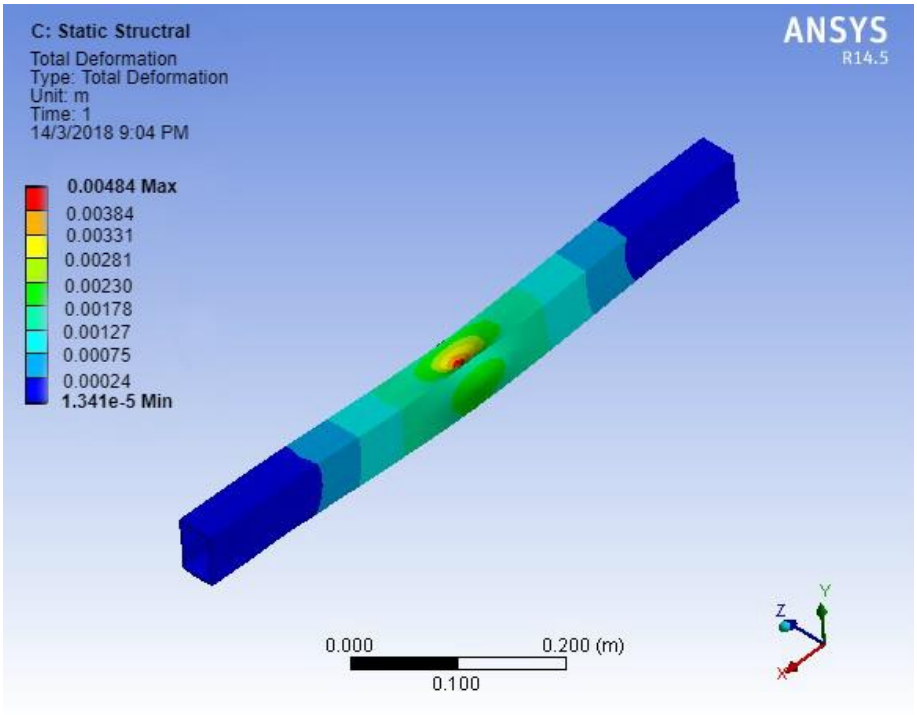


Figure No. 4.24 Deflection Diagram of Cold Formed Steel Beam of size 60x40x700on ANSYS Software

For the column section the analysis of sections was carried out as below:

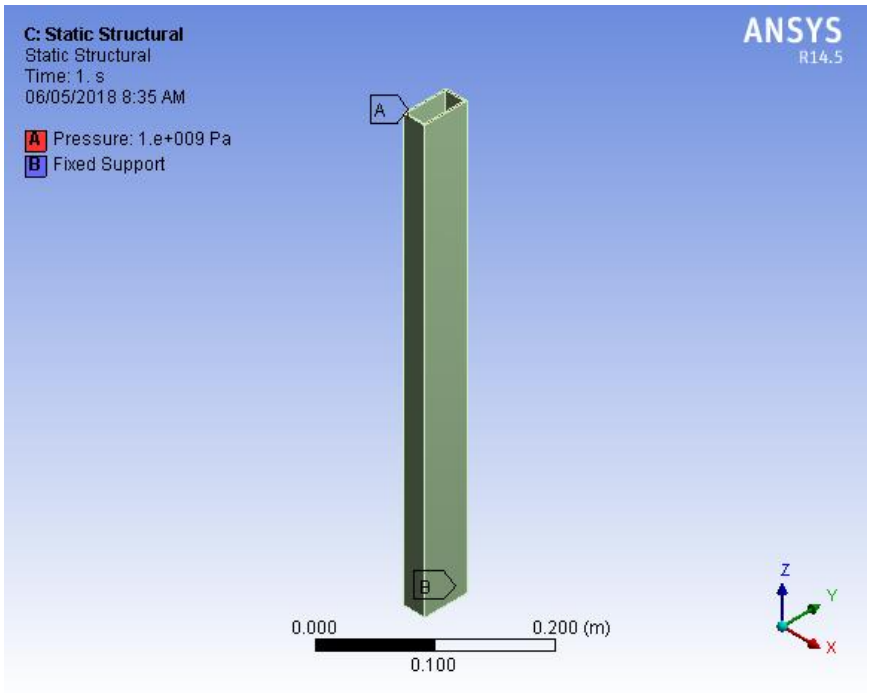


Figure No. 4.25 3D Loading Diagram of Cold Formed Steel Column of size 25x50x500on ANSYS Software

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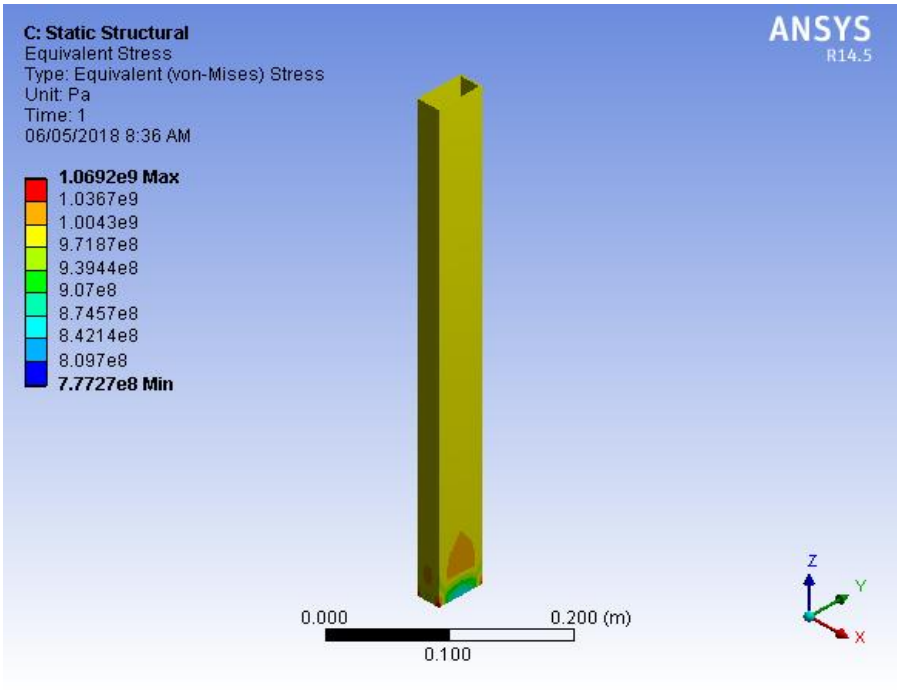


Figure No. 4.26 Stress Diagram of Cold Formed Steel Column of size 25x50x500on ANSYS Software

