INTERNSHIP REPORT

TENURE AT SGAWINGS CIVIL ENGINEERING CONSULTANT & ADVISOR (OPC.) PVT. LTD.

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Acknowledgements

As I write the report, the internship has come to end and I know I will go back with some answers to my career aspirations, a little less confused and a little wiser than I was when I first stepped into the office of SGAWings.

I have no one to thank but the people who supported me all along. Er. Vivek G. Abhyankar for giving me this opportunity to do this internship at his firm and constantly pushing me to realise that I can do much better, Er. Abhijeet V. Gawai – No words that I write can describe that amount of effort he put in to help me understand every little detail he could possibly teach me, Er. Sanket Mali – for his constant support and guidance and, Er. Darsh Maru – I will surely miss the discussions.

It was truly a wholesome experience and I have gotten much more than I could have asked – Site Visits, Factory Visits, Technical Webinars, Analysis and Design of a Real Structure and of course some theoretical modelling.

Parents are the backbone for their children and I am grateful to them for providing me with all the support I can hope for and backing me at every step.

It was a fulfilling experience, this internship, and my gratitude to all those who were part of it.

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Introduction

SGAWings is a company which deals with civil / structural engineering – conceptual planning, analysis, detail design calculations, detail drawings (GAD, Schemes, Fabrication / shop drawings), cost & quantity estimation, structural audits of existing structures, bid (EPC / HAM) optimization. SGAWings was registered in January 2021 under the ownership of Er. Vivek Ganesh Abhyankar.

I was in my 6th Semester of my BTech in Civil Engineering degree when I realized I have an interest in Construction. I was looking for structural design and construction management companies to further explore my interests in the subject. After a lot of cold mails, WhatsApp messages and research of such companies, I found out about SGAWings. I contacted Er. Vivek G. Abhyankar, and he agreed to offer me an unpaid internship during my summer break after a small interview. It was a short 2-month internship, during which I learnt about some of the basics in steel and structural design, using STAAD.Pro, benefited from various in-depth discussions on civil engineering and realised the differences and similarities between work experience and academic knowledge. I am thankful to everyone who was a part of this journey and I hope to learn more as I go forward.

This report is an attempt to summarize the concepts, problems and events I was involved in during this internship at SGAWings Consultants, Mumbai. I have started from the very basics – What is Civil Engineering, continued with the basics like types of supports, loads, structural forms and then moved onto STAAD.Pro (A software used for structural design and analysis) and some problems solved by me using excel. I hope the readers get a clear understanding of everything discussed below.

Civil Engineering

It is a branch of engineering that deals with building the infrastructure around us and preserving the nature so that people can live safely, move from one place to another with ease and grow sustainably. Civil Engineers are responsible for designing, building and maintaining most of the basic infrastructure we use every day like the offices we work in, schools and institutions we study at, our homes, industrial plants, metro, bridges, tunnels, dams, water supply systems, etc. It can be broadly divided into 7 categories:

- **Surveying and Geomatics:** It deals with measuring of land, boundary markings, topographic surveys so that we know where we can build the structure and what are the features of the site we are building on.

- **Geotechnical Engineering:** The main focus of geotechnical engineers is to understand the behaviour of soil and ensure the ground is strong enough to support the structure. They test the soil and design foundations based on it and other structures like retaining walls, piles, etc to make the ground strong enough to carry the load from the superstructure.

- **Structural Engineering:** Structural engineers study the strength of materials and design structures to safely stand against various loads like earthquakes, wind, etc that would affect a structure during its economic life. They use engineered materials such as steel, concrete and timber to design bridges, towers, metros, buildings, etc to be safe and economic.

- **Transportation Engineering:** This branch ensures that people and goods can safely and efficiently move from one place to another. They deal with highway, roads, bridges, airports design and construction, traffic management, pavement materials, etc.

- **Water Resources (Hydraulic) Engineering:** The management, storage and movement of water is addressed in this branch of civil engineering. Hydraulic Engineers deal with irrigation, flood control, stormwater drainage, building of dams and canals and efficient management of water for the region they are working for.

- **Construction Engineering & Management:** They deal with planning and management of construction projects. The scheduling, costing, equipment planning, quality control, ensuring of safety is the responsibility of a Construction Project manager. A Construction project manager must ensure that a project is built on time, on budget while being complaint with ethical practices.

- **Environment Engineering:** The goal of this branch is to protect nature and provide clean resources to us. It deals with water and waste water treatment, air and noise pollution, solid waste management.

Surveying

It is one of the most important steps in a construction project, as it ensures that the structure is built in the correct place and helps set correct levels for the various structural elements. Some key surveying tools are:

- **Theodolite:** It is an instrument used to measure horizontal and vertical angles and is essential for triangulation and alignment of structures. A Total station is an advanced version of a theodolite with distance measurement and data logging.

Fig 1: Theodolite

- **Dumpy Level:** It is a manually levelled optical instrument that is used to level ground, check elevations and slopes.
- **Auto Level:** This is a faster and more stable version of a dumpy level and reduces human errors.
- **Levelling Staff:** It is a graduated vertical pole with a levelling instrument used to read elevation differences. The reading taken trough dumpy level or auto levels gives the relative height.

To check whether a line is straight or not and if the tools aren't available, the check can be done using a simple 3-4-5 rule based out of the Pythagoras theorem. If a person holds a measuring tape and goes 3 meter in the direction of the line and another person goes 4 meter perpendicular to the line from the starting position of the first person, the smallest distance between the 2 persons should be 5 meters, the right-angled triangle's hypotenuse. If the measurement indeed turns out to be 5 meters, then the line is straight otherwise corrections need to be made.

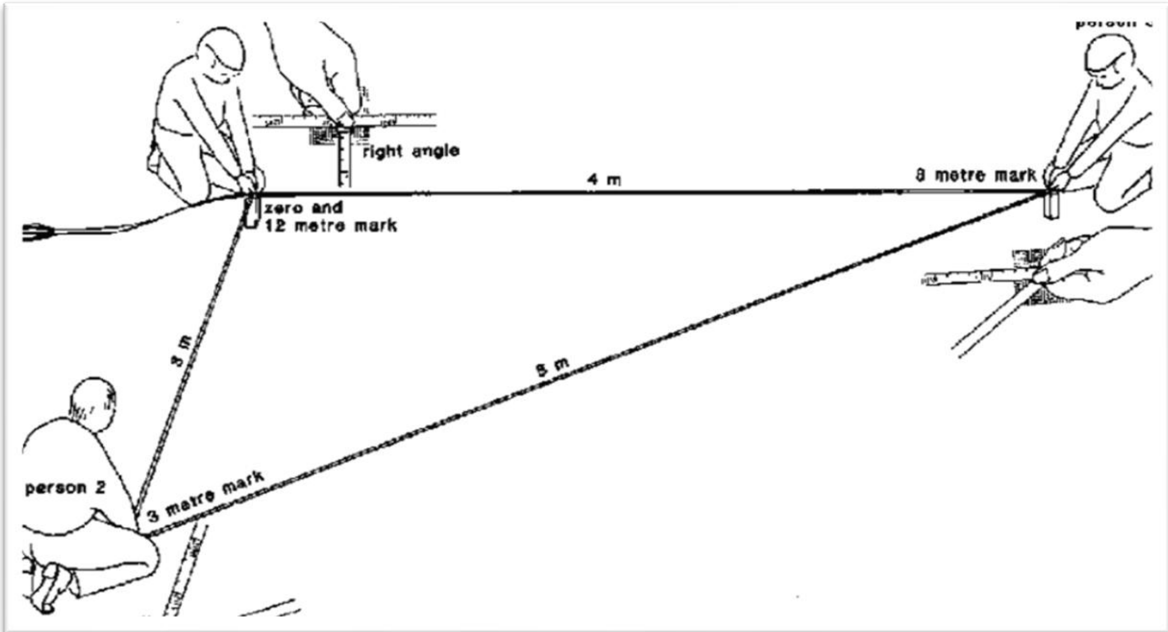


Fig 2: 3-4-5 rule in use

Construction Drawing

Construction Drawings are the universal language for engineers be it in the Civil, Mechanical, Electrical and other related department involved in the construction of a structure. It helps the designers convey their ideas to the people working at the site, people inspecting an undergoing task, quality control and standardization. It helps in quantity estimation, manpower planning and costing. Even minor deviations from the drawings can compromise structural safety. Hence, it goes without saying that Construction drawings must be made with utmost care and followed to the intricate details.

Some important elements of Construction Drawings are listed below:

- **Title Block:** It is found in the corner of a drawing sheet and contains essential details like the Project Name, drawing title & Name, Scale used, Date of issue, Name of designer/ drafter, approvals to ensure that every drawing can be identified and tracked correctly.
- **Symbols and Notations:** Standard symbols for steel rebars, door/ windows, plumbing, etc and notations to explain materials, slopes prevent cluttering of drawings and allow us to furnish all technical details.
- **Legends:** This is used to explain the meaning of the symbols, notations used so that anyone reading the drawing can interpret it correctly.
- **Dimensions and Scaling:** Dimensions are provided to give the exact size and distance of various elements in the drawings. The drawings are scaled from real life measurement to a specific scale like 1:100, 1:50, etc to fit into the drawing sheet to be used for construction. Attention to accurate dimensions and appropriate scaling is essential to ensure precise construction.
- **Plans:** This is the view from top of any structure to show layout of walls, openings and other critical elements that need to be displayed for the ease of construction at site.
- **Cross-sections and Elevations:** Cross Sections are cuts through a building to show internal details like depth of a footing, floor slab, staircase height, etc and elevations are front/ side views showing the exterior or interior of the building. It helps the reader understand the relationship between different parts when read in conjunction with the plan.

Construction Drawings evolve through several stages during a project and serve specific purposes as explained below:

- **For Reference/ Discussion:** They are basic conceptual drawings for early planning or meeting with clients that help visualize broad ideas and explore design options.
- **Preliminary Design:** These are more refined than conceptual drawings and include rough dimensions and structural system ideas to get initial approval and feasibility check.
- **Definitive Design:** This is the finalized design after multiple revisions in coordination with the various disciplines involved in the project like Architectural, Structural and MEP. It is useful for cost estimation and approval from the authorities.
- **Construction Reference Drawing**: This drawing includes all technical details for construction including all dimensions, levels, reinforcement details, materials to be used so that construction can begin.
- **Good for Construction:** This is the final approved construction drawing that is signed off by the consultant/ designer and used for on-site execution. It must be accurate, lucid and free of ambiguity.

- **As Built Drawing:** It serves as the permanent record for maintenance, repair or future renovation of the structure. It reflects all updated versions of the drawing after the construction is completed and accounts for all the modifications made during the process.

Construction Drawings may be of several types such as MEP, Structural, Architectural, etc. During the course of my internship, I have realised the significance of one such drawing – "GAD" (General Arrangement Drawing).

GAD shows how the overall layout and positioning of all elements in a structure. We can consider it to be a master plan that all teams in the workers refer to for execution of the project. It is of utmost importance to ensure that the GAD is lucid and free of errors because it the foundation for detailed reinforcement drawings and for coordination between architects, structural engineers, MEP engineers, contractors, etc. It is used by site engineers for planning and execution, by clients for budgeting and review and is easy to explain the project visually for approvals and permits. Without a good GAD, there may be mismatch in layouts, different teams may work with wrong assumptions and the project is doomed to be delayed.

Note: LOD in a drawing means the Level of Detail which defines how detailed a model or a drawing is. It is mostly used in BIM and higher LOD means higher detail present in the model.

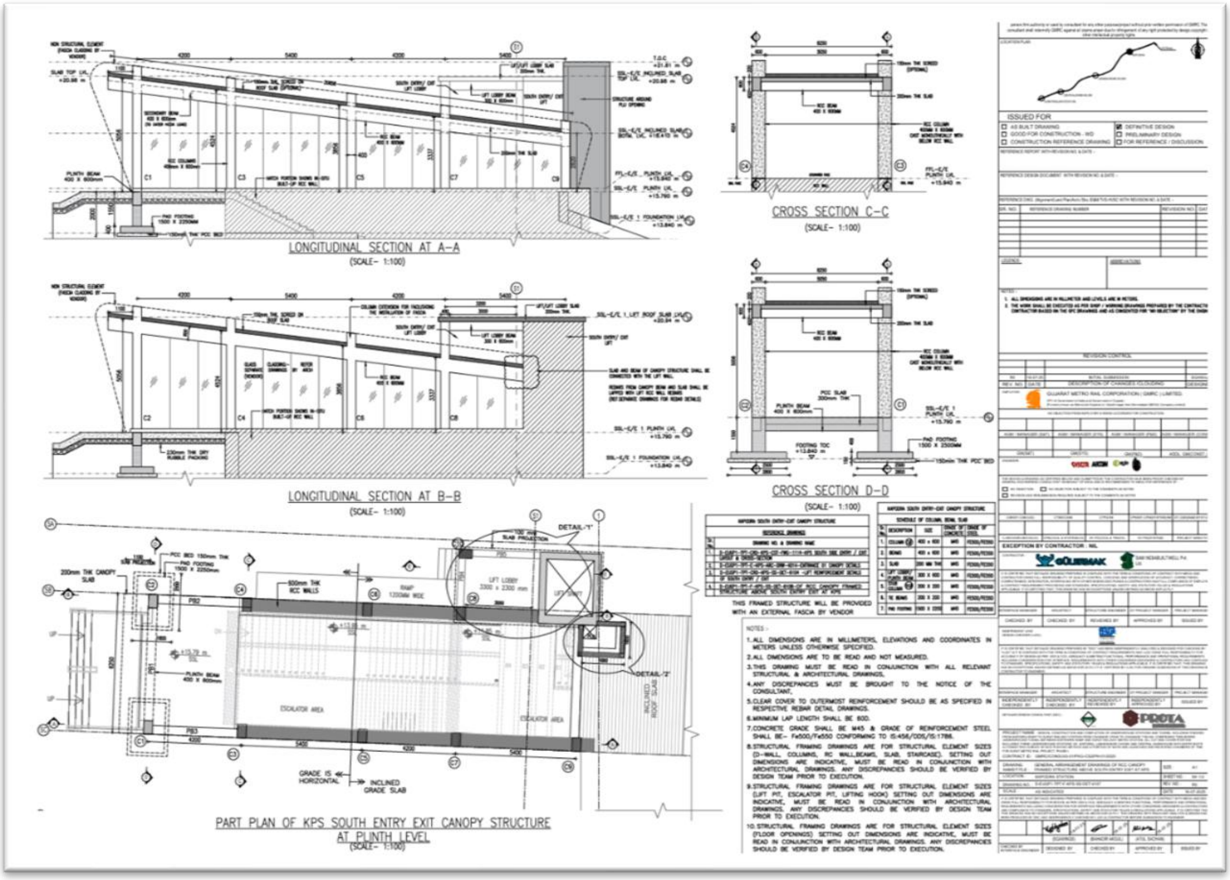


Fig 3: GAD for the South Entry Exit Canopy of KPS UG Metro

IS Codes

Indian Standard (IS) Codes are standard guidelines, specifications and procedures developed by the Bureau of Indian Standards (BIS) for engineering applications in India. With respect to civil engineering, IS Codes specify the design criteria for Steel, Masonry, RC Structures, etc, testing procedures for various materials, methods of construction and safety standards. They have been introduced to ensure uniformity in construction across the country thereby promoting public safety. Compliance with IS Codes is not optional and it serves as the minimum benchmark to be adhered to for construction in India. Brief details of some important IS Codes and IRC (Indian Road Congress) Codes I have come across during the course of my internship have been mentioned below:

- **IS 456:2000**: It is the code of practice for Plain and Reinforced Concrete structures in India. The design principles opted are LSM (Limit State Method) in most cases and WSM (Working Stress Method) for some specific situations when no cracking or deformation is allowed as in the case of Water Retaining Structures. The Preliminary draft of IS 456:2025 is available and it introduces six design criteria: Safety, Serviceability, Durability, Robustness, Integrity, and Restorability. It also includes special concrete like Fibre Reinforced Concrete, Self-Compacting Concrete and has expanded its scope to prestressed concrete and composite concrete systems.

- **IS 1893 (Part 1):2016**: It provides the design criteria and seismic loading for structures in earthquake prone areas ensuring the structure is safe against ground shaking and there is no loss of life during such an event. Response Spectrum Method is opted for most cases; however, the Time History Method is used for tall, irregular or critical structures. The BIS has released a draft of IS 1893:2023 for public review and feedback.

- **IS 1786:2008:** This code specifies the technical requirements, chemical composition, mechanical properties and testing methods for Hot-rolled deformed bars, TMT (Thermo-Mechanically Treated) bars and Cold-twisted bars. It is essential for all RC Structures including High-rise buildings and bridges.

- **IS 2911:2010:** This code provides the guidelines for design, construction and testing methods for pile foundations where shallow foundations are not feasible due to poor soil conditions or heavy loads. It is divided into 4 parts: Part 1 – Driven Cast In-situ Concrete Piles, Part 2 - Bored Cast In-situ Concrete Piles, Part 3 - Driven Precast Concrete Piles, Part 4 – Load Testing on Piles. It is mandatory for deep foundation projects and is often used in High-rise buildings, industrial structures, offshore structures, bridges, etc.

- **IS 875:** It provides guidelines for design loads other than Earthquakes for Buildings and other structures. It is divided into 5 parts to provide standards for consideration of different types of loads– Part 1 (1987) – Dead loads, Part 2 (1987) – Imposed Loads (Live Loads), Part 3 (2015) – Wind Loads, Part 4 (1987) – Snow Loads and Part 5 (1987) – Special loads like loads due to cranes, impact, etc and Load Combinations.

- **IS 13920:2016:** – This is the standard code of practice in India for Ductile Design and Detailing of Reinforced Concrete Structures subject to Seismic Forces. It is to be used in conjunction with IS 456 and IS 1893 and is mandatory for important structures like hospitals and moment resisting frames in Seismic Zones III, IV and V and structures > 15m in Zone II. Compliance with this code makes RC Structures more ductile, hence it is capable of undergoing large deformations without collapse during an earthquake.

- **IS 3370:2021:** It deals with the design and construction of RC Structures for the storage of liquids like Water tanks that may be overhead, underground or ground-level, Sewage tanks, Chemical storage structures, Swimming pools, etc. The minimum grade of concrete to be used is M30 as per IS 3370 for storage of liquids and the design philosophy adopted is WSM for more conservative crack control.

- **IS 14593:1998:** It specifies guidelines for the design and construction of Bored Cast-in-situ Pile foundations. It is a detailed supplement to IS 2911 and is used for design of large diameter bored piles and includes modern construction practices and equipment capabilities. The minimum cover shall not be less than 75 mm and concrete grade to be used shall be M25 or higher as per this code.

- **SP 34:** It is a handbook on Reinforcement detailing of RC Structures published by the BIS to supplement IS 456 and other related codes like IS 13920, IS 3370, etc. It is highly relevant since it provides guidelines that prevents congestion of reinforcement, standardizes symbols and drawing practices while being compliant with the principles of IS 456, IS 13920, etc. It provides general rules for cover, bar spacing, anchorage, reinforcement detailing in beams, slabs, columns, footings, walls, etc.

- **IS 800:2007:** It serves as the primary code for design of steel structures in India. It has adopted the LSM design philosophy and provides guidelines for design of connections, beams, columns, trusses, girders and partial safety factors that provides more accurate results.

- **IRC 5:2015:** This code lays down the general design principles and requirements for highway and road bridges in India acting as the base document for all other IRC bridge design codes. The LSM design philosophy has been adopted, according to which the structures must satisfy the Ultimate Limit State (Safety against collapse) and Serviceability Limit State (Checks against deflection, cracking, etc). As per this IRC 5, design life for permanent bridges must be 100 years and aesthetics and economy should be considered during the planning.

- **IRC 6:2017:** It specifies the types of loads and load combinations to be considered for design of highway and road bridges in India. For Live load consideration, the vehicular loads are classified into Class AA (Heavily loaded bridges for tracked or wheeled vehicles like Army tanks, etc), Class 70R (for highways, defence routes), Class A (Common public road bridges with normal traffic), Class B (Very light traffic for pedestrians, village roads, etc) and Footpath Loading (4 kN/m^2 (min)).

Structural Forms

It is the shape or geometry that a structural element can be idealized to analyse and design for the loads it shall carry.

- **1D Structural Forms:** They resist axial force, shear force and bending moment along a line. Their one dimension (length) is much greater than their other 2 dimensions (width and depth). Some 1D Structural forms are: Beams - Horizontal element resisting bending, Column – Vertical element resisting axial compression, Arch – Curved Structure carrying load primarily through compression and Cables – Resists tension as in suspension cable bridges.

- **2D Structural Forms:** Loads in 2D structural elements are carried in 2 directions. Examples of such forms are Slabs & plates – They resist bending in 2 directions, Walls – Vertical Elements that resist axial and shear forces, Truss & Frames – It is a combination of 1D members and can be 2D and 3D depending on the assemblage.

- **3D Structural Forms:** Such structural elements carry and transfer load in all 3 directions and exhibit complex stress combinations. Examples of this type are Mass Concrete – Large volumes of concrete without reinforcement like dams, gravity walls, etc and Pile Caps – Thick concrete slab over the piles to distribute the load from the columns to the piles.

Fig 4: Mass Concreting for a Dam

- **Axis of Revolution:** If we rotate a curve around an axis we get symmetrical 3D forms. For example, if we rotate a line about an axis, we get a cylinder with uniform cross section and circular base (e.g. water tanks, silos), if we rotate a slanted line about a fixed axis passing through its top, we get a cone (e.g. roofs) and if we rotate a curved element about an axis passing through one end, we get a hemisphere (e.g. domes).

Fig 5: Silos – Axis of Revolution

- **Axis of Generation:** Curved Surfaces formed by translating curves and it may be of two types: Anticlastic and Synclastic. If the curve is in same direction in both axes, it is synclastic (domes, spheres) and is called anticlastic (hyperbolic paraboloids, cooling towers) if curves are in opposite directions in orthogonal axes. Anticlastic and synclastic shells can resist more loads efficiently due to their geometry. Shell Membranes resist loads by internal forces in the surface itself and not by bending. It results in pretty efficient and strong structures. The uniform geometry allows for even stress distribution in synclastic shells like an egg shell which is very thin but pretty strong and anticlastic shells have double curvature that increases stiffness without increasing material and the shape naturally transfers loads to the supports in a stable way.

Fig 6: Cooling Tower – Axis of Generation

Basics

Supports: The connections/ joints between structure members are termed as supports. They govern how the structure will behave under a load and they can be of various types:

- **Free:** There is no restriction to movement or rotation of member in any direction

- **Hinged/ Pinned:** Translation is completely restricted but rotation is allowed.

- **Roller Support:** It prevents vertical movement but allows horizontal movement and rotation.

- **Spring Support:** Partial resistance against translation is provided.

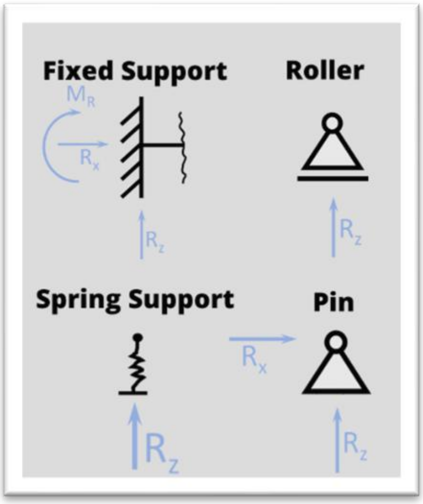


Fig 7: Types of Supports and their reactions

- **Simply Supported:** It allows rotation but prevents translation using one pin support at one end and roller at the other.

- **Fixed:** All movements and rotations are restricted.

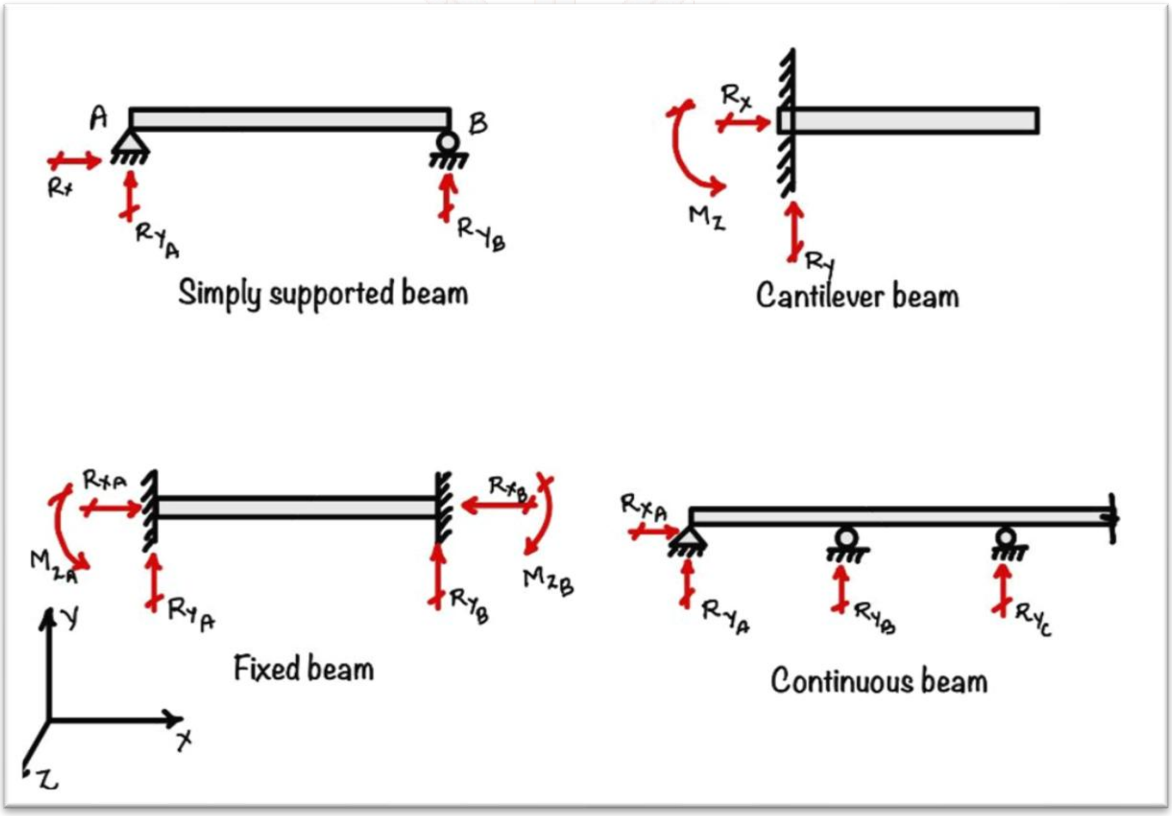


Fig 8: Types of beams and their reactions

Loads: Loads on a structure can be broadly classified into two types: Vertical Loads and Horizontal Loads.

Some common Vertical loads on a structure are:

- **Dead Load:** Due to the weight of the structure itself and load due to other objects that will be on the structure during its entire life. It is assumed as per recommendations in IS 875 Part 1.
- **Live Loads**: Due to people that may come and leave a building, vehicles moving on a road, etc. These loads will be acting variably on the structure but not during its entire life. Live load recommendations are specified in IS 875 Part 2.
- **Snow Loads**: Due to snow that gets collected on the roof in hilly regions during winter. If not considered, the effect due to snow loads could cause serious failures. We can design for snow loads as per IS 875 Part 4.

Some common Horizontal Loads are:

- **Earthquake loads**: Due to the shaking of the ground. Seismic design is done as per IS 1893, and the ductile detailing to ensure structure does not collapse is done as per IS 13920.
- **Wind loads**: Due to the pressure of air against a structure. It is often considered for building of height more than 10m. The design is done as per specifications in IS 875 Part 3.