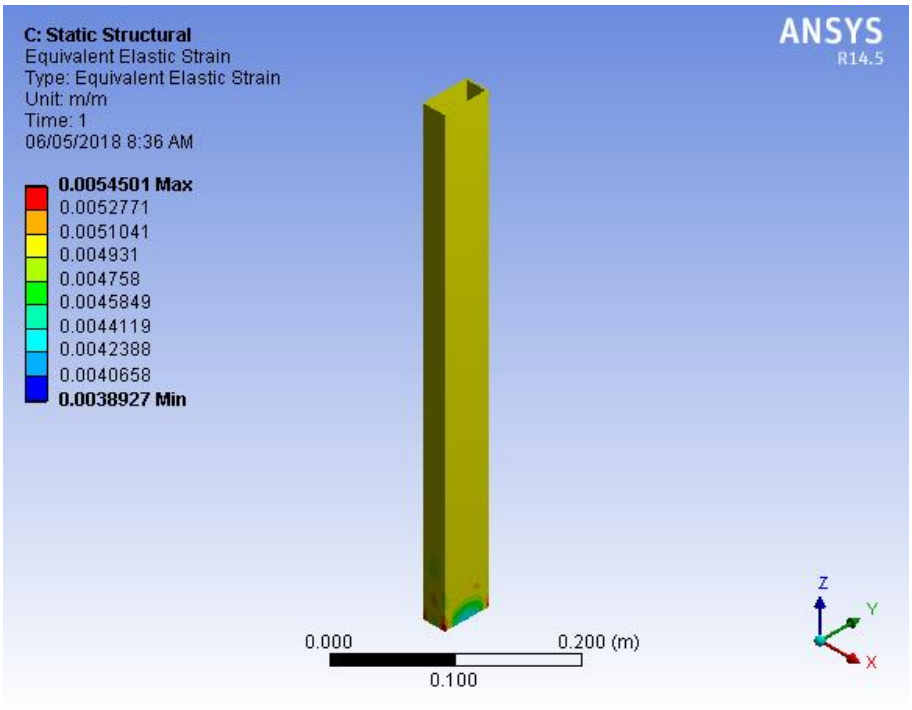


Figure No. 4.27 Strain Diagram of Cold Formed Steel Column of size 25x50x500on ANSYS Software

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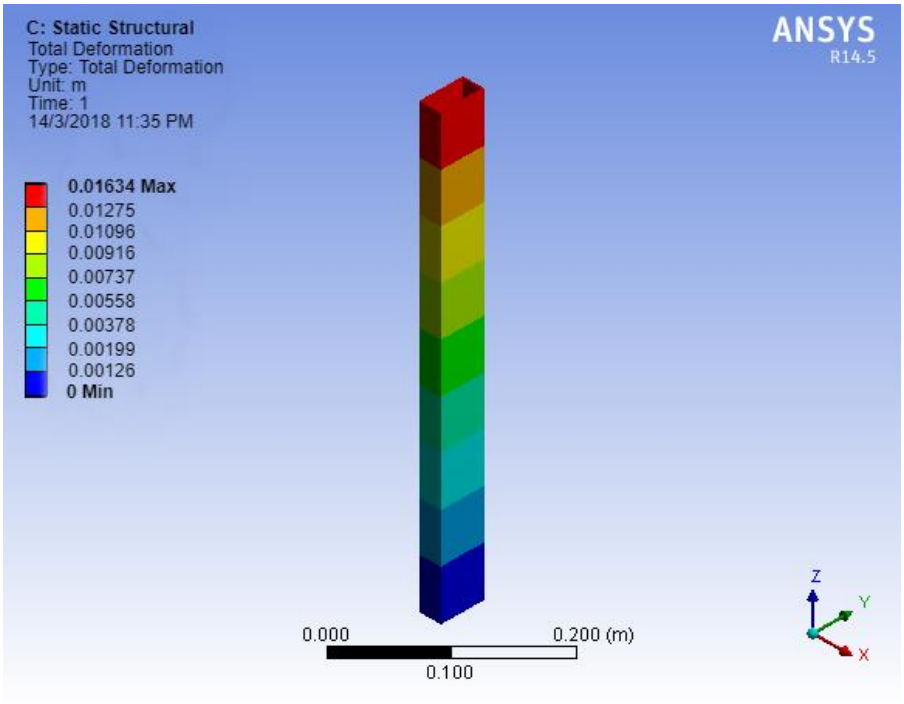


Figure No. 4.28 Deformation Diagram of Cold Formed Steel Column of size 25x50x500on ANSYS Software

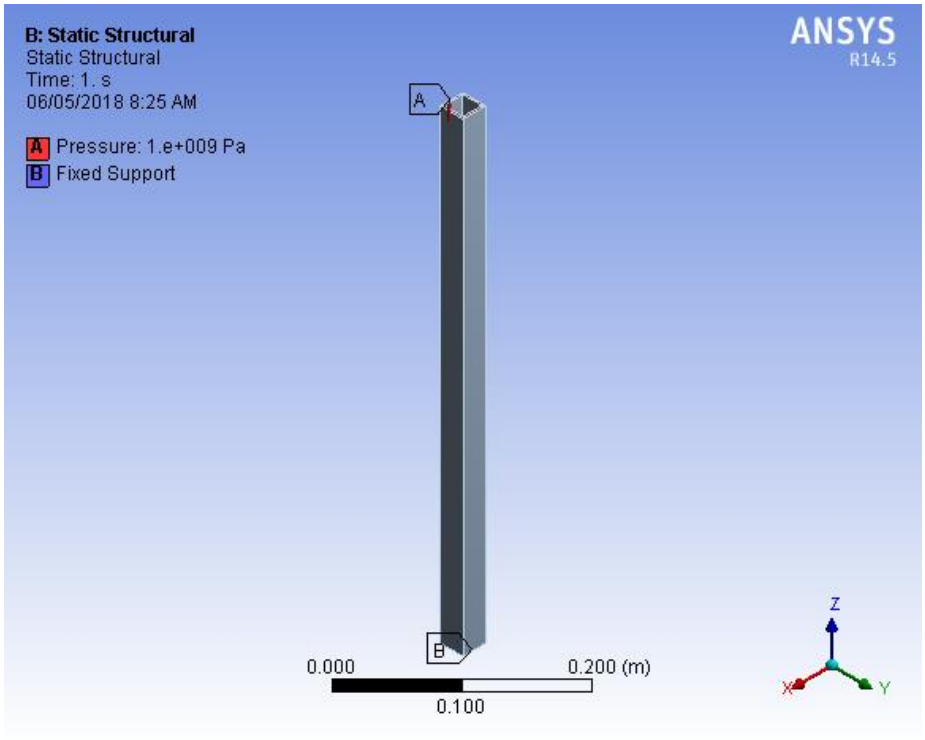


Figure No. 4.29 3D Loading Diagram of Cold Formed Steel Column of size 50x50x500on ANSYS Software

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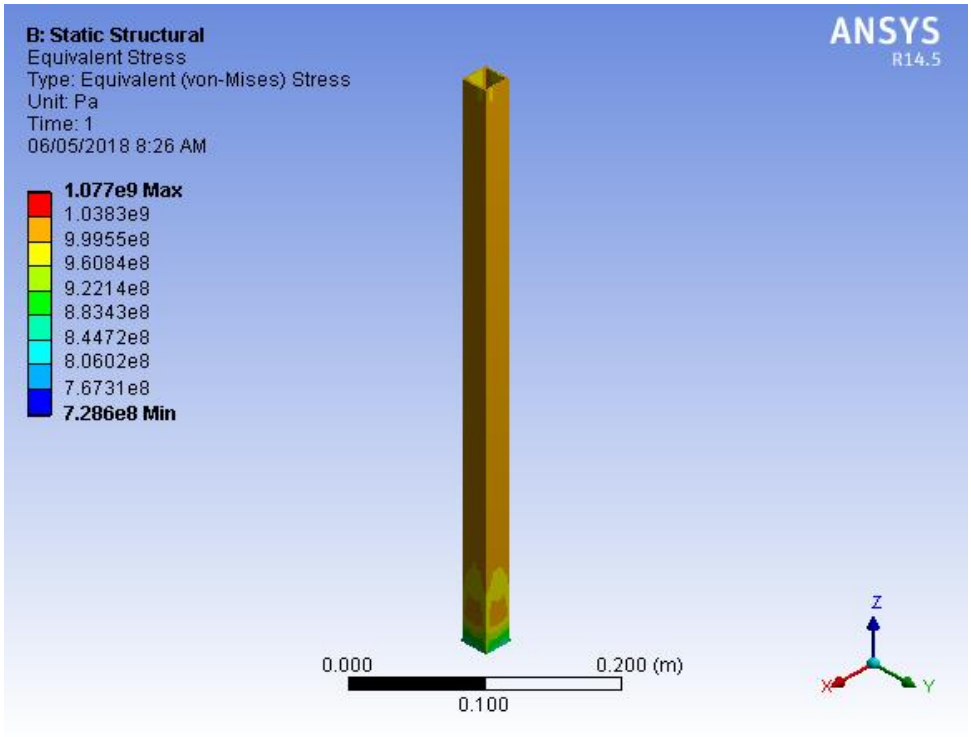


Figure No. 4.30 Stress Diagram of Cold Formed Steel Column of size 50x50x500on ANSYS Software

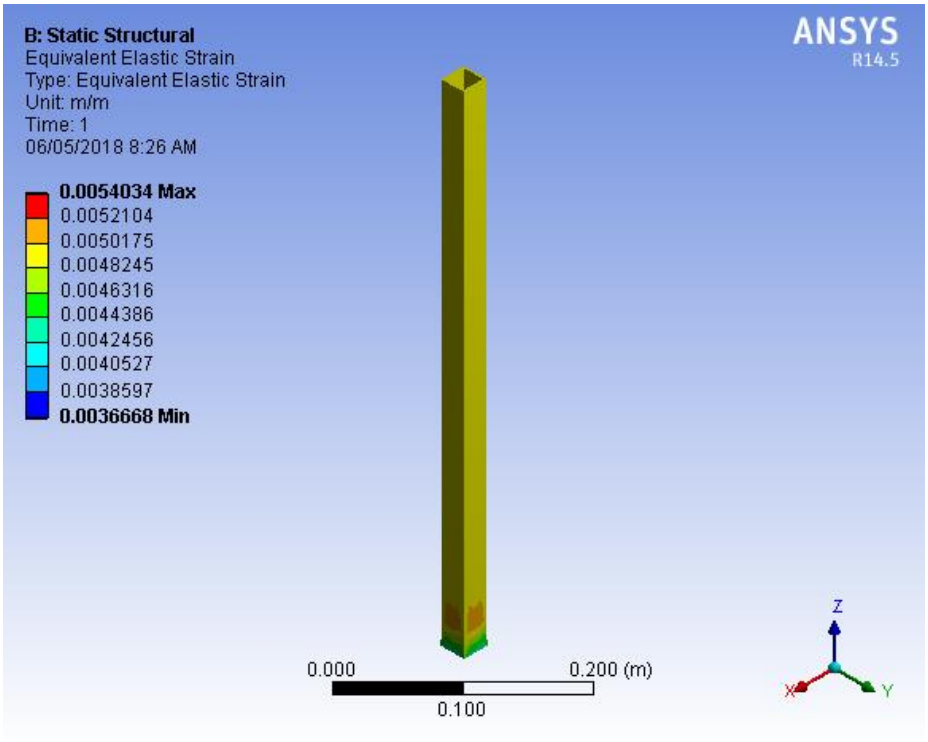


Figure No. 4.31 Strain Diagram of Cold Formed Steel Column of size 50x50x500on ANSYS Software

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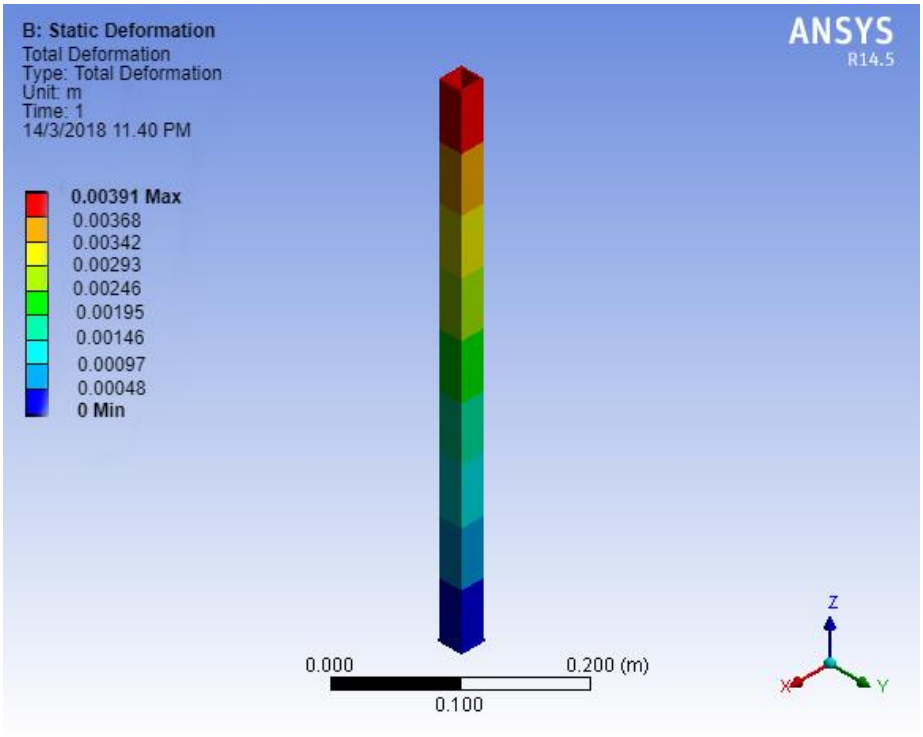


Figure No. 4.32 Deformation Diagram of Cold Formed Steel Column of size 50x50x500on ANSYS Software