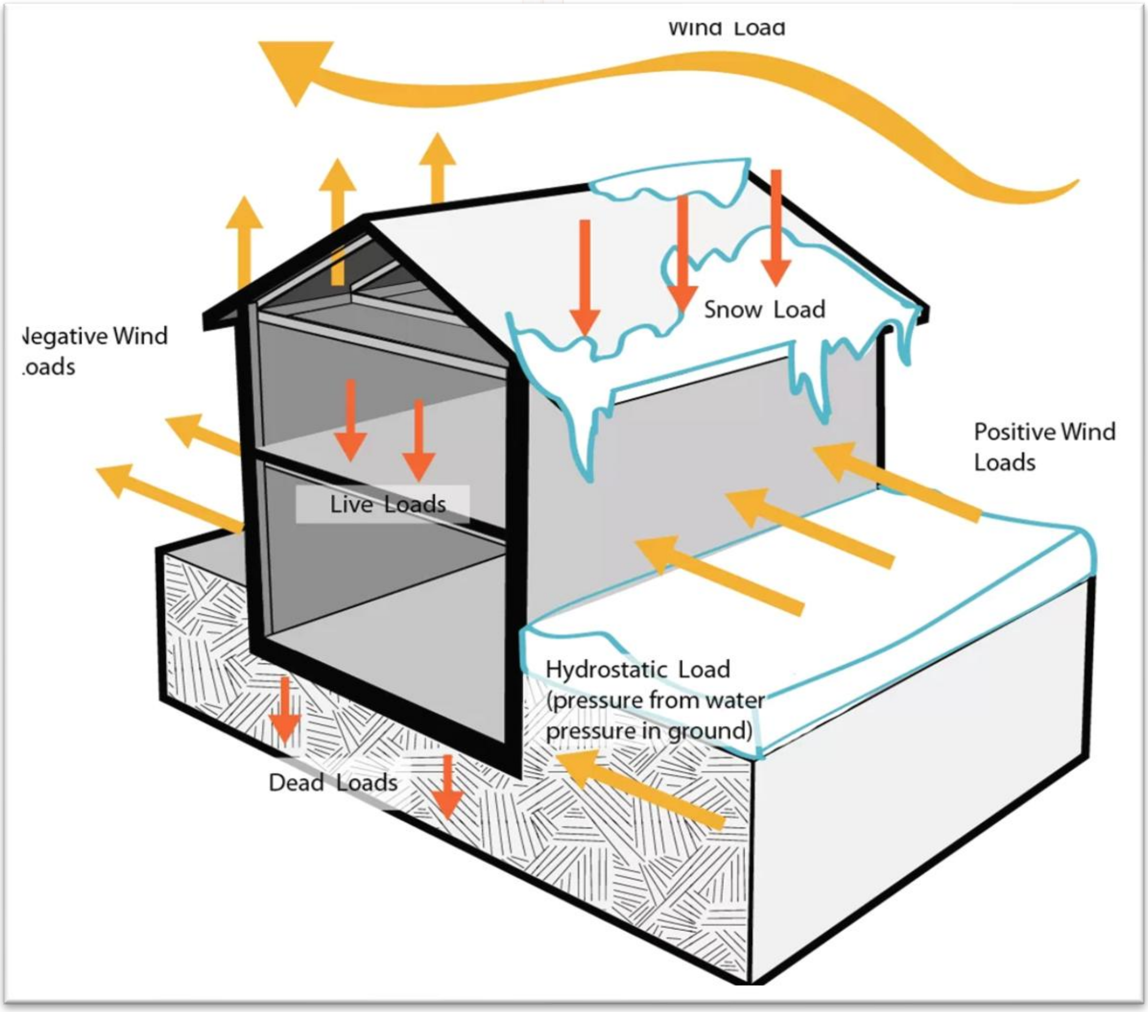


Fig 9: Various Loads on a Structure

Apart from the above-mentioned loads there could be other loads as well acting on the structure like:

- **Construction Load:** These are temporary loads acting on a structure during the construction stage. It includes the weight of the materials, workers, tools, etc that would come onto the structure. Failure may occur during the construction stage itself if construction loads overlooked. Design recommendations are given in IS 875 Part 2.
- **Accidental Load:** These are loads due to unexpected events like vehicle impact, fire, blast, etc and are considered for important structures like bridges, nuclear plants, etc. It is designed as per IS 875 Part 5.
- **Crane Load:** It is the load exerted by the overhead cranes or gantry cranes and specifications for such loads are provided in IS 875 Part 2.
- **Surcharge Load:** It is the extra load on soil near or above retaining structures, basements and are assumed as per IRC 78 and IS 14458 Part 2.
- **Vehicular Load:** It is the load due to moving vehicles on bridges, flyovers, etc. It is designed as per IRC 6.

The application of a load on a structure can be in various types and some of them are explained below:

- **Point Load:** Load applied at a specific point on a structure.
- **Uniformly Distributed Load:** A load spread over a length or area with constant intensity.
- **Uniformly Varying Load:** A load that varies linearly along its length like a triangular load.
- **Hydrostatic Pressure:** It is the force exerted by fluid at rest and is uniform in all directions at a particular point and increases with depth.
- **Floor Loads:** It is the total load on a floor slab due to the live load, dead load, etc.
- **Nodal Loads:** A load applied directly on a joint or a node.

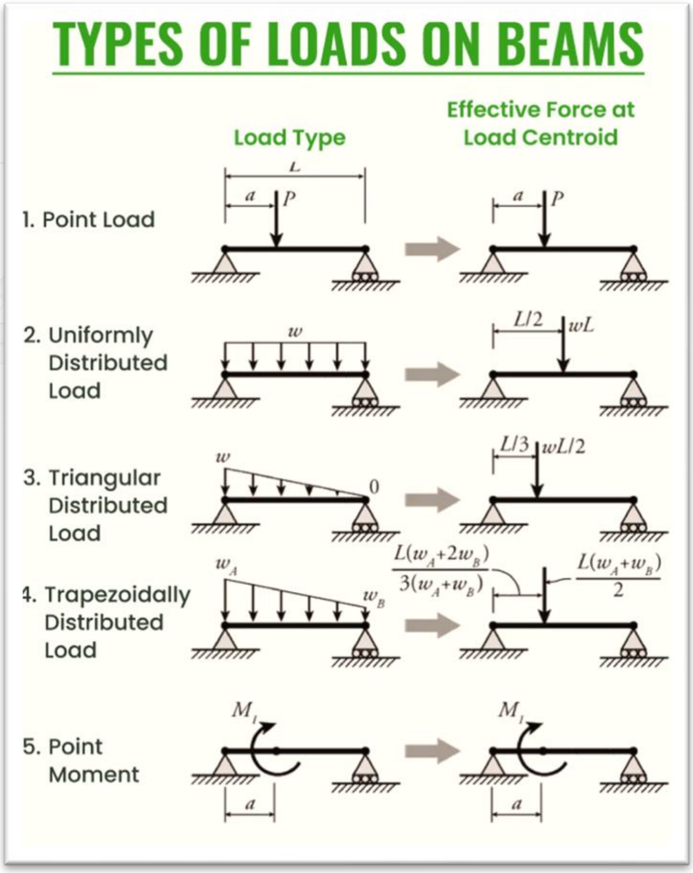


Fig 10: Types of Loads on a Beam

Special Note: *Effect of load in a distant member in continuous beam* - In a continuous beam, when a single span of the beam between two supports is loaded, it is observed that the effect is felt up to 3 beam spans in each direction after which the effects are negligible enough to be ignored.

Advanced

Equivalent UDL: This concept allows us to convert any type of loading like a point load, uniformly increasing load, triangular load, etc on a structure to an equivalent uniformly distributed load that has the same effect on it. To arrive at the equivalent UDL, we equate 4 effects due to the original load with 4 effects due to the effective UDL.

The 4 effects are:

1) Max Shear Force due to loading in each case.
2) Max Bending Moment due to loading in each case.
3) Max Deflection due to loading in each case.
4) Total loading in each case.

We choose the one which gives us the maximum value for the equivalent UDL.

Yield Line Theory: This theory states that at collapse the slab forms distinct plastic hinges or yield lines along which bending moments reach their ultimate capacity. For quadrilateral slabs supported on all sides, usually the yield line appears at an angle of 45° from each corner and the load within the region where two lines meet is the load carried by the member that supports the slab in that region. For triangular slab, the lines start at the corners and meet at the centre. For circular slabs, all diameters are the yield lines. Hence, theoretically a circular slab has infinite yield lines.

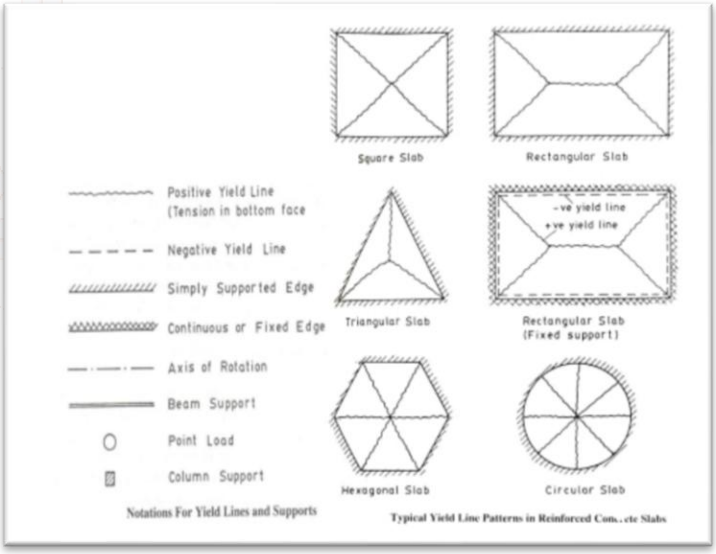


Fig 11: Yield Line Patterns in Slabs

As per this theory, the collapse load can be calculated using the principle of virtual work, external work done by load equals internal work done along yield lines. Since Circular slabs are symmetrical in all directions, all directions carry equal bending and there is not weak direction unlike rectangular slabs where corners have high stress concentrations. If we compare the collapse load for a circular slab and rectangular slab, it is seen that circular slabs can carry over 50% more collapse load for the same area and material.

Indeterminate Structures: Structures in which the number of unknown reactions is more than the number of equations of equilibrium. Hence, there are many ways for the load to travel and we cannot find the reactions and moments using simple equilibrium equations.

Such structures are hyperstatic and the analysis of such structures require the understanding of complex methods like the ones listed below:

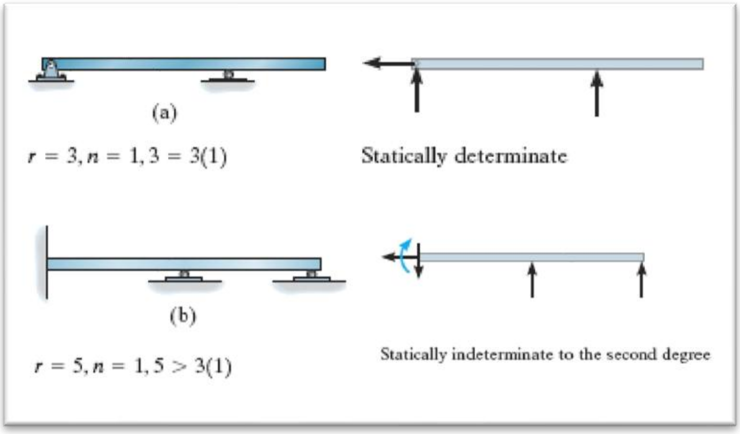


Fig 12: Finding Indeterminacy

Principle of Virtual Work: It states that for a structure in equilibrium, the external work done to cause a small virtual displacement is equal to the internal work done by the forces inside the structure. It is useful to find displacement, deflection or rotation at any point in a beam, frame, truss, etc especially when the structure is indeterminate.

Formulae: External Virtual Work = Internal Virtual Work

Strain Energy Method: When a structure is loaded, the energy is stored in form of internal strain energy due to the internal stresses. Hence, if the structure is elastic and conservative, the energy stored should be equal to the external work done. It is useful for structures under complex loading. The equation below can be used to find displacement or solve for unknown forces.

Formulae: $U=\int M^2/(2EI)\,dx$

Castigliano's Theorem: It states that the partial derivative of strain energy with respect to an external force equals to the displacement in the direction of that force. For indeterminate structures, we use the equation below to compute unknown forces or deflection at a point.

Formulae: $\delta=\partial U/\partial P$

Discussion on Stress and Compaction

Principal Stress Trajectory: It is the curve along which the maximum and minimum normal stresses act in a material. It is useful to visualize stresses in complex structures like dams, notches, etc to understand where the crack may initiate.

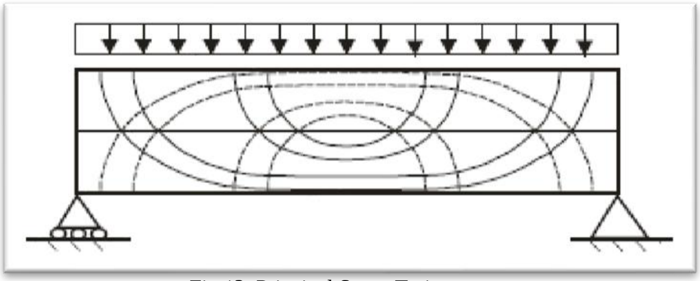


Fig 13: Principal Stress Trajectory

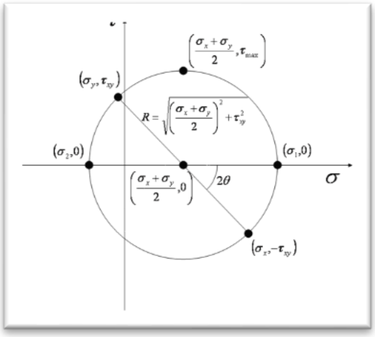


Fig 14: Mohr's Circle

Mohr's Circle: It is a graphical tool used to find the principal stresses, maximum shear stress and the orientation of shear planes. If the angle of the principal plane to the normal is φ, then in Mohr's circle it will be reflected as 2φ. This is used in 2D analysis of stresses in materials.

Stress Concentration: If there is a notch or sudden change in geometry or material properties, stress concentration affects can arise due to it. If we pass polarized light through a notched photo elastic sheet, place a receiver at the other end and then pull the sheet with a constant force we can see the see the fringe patterns for different stresses. They will be closely spaced in the region near the notch perpendicular to the direction of the pull and there will be not much difference in the notched region near the direction of the pull.

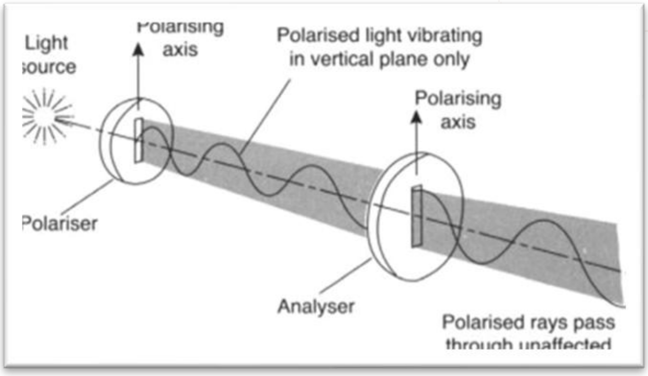


Fig 15: Setup for Stress Concentration Experiment

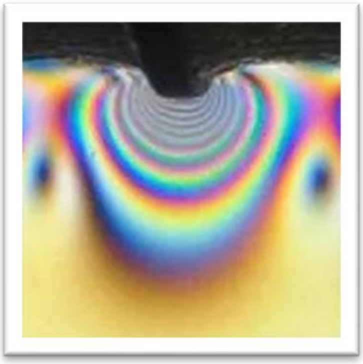


Fig 16: Fringe Patterns

Web Crippling & Web Buckling: Web crippling is a localized crushing failure occurring at the web usually near concentrated loads, supports or sudden change in geometry. It occurs when the local compressive stress exceeds the capacity of the web. Web buckling is the instability failure when an entire web panel buckles under compression due to the section being too slender.

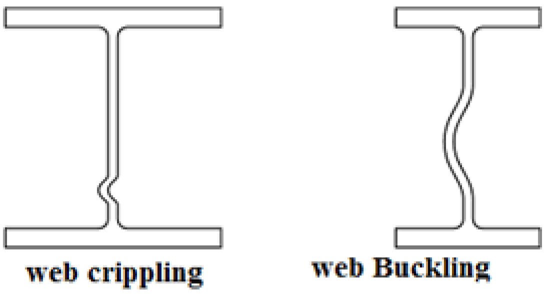


Fig 17: Failure in Web Crippling vs Web Buckling

Compaction & Consolidation: Compaction is the instantaneous removal the air voids in the soil to improve the bearing capacity and reduce settlement. It can be done using rollers, hammers, vibrators or some other machines by applying external force. Consolidation on the other hand is the gradual reduction of water content in saturated cohesive soils under static loading. It is a slower process than compaction but helps reduce long-term settlement.

To accelerate consolidation, drainage systems are installed especially in clayey soils where the natural drainage is very slow. Some drainage systems are:

- **Sand drain:** Vertical holes filled with clean sand act as drainage channels. When load is applied, the pore water flows horizontally into these drains and as the water level rises in it, they escape to the surface.