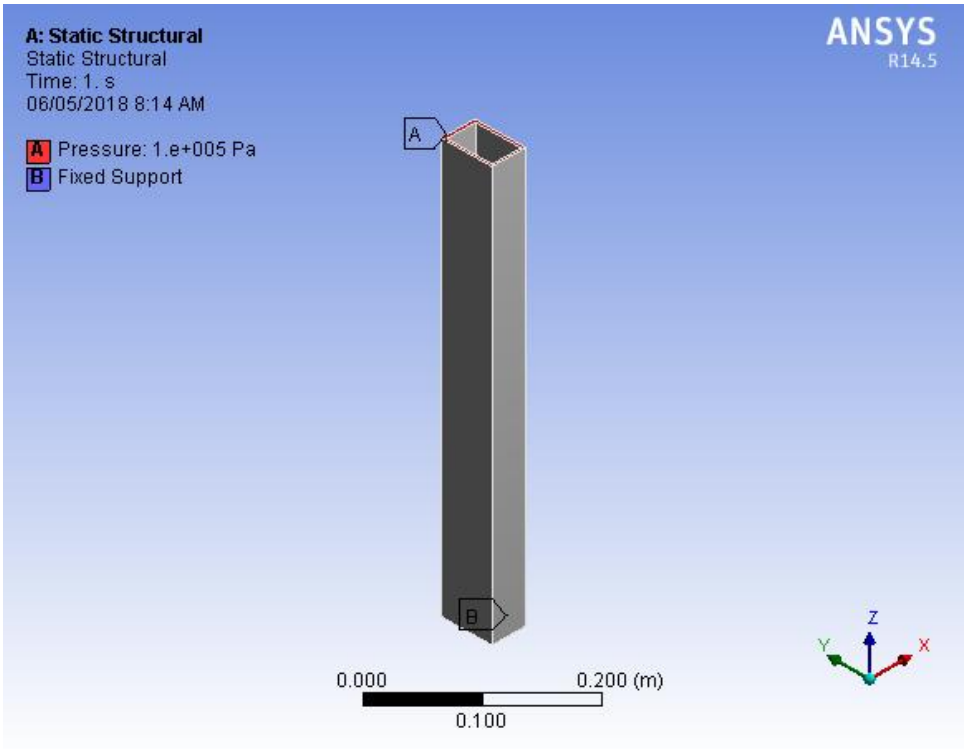


Figure No. 4.33 3D Loading Diagram of Cold Formed Steel Column of size 60x40x500on ANSYS Software

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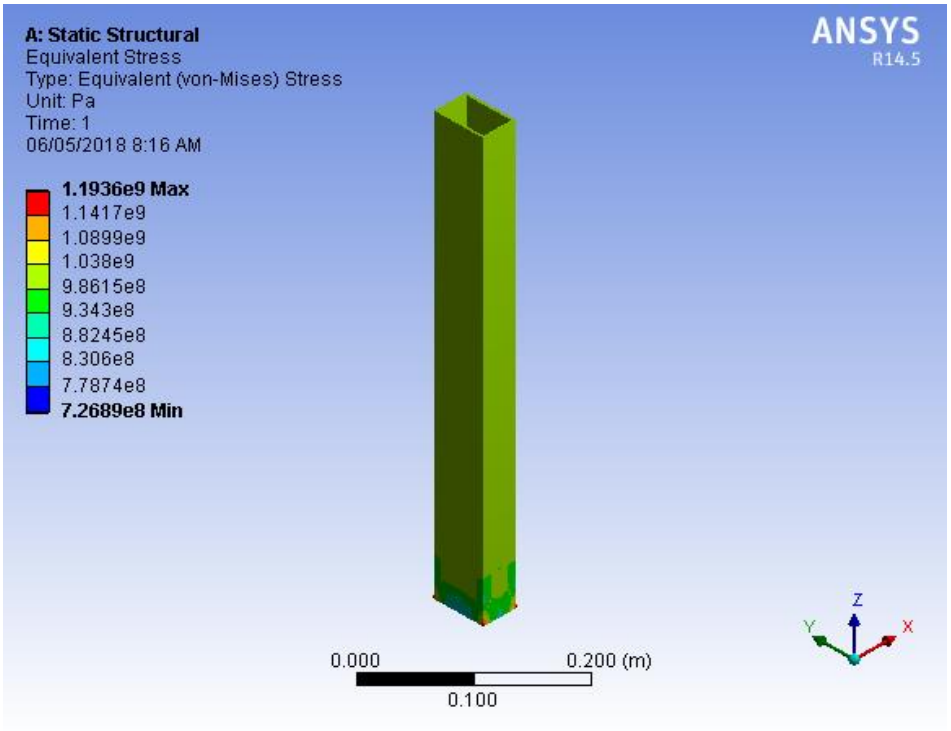


Figure No. 4.34 Stress Diagram of Cold Formed Steel Column of size 60x40x500on ANSYS Software

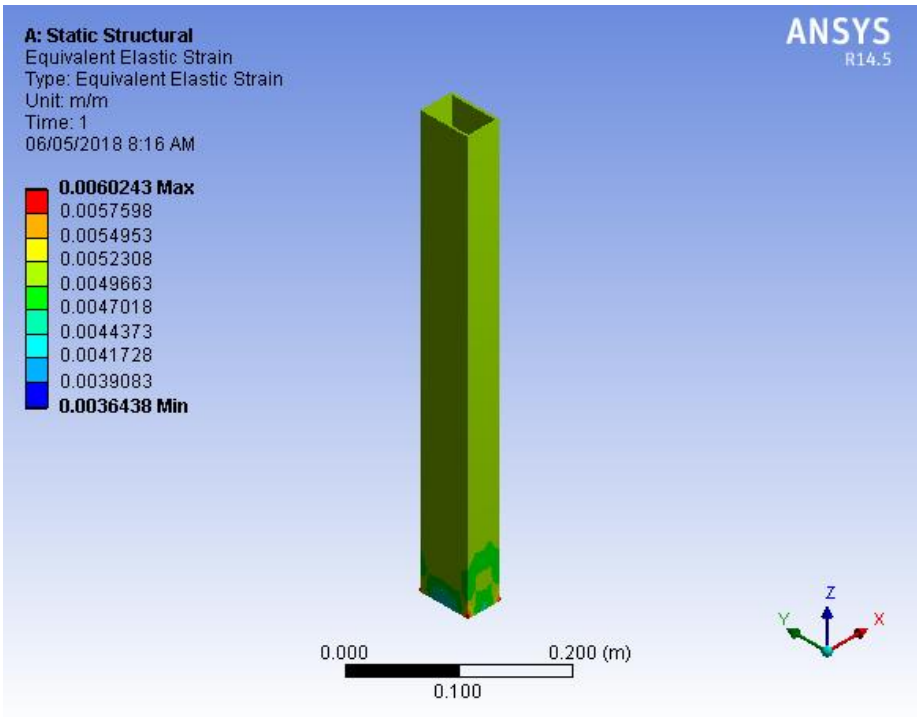


Figure No. 4.35 Strain Diagram of Cold Formed Steel Column of size 60x40x500on ANSYS Software

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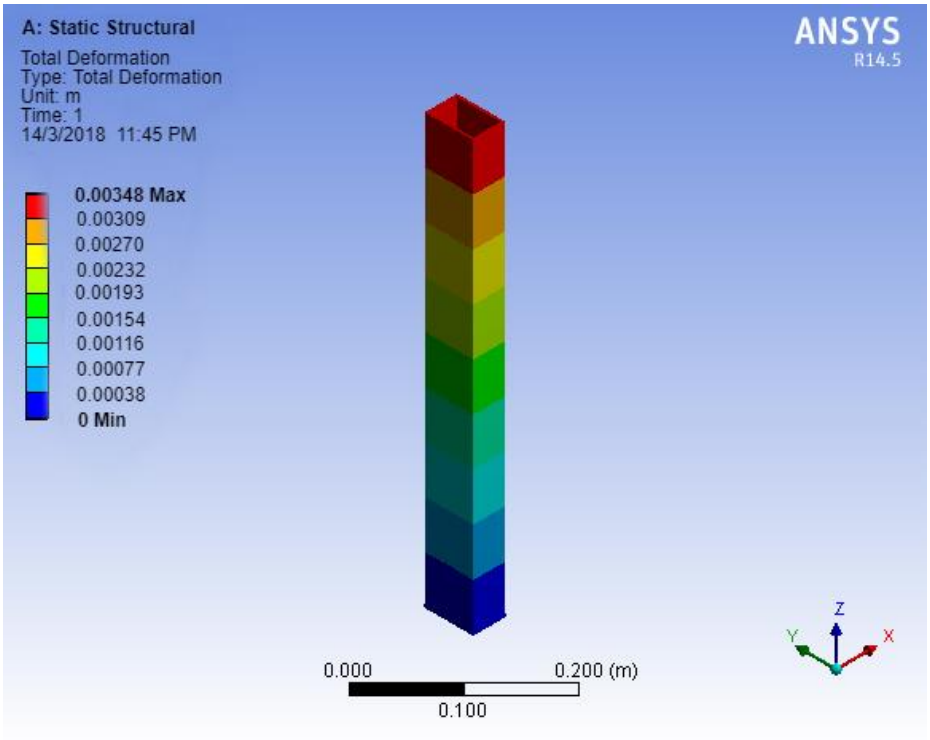


Figure No. 4.36 Deformation Diagram of Cold Formed Steel Column of size 60x40x500on ANSYS Software

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CHAPTER 5

RESULT AND DISCUSSION

5.1 General

After the analysis of the sections in the period during the project work we could attain efficient and economical load carrying capacity for the concrete infilled sections experimentally and test the hollow beam and column sections for analytical testing and compare the results of both the methods with the help of graph. Some permissible errors of calculations, casting, testing and other errors were observed while comparing the experimental results with the analytical results up to 15%. Testing results attained and the graphical values along with the equations for the line of regression are explained in this chapter.

5.2 Test Parameters

5.2.1 Flexural Parameters for Beam Sections

After 7 days the results obtained are as follows:

Table no.7: 7 Days Results for Beam Section 25x50x700 mm

Size of Section: 25x50x700			
Type of Section	**Size of Section**	**Total Load Carried by Section**	**Deflection**
Hollow	25x50x700	28.05	6
PCC	25x50x700	22.05	9.9
SFRC	25x50x700	32.6	10.6

After 28 days the results obtained are as follows:

Table no.8 28 Days Results for Beam Section 25x50x700 mm

Size of Sections: 25x50x700			
Type of Section	**Size of Section**	**Total Load Carried by Section**	**Deflection**
Hollow	25x50x700	28.05	6
PCC	25x50x700	34.4	9.1
SFRC	25x50x700	33.65	8.8

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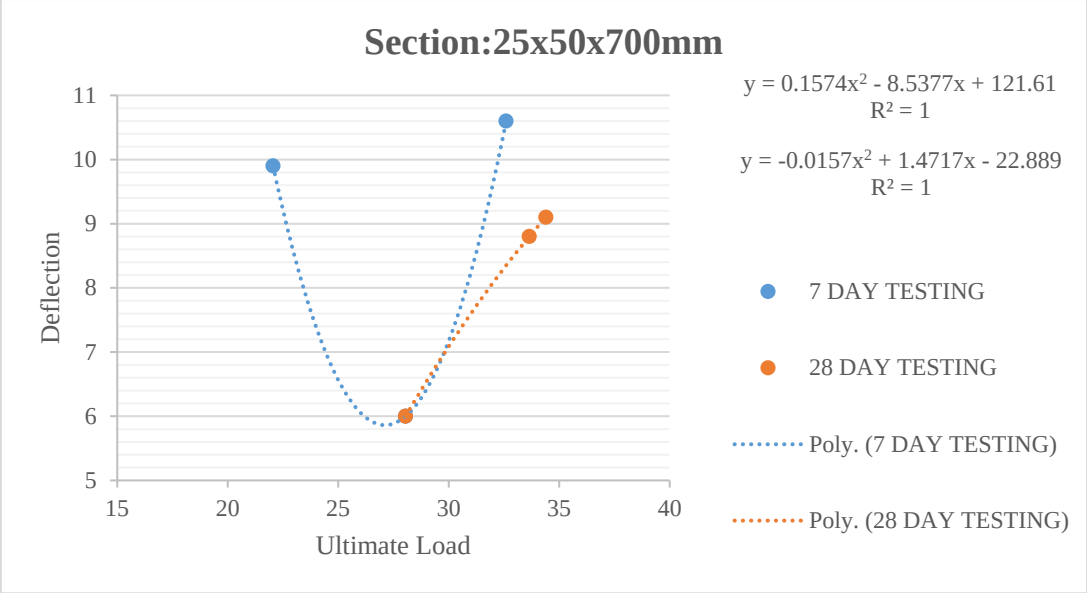


Figure No.4.38 Graph of Beam section of size 25x50x700 mm

For the 25x50x700mm section it was observed that the load carrying capacity after 28 days for SFRC section was decreased2.18 % of PCC section and from the observations, load carrying capacity of PCC section was achieved to be greater than SFRC section. Hence PCC section is efficient as composite beam section.

For section 50x50x700,after 7 days the results obtained are as follows:

Size of Sections: 50x50x700			
Type of Section	**Size of Section**	**Total Load Carried by Section**	**Deflection**
Hollow	50x50x700	32.9	23.9
PCC	50x50x700	43.3	11.6
SFRC	50x50x700	42.5	16.3

Table No.9 7 Days Results for Beam Section 50x50x700 mm

After 28 days the results obtained are as follows:

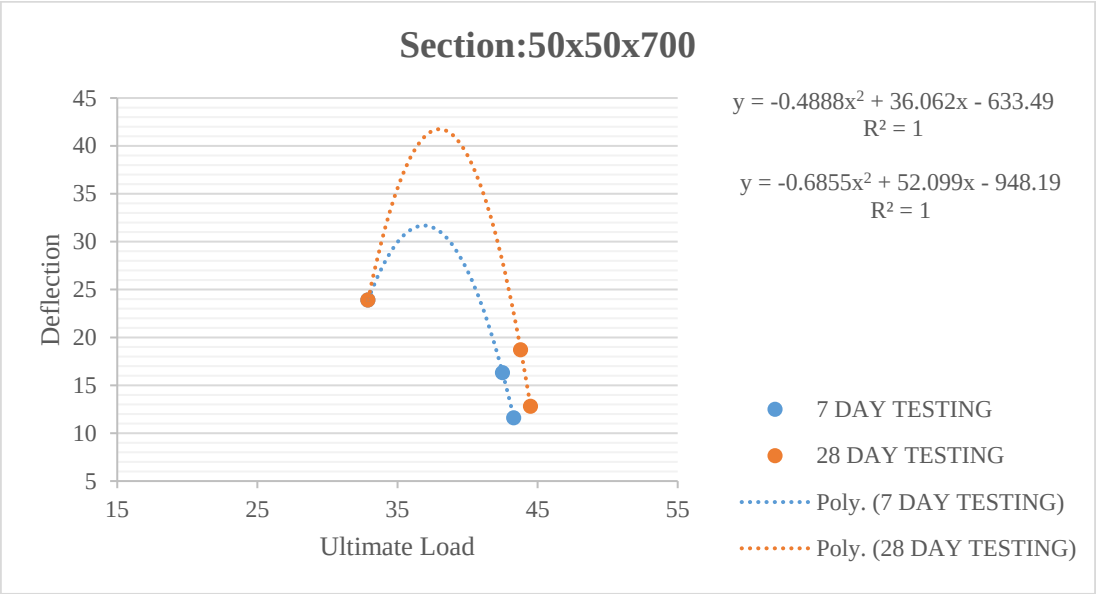
Table No.10 28 Days Results for Beam Section 50x50x700 mm

Size of Sections: 50x50x700			
Type of	**Size of Section**	**Total Load**	**Deflection**

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Section		Carried by Section	
Hollow	50x50x700	32.9	23.9
PCC	50x50x700	43.8	18.7
SFRC	50x50x700	44.5	12.8



FigureNo.4.39 Graph of Beam section of size 50x50x700 mm

For the 50x50x700 mm section it was observed that the load carrying capacity after 28 days for SFRC section was increased by 1.57 % of PCC section. Here, load carrying capacity of SFRC section is greater than PCC section and deflection of SFRC section is less than PCC section. Therefore, SFRC section is economical and efficient to use.