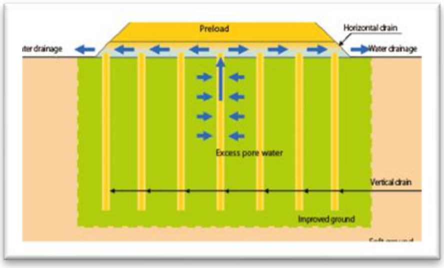


Fig 18: Sand Drain

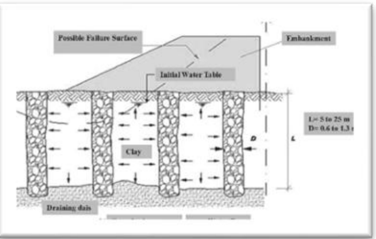


Fig 19: Gravel Column

- **Gravel/ Stone Column:** Vertical columns of gravel are inserted into the ground to provide drainage paths for water. It helps reduce settlement and also increases the bearing capacity.

- **PVDs (Prefabricated Vertical Drain/ Band drain):** Thin band type drains made of plastic core and geotextile filters act like sand drains and help remove water. They are faster, consume less space and cause less disturbance to surrounding soil.

Fig 20: PVDs

Structural Systems

Flat Slabs: Rectangular two-way slabs resting directly on columns are called Flat Slabs. It may be of different types:

- Flat Plates resting on columns. Usually, spandrel beams are provided at the edges of the building.
- Flat Slabs with column head/ capital
- Flat Slabs with column drop
- Flat Slabs with column head and Column drop

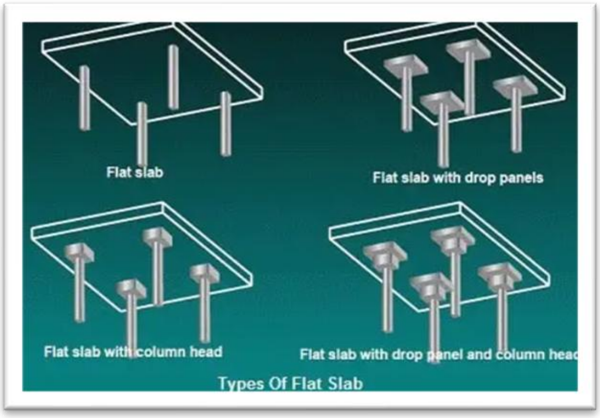


Fig 21: Types of Flat Slab

Flat Slabs are offer the following advantages:

- Reduced Building height & Simple formwork
- Reduced obstruction to service conduits
- Aesthetic Appeal

However, the use of flat slabs is discouraged due to the increased punching shear demand and the lack of a framed structure. It leads to poor performance against lateral loads, particularly earthquake.

Trusses: They are a framework of members connected in triangular units to carry loads such that the members are subject to axial forces and not bending. They are highly efficient structurally had have relatively light weight compared to the load they can carry. But why are trusses so efficient?

The answer lies in the loading they are subject to. The joints are pinned and not fixed, hence only axial forces are transferred and not bending. If you look at the bending stress diagram for the cross section of a cantilever beam subject to point load at the free end, you will find that the stresses are zero at the centre and varies linearly from the bottom fibre where there is compression to the top fibre where there is tension. Hence, the entire material is not optimally used and only the end fibres are utilized to their potential, whereas if you observe the stress diagram for the cross section of a column fixed at one end and axially loaded at the other, you will find that the entire area is subject to the same stresses, hence the utilization is maximum.

Trusses are also often called Open Web structures as the top and bottom chords are not connected with solid sections(plates) but rather has open spaces and are connected with triangular units(bars) serving as webs that resist shear through tension and compression.

Deriving the optimal height of a truss structure is critical so that we arrive at an economic and efficient solution. If the height is too large, the high fabrication/ lifting cost for the long web members will offset the material savings and a beam may be more economical. If the height is too small, the top and bottom chords need to be thicker so that it can carry the higher axial loads as the lever arm is reduced. Therefore, in principle they start behaving as a beam, hence a beam would be a smarter choice in this case too. Minimizing the total volume of material consumed, the rule of thumb for optimal height for a Truss of a span L can be taken as $h_{opt} = L/10$.

Fig 22: Structure made using Truss Elements

Bowstring Arch: It is a type of arch bridge in which the arches and the longitudinal beam act like a bow and the vertical suspenders like strings, hence the name 'Bowstring Arch'. The two arch ribs are connected by cross bracings on top and by cross beams under the deck which prevent them from spreading outward or inward.

The load due to vehicles act on the deck which are then transferred by the deck slabs to the cross beams, The cross beams transfer the load to the longitudinal beams due to which the lower chords span in the longitudinal direction. The longitudinal beams are supported by the vertical suspenders which transfer the load from these cross beams to the two arch ribs. The cross bracings between the two arch ribs ensures structural integrity. The loads are then transferred by the arch ribs to the heavy abutments and through a strong foundation, the loads are finally transferred to the strata.

Bowstring spans are preferred if the typical span length required is 50 – 100m and when support at the middle is not possible which may be in the case of a river, canal or railway is passing under. Bowstrings deliver aesthetic appeal and one of the most famous bridges like the Sydney Harbour Bridge (Sydney, Australia), Valiyazheekal Bridge (Kerela, India), etc serve as testimonials to the iconic design they offer.

Fig 23: Sydney Harbour Bridge, Australia

Fig 24: Valiyazheekal Bridge, Kerela

Piles: They are used to transfer loads from the superstructure to a deeper more stable soil layers or to rocks when the layers of soil on top have cannot resist the loads. A group of piles can also be used to support heavily loaded structural element like a pier. It must be noted that due to the overlapping stress zones, a group of piles may carry less load per pile than an individual pile. A special type of cast-in-situ pile called Under- Reamed Piles have bulb like enlargements which increase the bearing capacity and resists uplift. Their use is however limited as it is often found that the concrete near the bulb is honeycombed which may lead to failure.

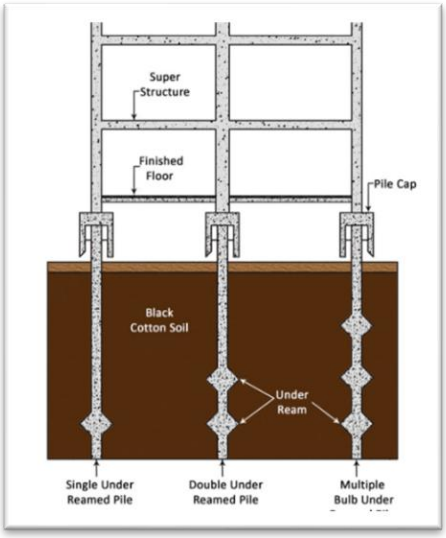


Fig 25: Under-reamed Piles

Construction

Construction Sequence: This might seem far-fetched, but the sequence of construction has a huge impact on the life of the building. Planning and scheduling of tasks and order of construction of various structural and non-structural elements in the building must be done such that the load transfer from each of these elements via structural elements like slabs, beams, columns, foundations and then to the strata follows a logical load path and there is no discrepancy. If any element is loaded in a way it isn't designed due to improper sequence of construction, the result can be a catastrophic failure immediately or lead to major problems later in the life of the structure. The effect of locked in stresses when the slab is supported by props should be carefully addressed and the sequence of construction should be followed to avoid any unfavourable situations.

Construction Stage Analysis: It is the structural analysis for a particular structure during its construction. We analyse the structure for the various loads like wind loads, equipment loads, live loads and the dead load that would affect the structure's behaviour. It is essential to carry out construction stage analysis because the structural elements like beams and columns would not have reached their full strength and are supported by props to avoid sudden collapse. However, when the props are removed to construct the next portion, the structure should be stable against all loads. During construction, there might be various loads that don't come on the structure during its service life time, such as crane loads or equipment loads. These load cases might govern its design; hence it is essential to conduct a construction stage analysis for structures that might have critical loads on structural elements during the construction period.

Pre-camber: Usually, slabs deflect downward from their original position due to the various loads applied on it. To avoid this, a technique called Pre-Camber is adopted in which the slab is designed to have curvature in the opposite direction after its construction. Hence, props of different heights are used to support it, and finally after the construction is complete and the props are removed, the slab will eventually bend and deflect, and we would have a slab that is flat with zero curvature in either direction.

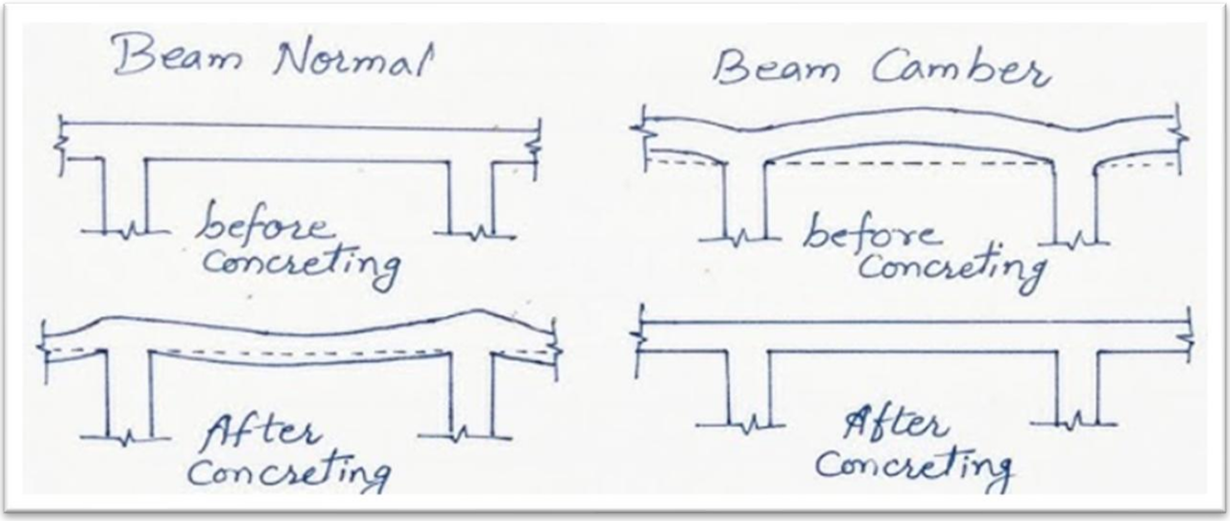


Fig 26: Camber

Low Carbon Concrete: Concrete that results in minimal carbon emissions during its entire life cycle, that is, from production until demolition is termed as Low Carbon Concrete. It can be achieved through usage of recycled aggregates, better curing, replacing of Cement with SCMs like fly ash, calcined clay, etc. It is currently used in green certified buildings (LEED, IGBC) and in metro, airports, etc.

High Performance Concrete: It is concrete with higher strength, durability, resistance to environmental conditions, not just compressive strength but overall performance. Currently it is used in High-rise buildings, long span bridges, marine structures, prestressed concrete members, industrial floors, etc. HPC often has high cement content and can be non-sustainable, but by the use of SCMs, recycled aggregates it is can be tailored to use in harsh environments for long term performance and low maintenance.

U bars: U-bars are often used in RC design for the economic and structural benefits they offer. They provide improved anchorage and help in developing full bond strength especially where straight bars cannot be provided due to space constraints. They provide extra embedded length due to the 2 legs and bends they have, also reducing the risk of pull out. One might be tempted to always use the U-bars but in case enough distance isn't provided before the bend there is chance of the U-bar failing. As a rule of thumb, one must avoid U-bars if the length available is less than 300 mm.

Fig 27: U-Bars

Poor Workmanship: Poor Workmanship simply means disaster. Even with a perfect design, poor workmanship can cause huge problems to the project either during the construction or soon after, the design life will simply not be fulfilled, as is the case with most projects in India. As a precaution to this, designers often take higher design values than required, analyse with lower grade of materials and recommend usage of higher grade which will lead to higher costs, but if not done with the workmanship available it will lead to a catastrophic failure. But is this the right thing to do? What can be done about this? It is nothing but upskilling of the labours – more programs by the government, the labour contractors, investment by companies on quality labour (it will have high short-term cost, but eventually with time the benefit will show in quality and efficiency). Proper site supervision and strict quality assurance measures must be taken. A long-term solution must be opted for, for the temporary ones like over design is just delaying a disaster to happen.

Arbitration: Construction projects are more often than not plagued with delays, quality issues, payment disputes and misunderstanding with the parties involved. When a mutual agreement cannot be reached in such matters, the parties involved chose Arbitration over moving the courts, as the former offers low and expensive judgements. The parties in question appoint a neutral arbitrator who conducts hearings, reviews documents, witnesses and does cross questioning and then awards a legally binding decision which the parties must follow. It helps avoid long court battles and allows for a more private dispute resolution.

Tunnels

In the construction of a Tunnel, often a desired smooth surface is not obtained at first. If the surface is behind of the desired line of the tunnel and needs filling, it is called an Over break and if the surface is protruding outward and needs to be removed/ cutoff, it is called an Under break. The space within the desired line of the tunnel is called the Kinematic Envelope. This is the final product in the construction of a tunnel, through which trains, metro, roads, etc may pass.

Fig 28: KPS UG Metro Main Tunnel

Hills/ mountains are made up of rocks and building tunnels through them is a meticulous task. There are high temperature differentials between the inside and the outside of a tunnel during construction. The outside temperature in regions like Ladakh can go below -15° and the inside region can have temperatures as high as +35°. This can cause serious issue for the workers; hence proper ventilation system should be provided to allow the workers to work in a safe environment. The opening of the tunnel is first constructed and is termed as the portal and then the construction of the entire tunnel begins. It is divided into segments with each segment at different stage of construction. Tunnels are bored using various techniques: using the New Austrian Tunnelling Method (NATM), Tunnel Boring Machine (TBM), Box Pushing, Cut and Cover etc.

Described below is an overview of the NATM:

The Kinematic envelope to be constructed is divided into parts with the top region termed as the Heading and the bottom region termed as the bench. Explosives are drilled into the middle portion of the Heading at some angle to increase the area of target. Controlled blasting is performed and this method is continued until the desired envelope is formed. Jet sprays are used to settle down the smoke released due to the blasting and there is ventilation system provided to allow the workers to work in a proper condition.