After 7 days the results obtained are as follows:

Table No.11 7 Days Results for Beam Section 50x50x700 mm

Size of Sections: 60x40x700			
Type of Section	**Size of Section**	**Total Load Carried by Section**	**Deflection**
Hollow	60x40x700	38.3	5.5
PCC	60x40x700	37.5	11.8
SFRC	60x40x700	43.5	14

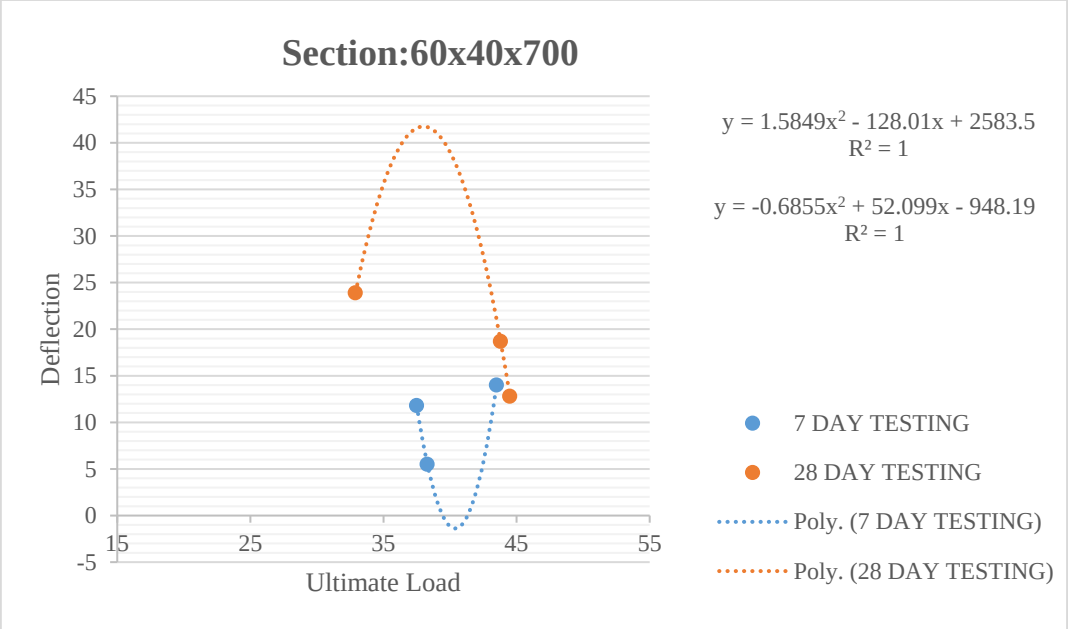
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After 28 days the results obtained are as follows:

Table No.1228 Days Results for Beam Section 50x50x700 mm

Size of Sections: 60x40x700			
Type of Section	**Size of Section**	**Total Load Carried by Section**	**Deflection**
Hollow	60x40x700	38.3	5.5
PCC	60x40x700	51.55	15.7
SFRC	60x40x700	48.15	10.7



FigureNo.4.40 Graph of Beam section of size 60x40x700 mm

For the 60x40x700mm section it was observed that the load carrying capacity after 28 days for SFRC section decreased by 6.59 % of PCC section, as the load carrying capacity of PCC section is more than SFRC section, PCC section is efficient to use.

5.2.2 Compressive Test Parameters for Column Sections

After 7 days the results obtained are as follows:

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Table No.137 Days Results for Column Section 25x50x500 mm

Size of Section: 25x50x500			
Type of Section	**Size of Section**	**Total Load Carried by Section**	**Deflection**
Hollow	25x50x500	100.25	19
PCC	25x50x500	123.75	2.9
SFRC	25x50x500	121.4	5.4

After 28 days the results obtained are as follows:

Table No. 14 28 Days Results for Column Section 25x50x500 mm

Size of Sections: 25x50x500			
Type of Section	**Size of Section**	**Total Load Carried by Section**	**Deflection**
Hollow	25x50x500	100.25	19
PCC	25x50x500	124.4	8
FRC	25x50x500	122.15	6.7

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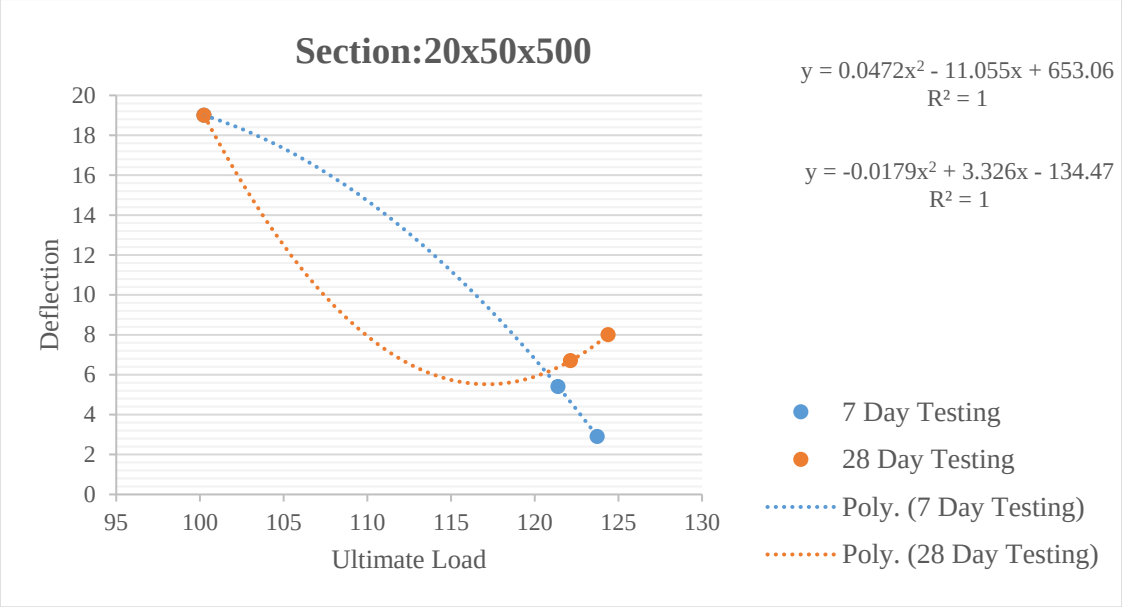


Figure No.4.41 Graph of Column section of size 25x50x700 mm

For the 25X50X500mm column section it was observed that the load carrying capacity after 28 days for SFRC section decreased by 1.84% of PCC section. From the above results, load carrying capacity of PCC section is observed to be greater than SFRC section. Thus, PCC section is more efficient to use.

After 7 days the results obtained are as follows:

Table No. 15 7 Days Results for Column Section 25x50x500 mm

Size of Sections: 50x50x500			
Type of Section	**Size of Section**	**Total Load Carried by Section**	**Deflection**
Hollow	50x50x500	142.75	4.5
PCC	50x50x500	234.5	6.9
SFRC	50x50x500	228.2	6.7

After 28 days the results obtained are as follows:

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Table No. 16 28 Days Results for Column Section 25x50x500 mm

Size of Sections: 50x50x500			
Type of Section	**Size of Section**	**Total Load Carried by Section**	**Deflection**
Hollow	50x50x500	142.75	4.5
PCC	50x50x500	249.55	6.1
SFRC	50x50x500	247.9	18.8

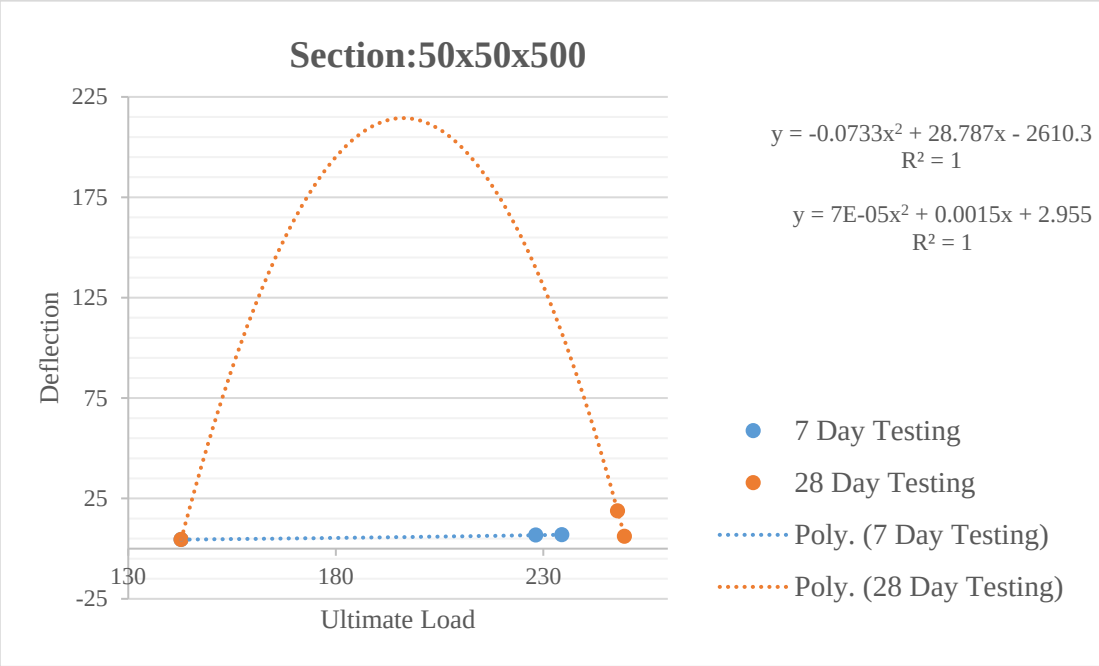


Figure No.4.42 Graph of Column section of size 50x50x700 mm

For the 50x50x500mm section it was observed that the load carrying capacity after 28 days for SFRC section decreased by 0.66 % of PCC section. As we can observe, deflection of PCC section is less and load carrying capacity is greater than SFRC section, hence this PCC section is more efficient and economical to use.

After 7 days the results obtained are as follows:

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Table No.17 7 Days Results for Column Section 25x50x500 mm

Size of Sections: 60x40x500			
Type of Section	**Size of Section**	**Total Load Carried by Section**	**Deflection**
Hollow	60x40x500	174.5	4.1
PCC	60x40x500	237.8	9.8
SFRC	60x40x500	214.05	16.6

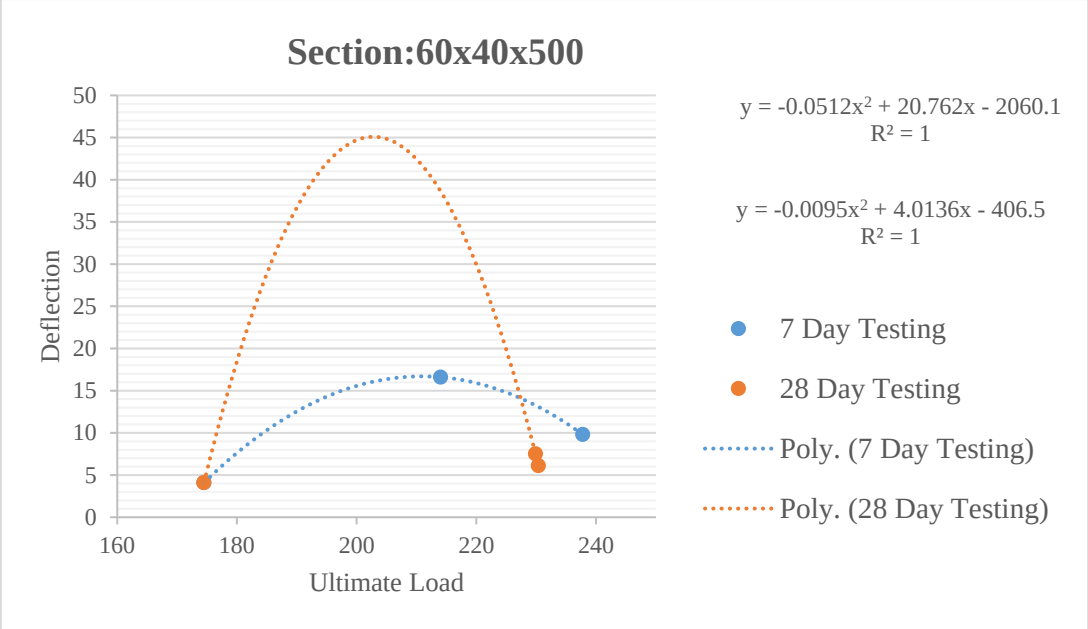
After 28 days the results obtained are as follows:

Table No.18 28 Days Results for Column Section 25x50x500 mm

Size of Sections: 60x40x500			
Type of Section	**Size of Section**	**Total Load Carried by Section**	**Deflection**
Hollow	60x40x500	174.5	4.1
PCC	60x40x500	229.9	7.5
SFRC	60x40x500	230.4	6.1

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FigureNo.4.43 Graph of Column section of size 60x40x700 mm

For the 60x40x500mm section it was observed that the load carrying capacity of the section after 28 days for SFRC section was increased by 0.21 % of PCC section. Deflection in PCC section is greater than SFRC section, but the load carrying capacity of SFRC section is greater than PCC section. Thus, SFRC section is economical and efficient to use for cross sectional size 60x40mm.