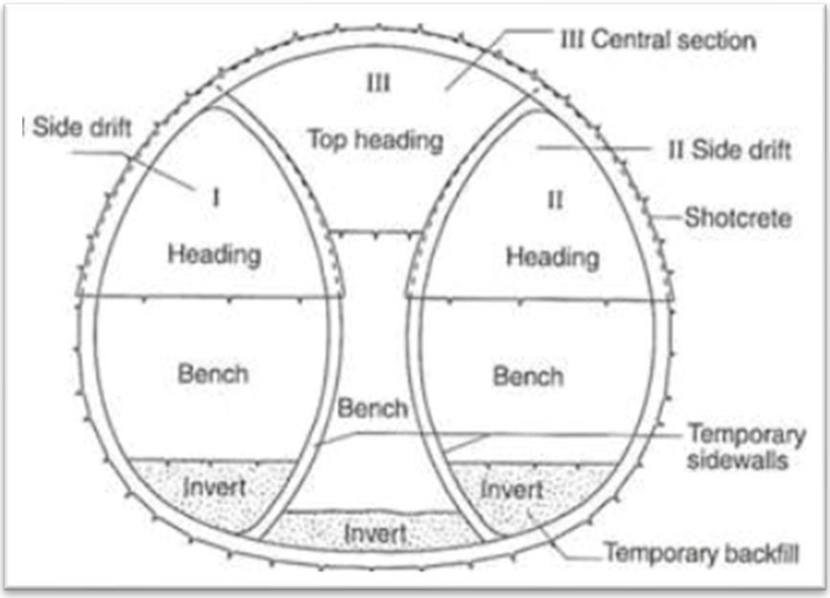


Fig 29: Demarcation for Blasting of Tunnel using NATM

The section last operated on for boring of the tunnel is termed as the Tunnel Face. The region just before is exposed rock. Shotcrete is done to stabilise the tunnel as soon as more length is bored. As the Shotcrete is done, waterproofing membrane is provided to prevent water leakage and avoid associated problems.

The earlier regions already bored are then lined with precast concrete tunnel members up to the portal as the boring progresses further ahead. For the lining of the precast members, anchor bolts are used and the holes are filled with grout.

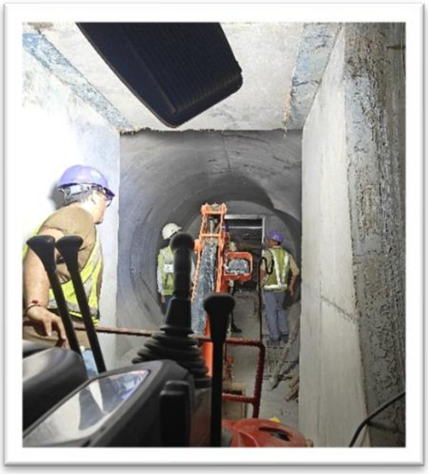


Fig 30: KPS UG Metro Cross Passage

Jumbo/ Carrier is an essential support system used during tunnelling. They are large carrier type temporary structures with wheels used to reach higher points of access in a tunnel, for waterproofing, cutting of extra soil/ rock, arrangement of rebar for the lining and rock anchoring.

There are cross passages provided to move from one tunnel to another in case of an emergency and exit tunnels connected with the main tunnel are also provided for safety purposes.

STAAD.Pro

STAAD.Pro is a structural analysis and design software developed by Bentley Systems Inc. that is used to model, analyse and design structures in compliance with national and international codes. It can perform code compliance checks for IS, ACI, BS, Eurocode, etc and be integrated with Revit, AutoCAD and BIM software.

The basic steps involved to model and analyse structures are as follows:

1. Select Space/plane/truss, etc based on the type of structure you want to model. Select the option to add beams/ solids/ plates, etc as per your requirement.

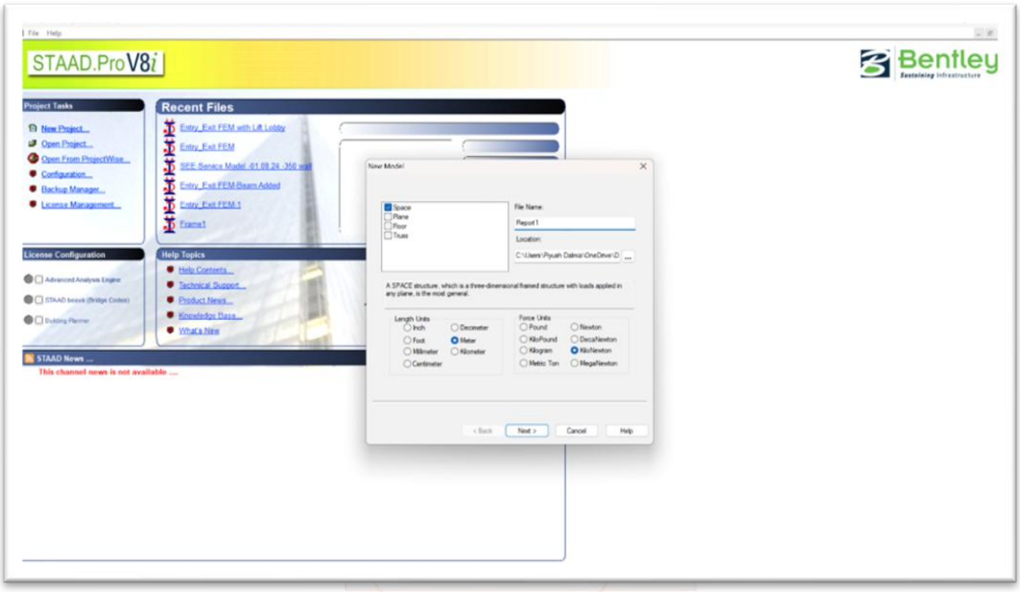


Fig 31: Select Model Type

2. Add nodes (coordinates) as per the critical positions in the structure.

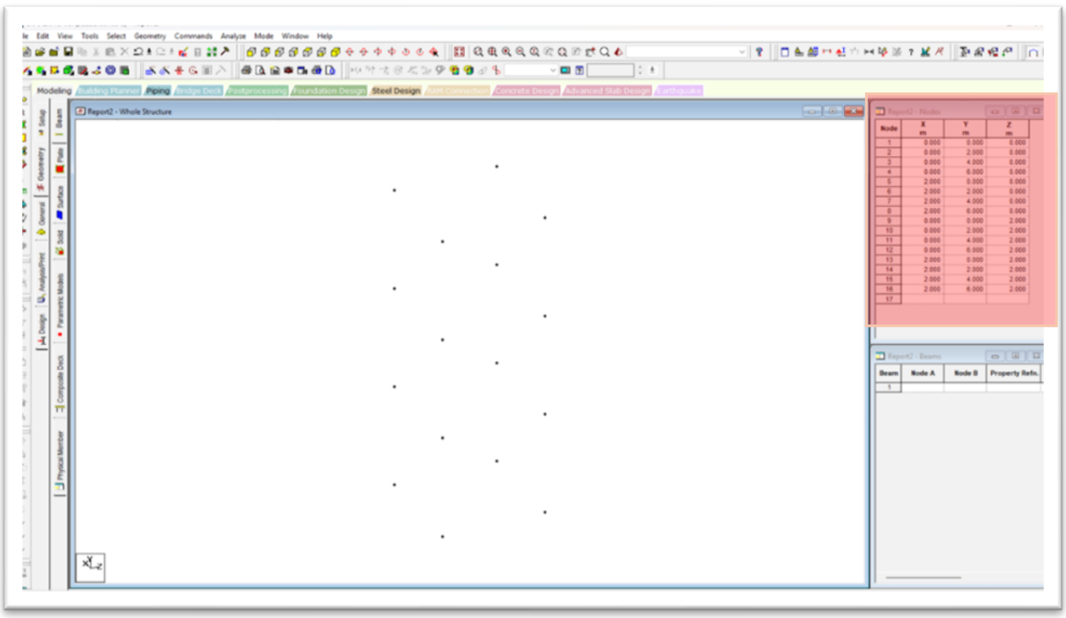


Fig 32: Add coordinates as per drawing

3. Connect the nodes using beams to simulate the element as a beam or column. Use plate to simulate a wall or a slab.

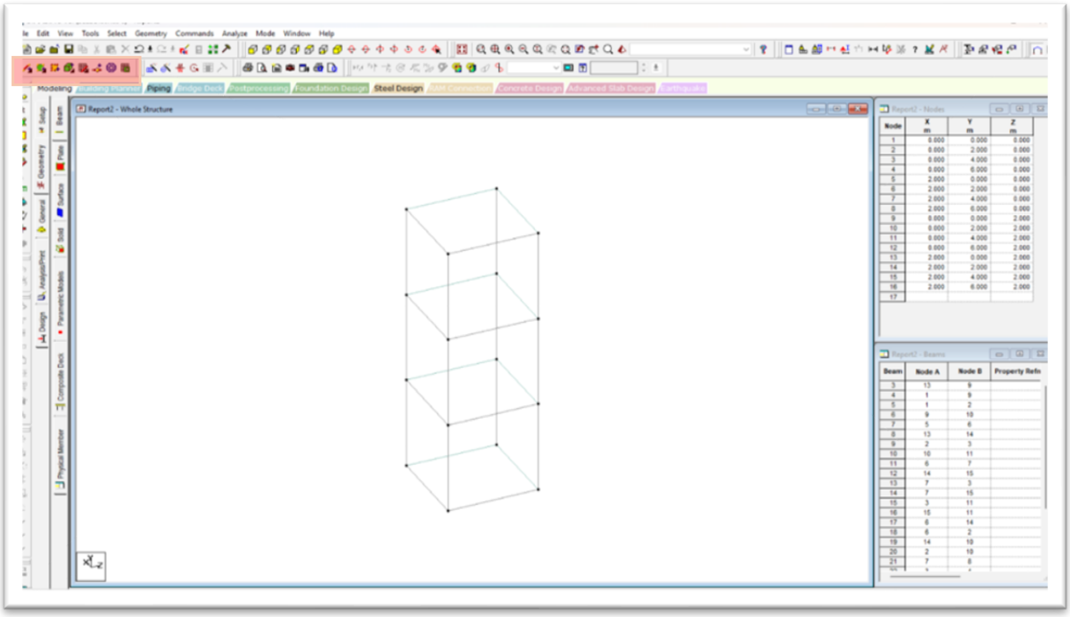


Fig 33: Assign Beams/ Plates by connecting nodes

4. Assign supports to the nodes (fixed and pinned are available, roller can be designed using the "Fixed but" option.

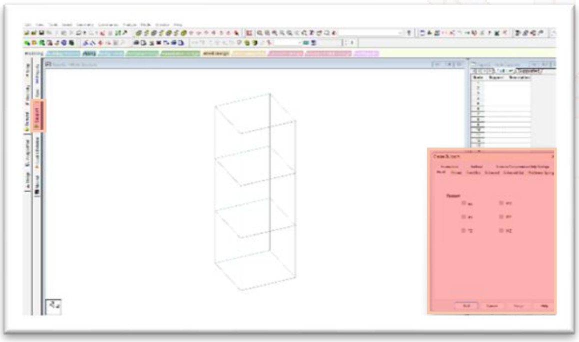


Fig 34: From Support Option create the support you need

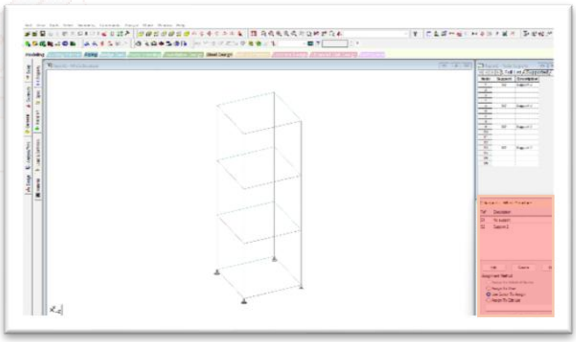


Fig 35: Assign the support to the nodes as per drawing

5. Check for duplicate nodes, beams, plates and other elements.

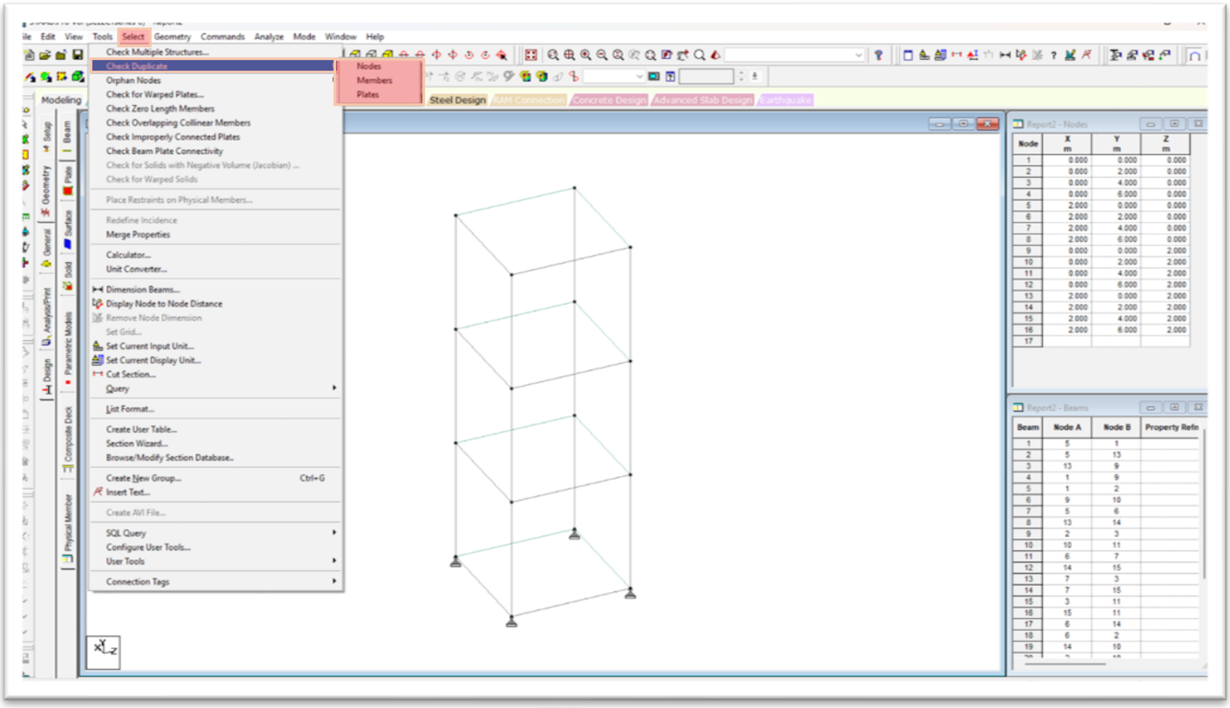


Fig 36: Check for duplicate nodes, members, nodes from the Select Option

6. Add section dimensions and material properties for all structural elements.

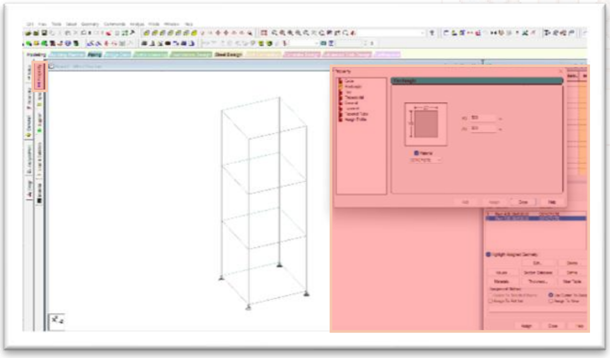


Fig 37: Create Section as per requirements from Property Option

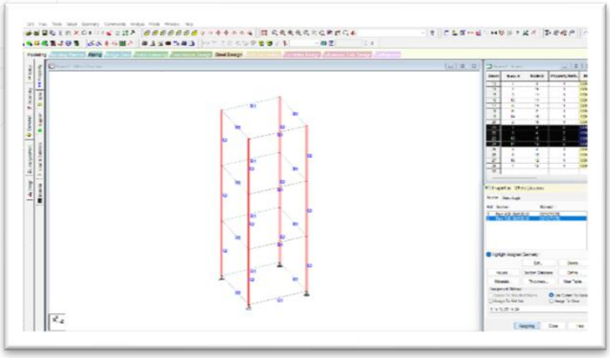


Fig 38: Assign the sections to the structural elements

7. Add loads and the various load combinations for the structure to be analysed.

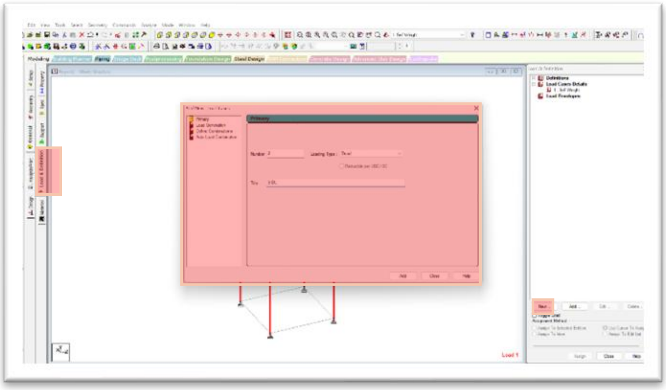


Fig 39: Create New Load Cases from the Load & Definition Option

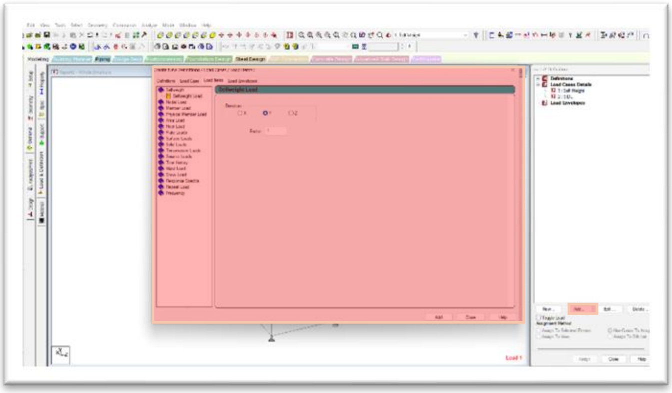


Fig 40: Add Loads (DL, LL, etc) as per requirements and define how they will act (Point load, Uniform Pressure, etc)

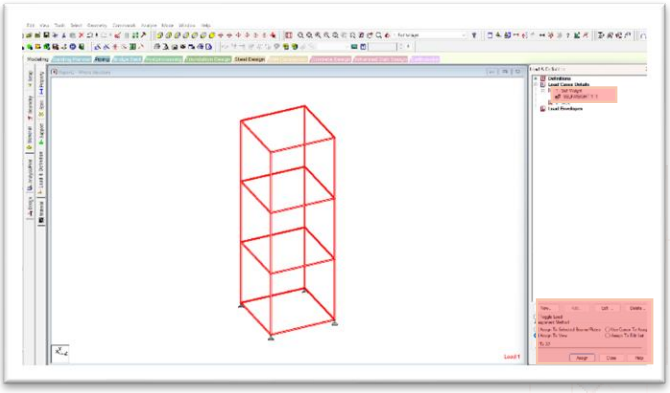


Fig 41: Assign loads to the structural elements

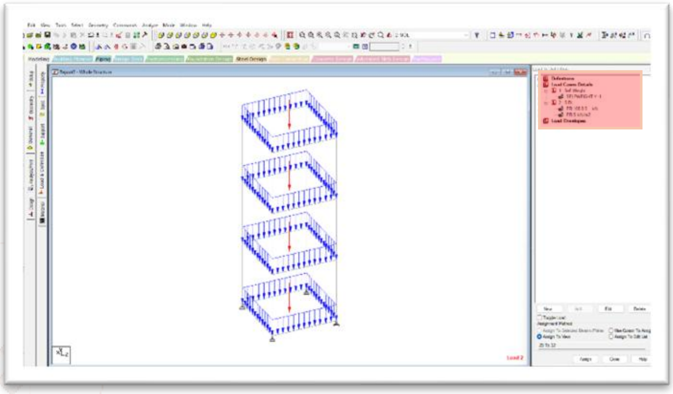


Fig 42: We can add various load combinations

8. Choose your design code and the run the analysis.

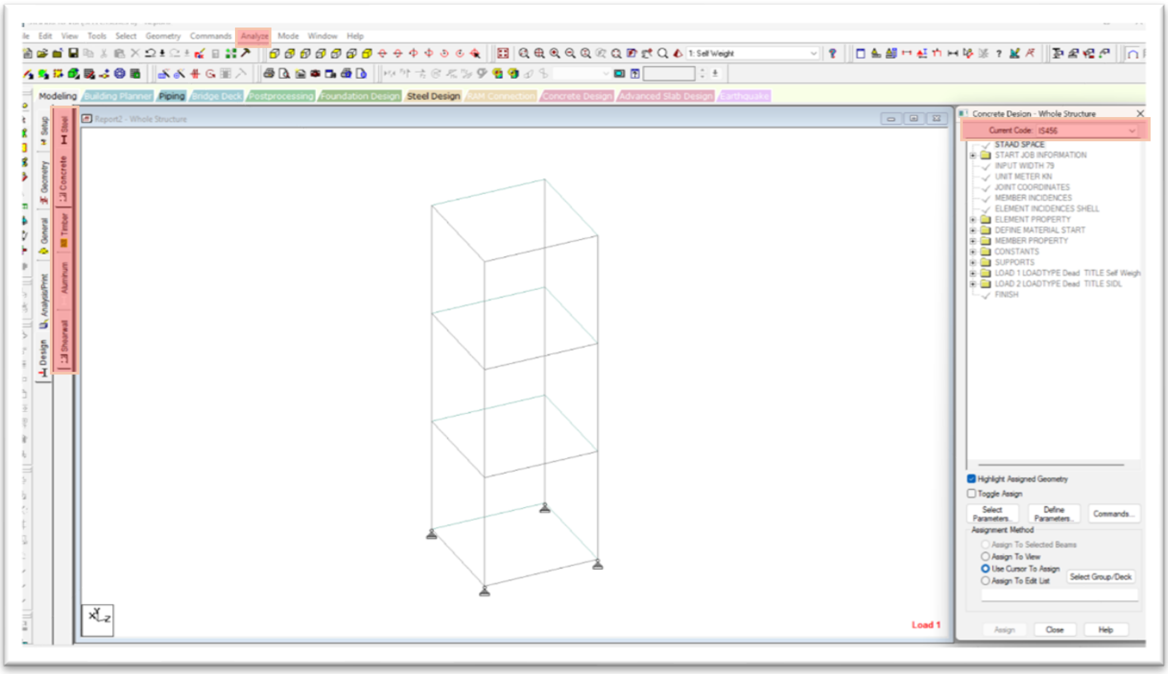


Fig 43: Choose the design code from the drop down as material and compliance requirement

9. You can view the deflection of nodes, bending moment diagrams, shear force diagrams, axial forces, etc using the various options available after going to the postprocessing section
10. Check if any structural element has failed.

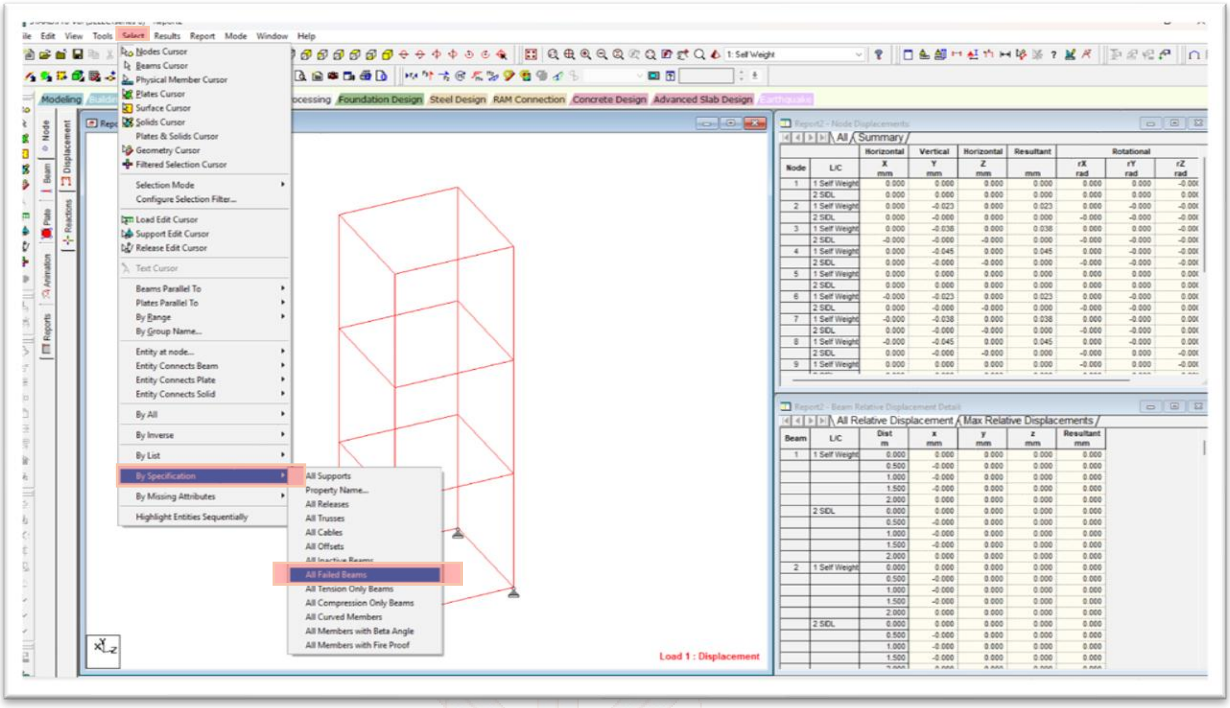


Fig 44: From Select Options choose by specification option to check if any beam has failed

11. Using the data available for various forces/moments acting on the structure, you may perform the SLS and ULS checks, or command STAAD.Pro to design the elements for you.

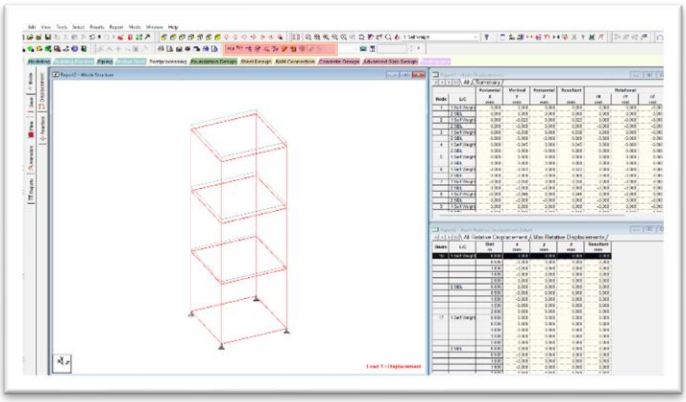


Fig 45: Deflection

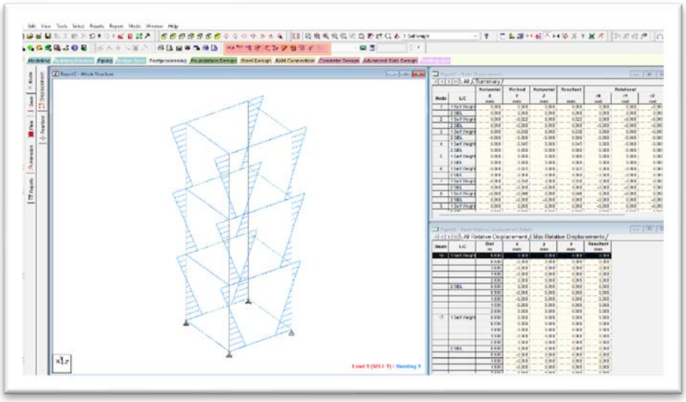


Fig 46: Bending

It is essential to watch out for the global and local axis for the structural elements. The forces/ moments for nodes are displayed as per the global axis while for beams/ plates it is displayed as per their local axis. To avoid confusion, we must ensure that the global and local axis align with each other and have the same direction.

As a suggestion, the beams should start from the left and end at the right (the longitudinal axis of the beam should align with the positive direction of the global axis it is being assigned in) and the plates ends should be connected in clockwise direction. If a uniform convention is followed then the user should not face any difficulty in understanding the results or receive absurd outputs.

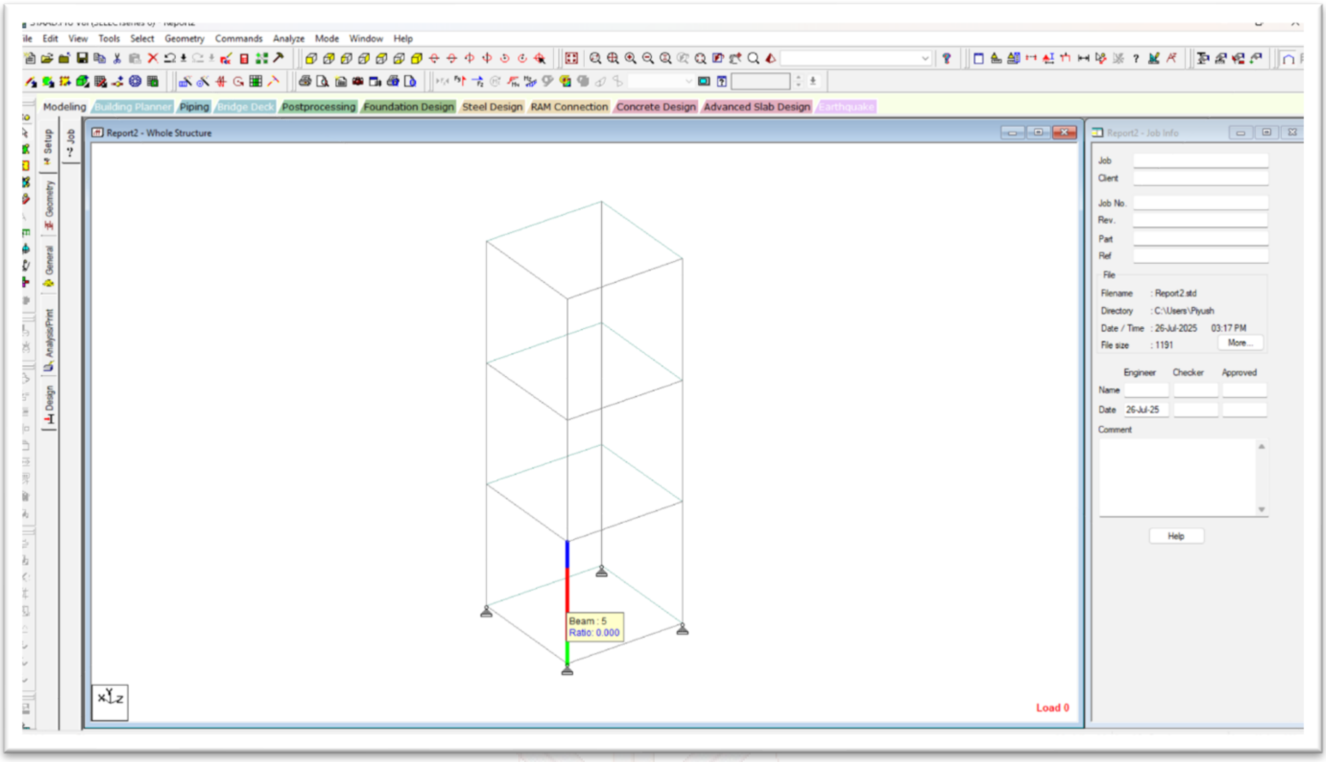


Fig 47: Green shows start of the beam and the blue shows the end of the beam

For sections like beams, the force results must be viewed from the “Section Forces” option and not the “Beam End Forces” since the former displays results with respect to global axis which is uniform provide the sign conventions are adhered to. Beam End forces provide forces at the ends of the beam with respect to the local axis which has will have different sign for 2 beams at the same joint. For slabs, the “Plate Stresses” options provide detailed results of the shear forces, axial forces and bending moments acting on it.