Comparison between results of Ansys software and Experimental testing:

1. **For Hollow Beam Sections:**

The analytical and experimental results obtained after ANSYS and experimentation of hollow column sections are:

Table No.19 7 Days Results for Hollow Beam Section 25x50x700 mm

Hollow Beam sections			
Size of Section	**Total Load Carried by Section**	**Deflection**	**Deflection by ANSYS**
25x50x700	28.05	6	5.1
50x50x700	32.9	23.9	20.076
60x40x700	38.3	5.5	4.84

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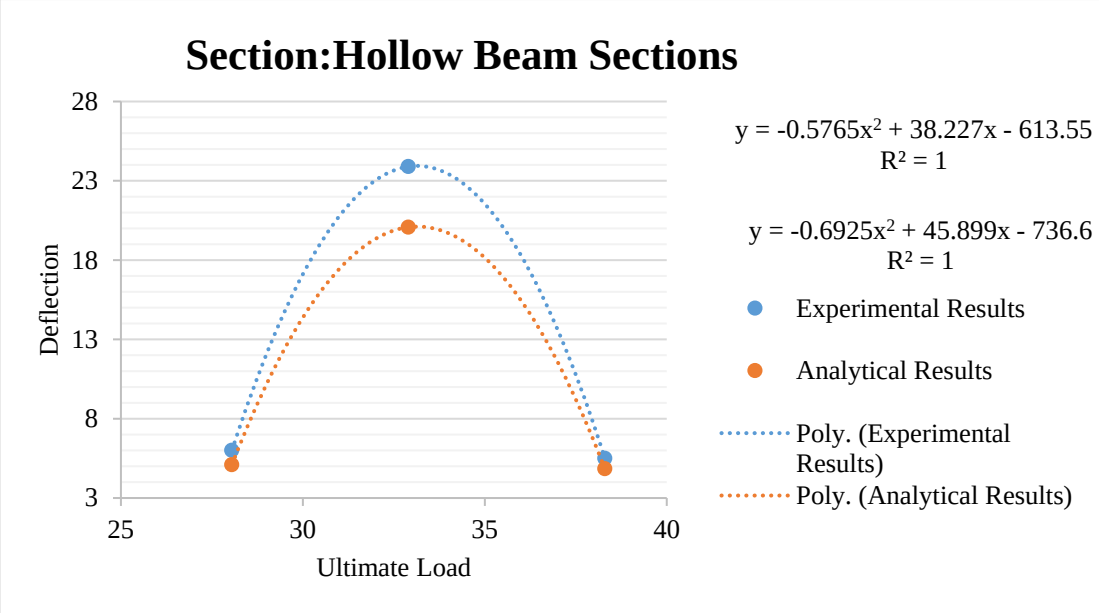


Figure No. 4.44 Graph of Hollow beam sections

By the comparison between the experimental results of tests performed and analytical results from ANSYS Workbench v14.5 we can analyze that for the hollow beam sections There seems an increment in deflection as the square section is adopted. If the same analysis is performed on rectangular sections with increased cross sections improvement in load carrying capacity of the section along with lesser deflection . From the graph and results we can determine that as the cross-sectional area of the section increase the load carrying capacity of the section also increase along with lesser buckling or deformation in the section.

2. **For Hollow Column Sections:**

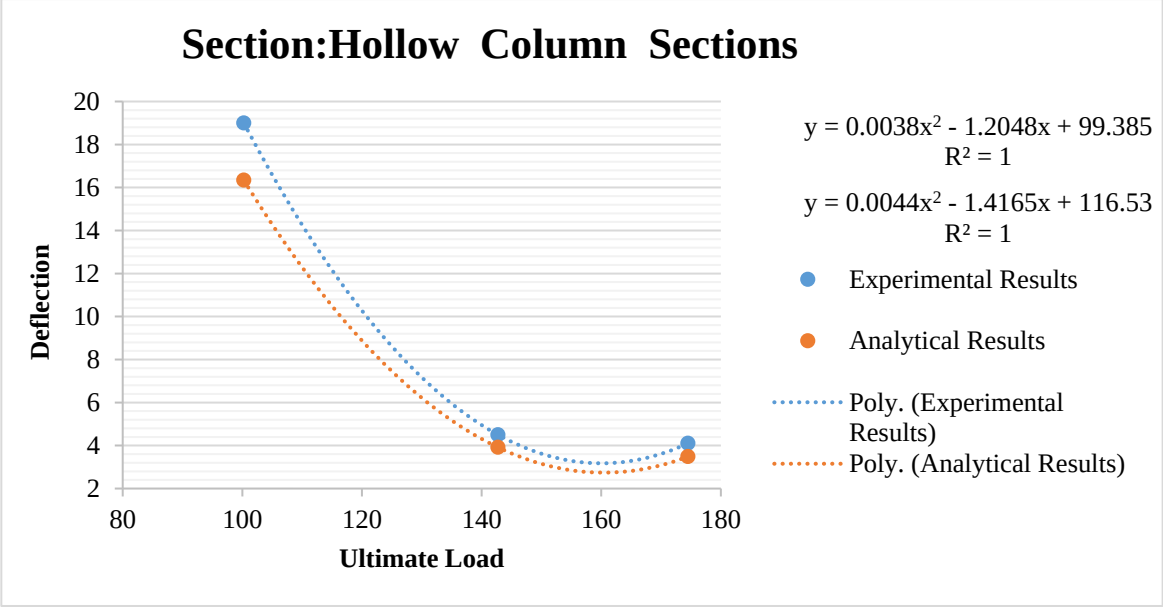
   The analytical and experimental results obtained after ANSYS and experimentation of hollow column sections are:

Table No.20 28 Days Results for Hollow Column Section 25x50x500 mm

Hollow Column sections			
Size of Section	**Total Load Carried by Section**	**Deflection**	**Deflection by ANSYS**
25x50x500	100.25	19	16.34
50x50x500	142.75	4.5	3.915
60x40x500	174.5	4.1	3.485

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FigureNo.4.45 Graph of Hollow Column Sections

By the comparison between the experimental results of tests performed and analytical results from ANSYS Workbench v14.5 we get clearer view of the analysis of the hollow column sections. From the graph and results we can determine that as the cross-sectional area of the section increase the load carrying capacity of the section also increase along with lesser buckling or deformation in the section.

6. CONCLUSIONS

6.1 Summary

The project work was focused on the analysis of the beams and columns as structural members by the experimental and the analytical methods. A total 15 Number of beam sections were tested for flexural load carrying capacity out of which 3 sections were hollow sections of sizes 25x50x700, 50x50x700 and 60x40x700 each. The 3 sections each of concrete infill of PCC and SFRC were casted with concrete of grade M25 and simultaneously tested on the UTM for flexural tests and the ANSYS analysis for the same sections was carried out. Similar experimentation and analysis for the column section of sizes 25x50x500, 50x50x500 and 60x40x500 was carried out for the buckling test and the experimental results of each of the tests were compared with the analytical results from the ANSYS software with the help of the graphs.

6.2 Conclusion

From test results of hollow sections i.e. beam and column, it is observed that

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1. The load carrying capacity of the section is directly proportional to the cross-sectional area i.e. as the cross-sectional area of section increases so does the load carrying capacity of that section.
2. While the sections with infill could perform more efficiently than the hollow sectionsit was observed amongst the PCC infilled sections and SFRC infilled sections that PCC infilled sections could attain somewhat higher load carrying capacity than that of the SFRC sections but the SFRC in filled sections were observed to perform with lesser values of deflection than the PCC sections thereby providing to be more efficient for use in terms of design and safety.

6.3 Future Scope:

- Analysis and comparison of concrete infilled cold formed light gauge steel section using analytical methods.
- Testing the concrete infilled sections for different geometry and shapes and sizes before actual use and determining the most efficient section
- Study of crack pattern and factors influencing the errors in analytical and experimental testing.
- Study of comparison between conventional RCC structural members and concrete infilled cold formed light gauge steel sections.
- Study on rate and quality analysis of these members can be performed.
- Study of torsion property of beam section can be done.
- Testing the sections for heat resistance.

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