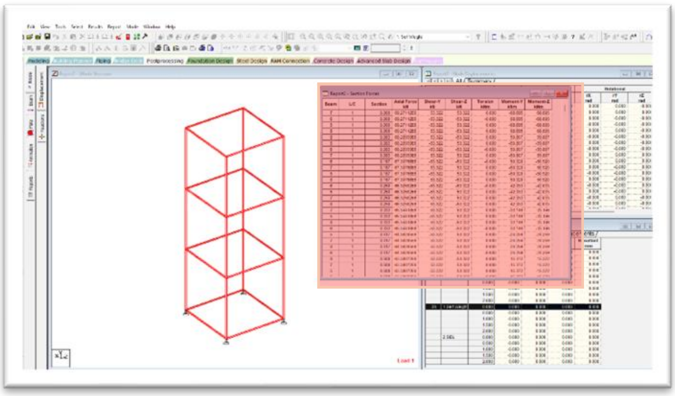


Fig 48: Section Forces sorted by Axial Forces on Member

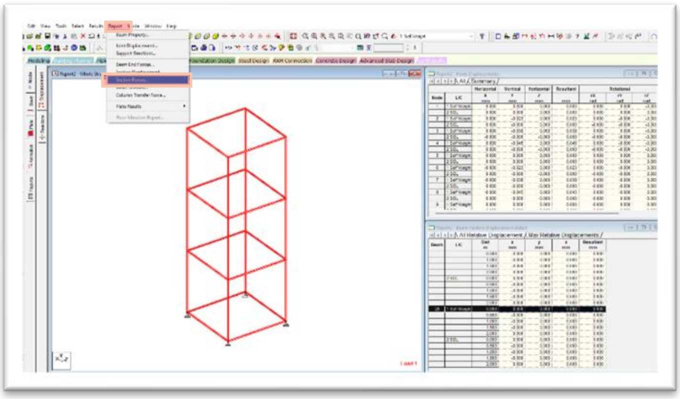


Fig 49: Select Section Forces from the Report Option

There's something called the 'Envelope' that is displayed as an option below the Load cases. It can be considered as an aggregate of all cases, and it displays the maximum and minimum values of each force/ moment that would come on the structure for the loads cases assigned.

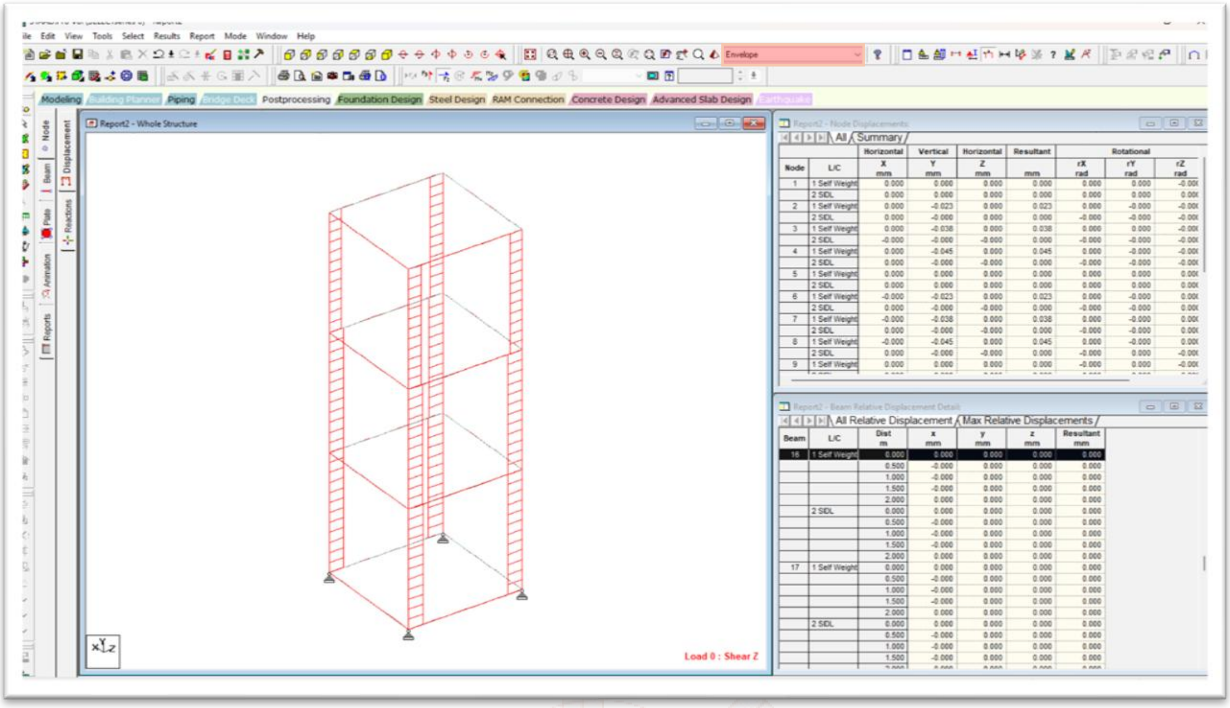


Fig 50: Force Envelope for Shear in Z Direction

Excel Models

During the internship, I was given some problems to solve by Er. Vivek Abhyankar and with his guidance I tried to automate their solution using Excel. The three major problems I worked upon are listed below:

- **Loading in a circular arch (UDL & Point Load):** The problem was to find out the reactions at the supports in a Three Hinged Circular arch for a point load at the centre. I solved it manually for 1 case and then tried to create an automated excel model that can find the reactions, bending moment and shear force for any given 3 hinged circular arch pinned at support for UDL or a point load at any point. I have successfully developed the model to find reactions and bending moments for the above cases and am working on automating the solution for shear force for the same. The user must enter the details of the Arch such as the radius, the angle subtended at the centre, whether the load is UDL or point load and the location from the first support if it is a point load and then the reactions and bending moment is automatically calculated.

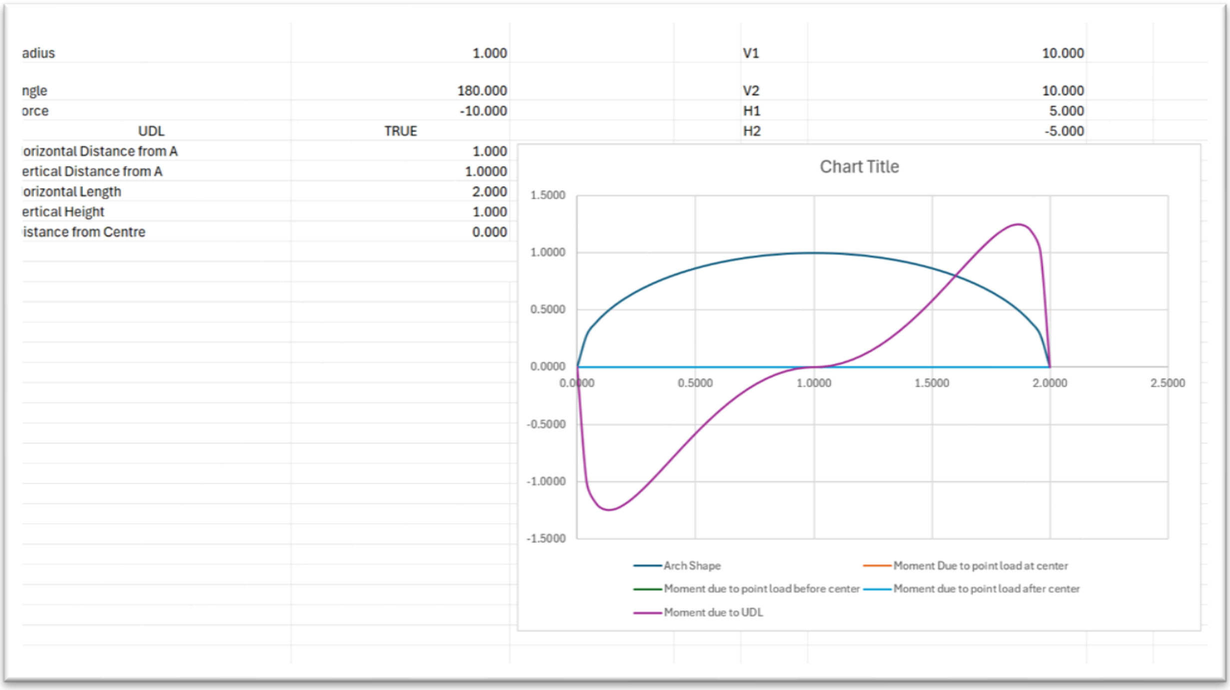


Fig 51: BMD for an Arch under UDL

- **Optimal Bridge Width and Angle:** This problem was to find the optimal bridge width for a span of a bridge given the distance between the two supports and the angle subtended by the arc are variables as well. The idea is to ensure that the geometric cg and the load cg are within the line of supports for the bridges and are not too far apart from each other which would otherwise cause high uplift pressure leading to a collapse of the bridge. The result I found was for a fixed distance between 2 supports (D), breadth (B) varying from 0.2 times the distance to 2 times the distances, the maximum angle allowed for the bridge rises from 55° for B = 0.2D to 105° for B = D & 1.5 D and then drops again to 100° for B = 2D.

Distance B/w Points (m)	Breadth of the Span	Item	5	10	15	20	25	30	35	40	45	50
10.00	10.00	Radius	114.628	57.369	38.306	28.794	23.101	19.319	16.628	14.619	13.066	11.831
		Span (Arc Length)	10.003	10.013	10.029	10.051	10.080	10.115	10.157	10.206	10.262	10.325
		Deflection	0.109	0.218	0.328	0.437	0.548	0.658	0.770	0.882	0.995	1.108
		Outer Support Line	119.514	62.131	42.936	33.280	27.435	23.490	20.627	18.436	16.690	15.254
		Geometric Center	114.664	57.441	38.414	28.936	23.276	19.525	16.864	14.882	13.354	12.141
20.00	20.00	Radius	229.256	114.737	76.613	57.588	46.202	38.637	33.255	29.238	26.131	23.662
		Span (Arc Length)	20.006	20.025	20.057	20.102	20.160	20.230	20.314	20.412	20.523	20.649
		Deflection	0.218	0.437	0.655	0.875	1.095	1.317	1.539	1.763	1.989	2.217
		Outer Support Line	239.028	124.262	85.872	66.561	54.870	46.980	41.253	36.872	33.381	30.508
		Geometric Center	229.328	114.882	76.828	57.872	46.552	39.050	33.727	29.765	26.708	24.283
30.00	30.00	Radius	343.884	172.106	114.919	86.382	69.303	57.956	49.883	43.857	39.197	35.493
		Span (Arc Length)	30.010	30.038	30.086	30.153	30.239	30.345	30.472	30.618	30.785	30.974
		Deflection	0.327	0.655	0.983	1.312	1.643	1.975	2.309	2.645	2.984	3.325
		Outer Support Line	358.542	186.394	128.808	99.841	82.305	70.470	61.880	55.308	50.071	45.762
		Geometric Center	343.993	172.323	115.242	86.808	69.829	58.575	50.591	44.647	40.062	36.424
40.00	40.00	Radius	458.512	229.474	153.226	115.175	92.405	77.274	66.510	58.476	52.263	47.324
		Span (Arc Length)	40.013	40.051	40.114	40.204	40.319	40.461	40.629	40.824	41.047	41.298
		Deflection	0.436	0.873	1.311	1.750	2.190	2.633	3.078	3.527	3.978	4.434
		Outer Support Line	478.056	248.525	171.744	133.122	109.740	93.960	82.506	73.743	66.762	61.016
		Geometric Center	458.657	229.763	153.656	115.743	93.105	78.100	67.455	59.530	53.416	48.566
50.00	50.00	Radius	573.140	286.843	191.532	143.969	115.506	96.593	83.138	73.095	65.328	59.155
		Span (Arc Length)	50.016	50.064	50.143	50.255	50.399	50.576	50.786	51.030	51.309	51.623
		Deflection	0.546	1.092	1.639	2.187	2.738	3.291	3.848	4.408	4.973	5.542
		Outer Support Line	597.570	310.656	214.680	166.402	137.175	117.449	103.133	92.179	83.452	76.270
		Geometric Center	573.321	287.204	192.071	144.679	116.381	97.625	84.318	74.412	66.770	60.707
Span/Radius Ratio			0.087	0.175	0.262	0.349	0.436	0.524	0.611	0.698	0.785	0.873
Span/ Breadth Ratio			1.000	1.001	1.003	1.005	1.008	1.012	1.016	1.021	1.026	1.032
Breadth/Radius Ratio			0.087	0.174	0.261	0.347	0.433	0.518	0.601	0.684	0.765	0.845

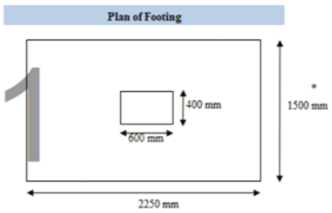
Distance B/w Points (m)	Breadth of the Span	Item	55	60	65	70	75	80	85	90	95	100	105	110	115	120
10.00	10.00	Radius	10.828	10.000	9.306	8.717	8.213	7.779	7.401	7.071	6.782	6.527	6.302	6.104	5.928	5.774
		Span (Arc Length)	10.395	10.472	10.557	10.650	10.751	10.861	10.980	11.107	11.244	11.392	11.550	11.719	11.899	12.092
		Deflection	1.223	1.340	1.457	1.576	1.697	1.820	1.944	2.071	2.200	2.332	2.466	2.603	2.743	2.887
		Outer Support Line	14.040	12.990	12.065	11.237	10.483	9.789	9.143	8.536	7.960	7.409	6.880	6.369	5.872	5.387
		Geometric Center	11.158	10.345	9.663	9.083	8.583	8.148	7.766	7.427	7.124	6.850	6.602	6.374	6.164	5.968
20.00	20.00	Radius	21.657	20.000	18.612	17.434	16.427	15.557	14.802	14.142	13.563	13.054	12.605	12.208	11.857	11.547
		Span (Arc Length)	20.789	20.944	21.114	21.300	21.503	21.722	21.959	22.214	22.489	22.784	23.099	23.437	23.798	24.184
		Deflection	2.447	2.679	2.915	3.153	3.395	3.640	3.889	4.142	4.400	4.663	4.931	5.206	5.486	5.774
		Outer Support Line	28.080	25.981	24.131	22.473	20.966	19.578	18.286	17.071	15.919	14.819	13.761	12.738	11.744	10.774
		Geometric Center	22.316	20.690	19.326	18.165	17.166	16.297	15.532	14.854	14.248	13.701	13.203	12.747	12.327	11.937
30.00	30.00	Radius	32.485	30.000	27.917	26.152	24.640	23.336	22.203	21.213	20.345	19.581	18.907	18.312	17.785	17.321
		Span (Arc Length)	31.184	31.416	31.671	31.950	32.254	32.583	32.939	33.322	33.733	34.175	34.649	35.156	35.697	36.276
		Deflection	3.670	4.019	4.372	4.729	5.092	5.460	5.833	6.213	6.600	6.995	7.397	7.809	8.229	8.660
		Outer Support Line	42.120	38.971	36.196	33.710	31.449	29.367	27.429	25.607	23.879	22.228	20.641	19.107	17.616	16.160
		Geometric Center	33.473	31.035	28.989	27.248	25.749	24.445	23.299	22.282	21.372	20.551	19.805	19.121	18.491	17.905
40.00	40.00	Radius	43.314	40.000	37.223	34.869	32.854	31.114	29.604	28.284	27.127	26.108	25.209	24.415	23.714	23.094
		Span (Arc Length)	41.578	41.888	42.228	42.600	43.005	43.444	43.918	44.429	44.978	45.567	46.199	46.874	47.597	48.368
		Deflection	4.894	5.359	5.829	6.306	6.789	7.279	7.778	8.284	8.800	9.326	9.863	10.411	10.972	11.547
		Outer Support Line	56.160	51.962	48.262	44.946	41.932	39.156	36.572	34.142	31.838	29.638	27.522	25.476	23.487	21.547
		Geometric Center	44.631	41.380	38.652	36.331	34.333	32.593	31.065	29.709	28.496	27.401	26.406	25.495	24.654	23.873
50.00	50.00	Radius	54.142	50.000	46.529	43.586	41.067	38.893	37.005	35.355	33.909	32.635	31.512	30.519	29.642	28.868
		Span (Arc Length)	51.973	52.360	52.785	53.251	53.757	54.305	54.898	55.536	56.222	56.959	57.748	58.593	59.496	60.460
		Deflection	6.117	6.699	7.287	7.882	8.486	9.099	9.722	10.355	11.000	11.658	12.329	13.014	13.715	14.434
		Outer Support Line	70.200	64.952	60.327	56.183	52.414	48.945	45.715	42.678	39.798	37.047	34.402	31.845	29.359	26.934
		Geometric Center	55.789	51.725	48.315	45.414	42.916	40.742	38.831	37.136	35.620	34.252	33.008	31.869	30.818	29.842
Span/Radius Ratio			0.960	1.047	1.134	1.222	1.309	1.396	1.484	1.571	1.658	1.745	1.833	1.920	2.007	2.094
Span/ Breadth Ratio			1.039	1.047	1.056	1.065	1.075	1.086	1.098	1.111	1.124	1.139	1.155	1.172	1.190	1.209
Breadth/Radius Ratio			0.923	1.000	1.075	1.147	1.218	1.286	1.351	1.414	1.475	1.532	1.587	1.638	1.687	1.732

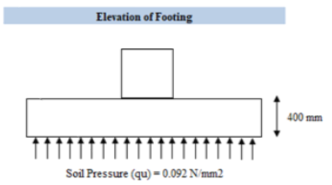
Fig 52: Calculation for Max angle for a Span = Distance b/w points of support

Shown above are the calculations assuming B = D, and we can see that marked in red, the angles after 105° fail for each span as the geometric cg is not within the line of supports.

- **Axially Loaded Pad Footing:** Some columns of the South Entry Exit Canopy and Lift Lobby of Kapodra UG Metro Project did not have a RC Wall to transfer the loads to the soil, hence isolated footings had to be designed for it. I made an excel model to automate the calculation of the required footing area, the depth of the footing, checks against one-way and two-way shear and bending and reinforcement requirements in both directions. The calculations are currently automated for axial loads only and not no eccentric loading or moment transfer from the columns.

a)	**Given Data**				
	Grade of Concrete	=	M35		
	Grade of Steel	=	Fe500		
	Column Breadth	=	400	mm	
	Column Thickness	=	600	mm	
	$x_{u, max}$	=	0.479d		
	$p_{t, min}$	=	0.12	%	
	$M_{u, lim}$	=	$0.138f_{ck}$		
	Factored Axial Load on Column	=	280	kN	
	Safe Bearing Capacity of the Soil (Assumed)	=	100	kN/m^2	
b)	**Size of Footing**				
	Factored Load on Footing	=	308.000	kN	
	Area of Footing	=	3.080	m^2	
	Footing Breadth	=	1500	mm	
	Footing Length	=	2250	mm	
	Clear Cover (Assumed)	=	75	mm	
	Rebar Dia (Assumed)	=	16	mm	
c)	**Upward Soil Pressure**				
	Soil Pressure (q_u)	=	0.092	N/mm^2	
d)	**Depth of Footing**				
	k_s	=	1.000	N/mm^2	
	t_c	=	1.479	N/mm^2	
	t_v	=	1.479	N/mm^2	
	Depth Provided (Assumed)	=	400	mm	
	d	=	309	mm	
	Case 1: One Way Action				
	Width 1	=	550	mm	
	Width 2	=	825	mm	
	Width to be used for One Way Shear Check	=	825	mm	
	Length to be used for One Way Shear Check	=	2250	mm	
	Vu on Shaded Region	=	106.81	kN	
	Vu resisted by Concrete	=	1028.29	kN	Ok





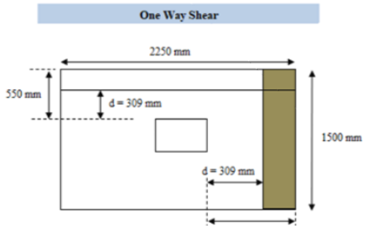


Fig 53: One Way Shear Check for Pad Footing

Case 2: Two Way Action

Shaded Area	=	2730519.00	mm^2	
Bo	=	3236	mm	
Vu on Shaded Region	=	251.21	kN	
Vu resisted by Concrete	=	1478.91	kN	Ok

e) **Bending Moment**

My	=	31.309	kN-m	
Mx	=	13.915	kN-m	
$M_{u, lim}$ should be greater than	=	31.309	kN-m	
Effective Depth d Required	=	81	mm	Ok

f) **Steel**

Y Direction

A_{st} required	=	360	mm^2	
A_{st} min	=	1080	mm^2	
Spacing Provided (Assumed)	=	150	mm	
A_{st} provided	=	2793.42	mm^2	Ok

X Direction

A_{st} required	=	530	mm^2	
A_{st} min	=	720	mm^2	
Spacing Provided (Assumed)	=	150	mm	
A_{st} provided	=	1788.11	mm^2	Ok

g) **Summary of Design**

Depth of Footing	=	400	mm
Breadth of Footing	=	1500	mm
Length of Footing	=	2250	mm
Cover	=	75	mm
Rebar Dia	=	16	mm
Steel in X Direction	=	16 Φ @ 150mm c/c	

Fig 54: Two Way Shear Check and Reinforcement Requirements for Pad Footing

The user must provide details of the elements in red – column dimensions, grade of steel and concrete, axial load coming onto the footing, rebar size to be used and spacing between them, desired cover and footing depth. Based on these inputs the model can do the aforementioned checks and inform the user if the footing depth and reinforcement desired is passing the checks.

Visits & Technical Webinars

Kapodra UG Metro: Kapodra Underground metro station is a part of the Surat Metro Rail Project Phase 1 under Gujarat Metro Rail Corporation (GMRC) Limited. The tender was awarded by GMRC in March 2021 and is being built by Gulermak-Sam India Builtwell JV as part of Package CS2/UG-01, which is a 3.46 km stretch connecting Kapodra Ramp to Surat Railway Station. The package includes the construction of three underground stations: Kapodra, Labheshwar Chowk, and Central Warehouse, along with the associated tunnels and finishes.

SGAWings Consultants are responsible for the design of the Ancillary Building, South Entry Exit, Fireman Staircase and the Toilet block for the Kapodra UG Metro of Surat. SGAWings team organized a site visit to the metro station on 5th June, 2025 in which I was fortunate enough to have been a part of.

I learned about the various elements in construction like plunge columns, diaphragm walls, capping beams, couplers, drill and bond technique, different types of piles, etc. It was an exhilarating experience to see the complexities of construction at site and how different it can be from designing in an office. I have compiled a detailed site report for interested readers and it can be accessed from the following link: *KAPODRA UG METRO SITE VISIT REPORT*

Fig 55: KPS Metro Site Visit

I was presented with the opportunity to analyse and design a RCC Framed Structure for the Canopy of the South Entry Exit and the Lift Lobby for this Station. I analysed the model on STAAD.Pro for dead loads, live loads, hook loads and wind loads. The structure was designed using excel sheets for the Ultimate Limit state and the Serviceability limit state. Due to lack of provision of RCC walls for some columns, isolated footings had to be designed as well.

KNEST Aluform Factory Visit: The Indian Society of Structural Engineers (ISSE) organized a factory visit in collaboration with Knest Manufacturers to Knest Aluform Factory in Talegoan, Pune on 21st June, 2025. Our team at SGAWings took part in this factory which provided us insights into Aluminium formwork and its manufacturing process. The visit comprised a guided tour to two of their major production units — Factory 1 and Factory 3. Factory 1 showcased a semi-automated setup, where robotics are integrated into several key production stages, while Factory 3 is a fully automated facility, demonstrating advanced manufacturing processes with minimal human interventions. We gained valuable insights into aluminium formwork systems, the manufacturing workflow, and the various quality tests conducted on raw materials to ensure durability and precision. The visit provided us with a deeper understanding of how aluminium formwork can be utilized for faster construction, and how automation is enhancing efficiency in the manufacturing of aluminium formwork. A detailed understanding can be obtained from the following Factory Visit Report prepared by Er. Sanket Mali:

TECHNICAL VISIT REPORT TO KNEST ALUMINIUM

Fig 56: KNEST Aluform Factory Visit

Mechanized Reinforcement and Tall Structures: ISSE in collaboration with Tata Steel had organized a webinar on Mechanized Reinforcement Solutions and Structural Engineering of Tall buildings on 11th July, 2025. The first session was conducted regarding mesh reinforcement and how it is an economical alternative to reinforcement using HYSD in slabs, roads and some more mechanical specifications. The second session on tall buildings by Er. Ranjith Chandnuni was an overview of the various aspects in the construction of a tall building.

He spoke about the various loads affecting the design of tall buildings – governing majority of which are seismic loads and wind loads. Wind loads were discussed in detail regarding what are its effects, the return period to be designed for and what considerations must be made while designing. By taming the wind through building orientation, corner modifications, etc we can significantly reduce its effect on the structure.

The cost due to floors and columns remains almost constant and vary linearly respectively with increase in building height but there is significant increase in cost due to the Lateral Load resisting systems (LLRS). LLRS are necessary for the structure to be safe and resilient.

There was brief information provided on some types of LLRS like Cores & Outriggers and Tubes & Modular Tubes. Smart use of these systems reduces the sway of the building by almost 50%. Special considerations like column shortening – approximately 1mm for every 1m, the effect of which might be significant for tall buildings which are usually over 150m in height. We must also consider the effects of high heat of hydration due to the high strength concrete used (M45 – M90) for raft foundations. Innovative formwork to reduce the timeline of construction while also ensuring high quality can be opted like Jump formwork.

Overall, it was a brief but insightful webinar organized by ISSE on new technological advancement in formwork and overview on design of Tall Buildings.

Fig 57: ISSE Webinar on Mechanized Reinforcement and Tall Structures

Organizations and Technical Publications

There are multiple civil/ structural engineering societies in India and being a part of these associations definitely enhances a person's growth – both technically and professionally. To name a few societies that I have come across during my internship:

1) ISSE: Indian Society of Structural Engineers is a professional body headquartered in Mumbai for Structural Engineers in India and was founded in 1999. Their aim is to promote structural engineering knowledge, research and best practices.

2) IAStructE: Indian Association of Structural Engineers is a leading body of Structural Engineering Professionals that works closely with BIS, CPWD and some international bodies. It conducts regular technical lectures, releases technical publications, hosts design competitions to promote Structural Engineering.

3) IEI: The Institution of Engineers India is one of the oldest professional bodies of India for engineers from all branches, founded in 1920 and is recognized by Govt. of India, AICTE and international bodies like FEANI, WFEO, etc. It conducts technical sessions, training and certification programs, event and workshops, etc to promote engineering education and ethics.

I had the opportunity to go for a Factory Visit to Knest Aluform conducted by ISSE and a technical webinar on Mechanized Reinforcement solutions and Structural Engineering for tall buildings also conducted by ISSE and sponsored by TATA Steel. These sessions were very well organized by the ISSE team and helped me understand a lot of technical details about Aluminium formwork, mechanized mesh formwork and about the design of tall buildings. Many organizations like ISSE, NBM&CW, IRC, etc release technical publications frequency and reading them is a fantastic way of staying updated with trends, innovations and best practices in Civil Engineering.

ISSE publishes their journal every quarter which comprises technical papers on structural analysis, design, case studies of actual structures, special issues on structural failures, code updates, etc from academics and industry professionals.

NBM&CW – New Building Materials & Construction World releases a monthly magazine that comprises news on metro projects, highways, smart cities, case studies on precast and high-rise construction, interview with accomplished individuals in the field, information on emerging materials and technology, etc.

IRC – Indian Roads Congress releases IRC Codes and Manuals that are to be complied with for construction of Roads, highways and bridges, etc. They also release IRC Journal and reports by their technical committee which serve as a source of knowledge for engineers and consultants in the field.

As a student or a Young Professional, being updated with such publications and staying connected with organizations provide opportunity for networking with experienced engineers, professors and peers in the industry, sharing of knowledge and help stay updated with latest innovations, IS Code revisions and design practices. Hence, it is highly recommended to choose to be a member of such societies promoting Civil Engineering as it is essential to deliver the standards that are expected for a project and build structures that are elegant and can stand the test of time.

Conclusion

Two months cannot be described in some 30-40 pages. This report serves as a documentation of all the learnings and observations I have made during this internship at SGAWings. The discussions with the team, the explanations by Er. Vivek G. Abhyankar and Er. Abhijeet V. Gawai, the experience from site and factory visits, learning how to use STAAD, basics of civil engineering, clarity of thought, some information about the construction industry and the relationships made with everyone at SGAWings – I believe these would be my take-ways from this duration of 2 months. It was indeed a short duration but a memorable experience and I shall count on this to make some good decisions in my life.

To everyone at SGAWings, thank you for bearing with me, thank you for your patience, thank you for the opportunity and thank you for everything in between.