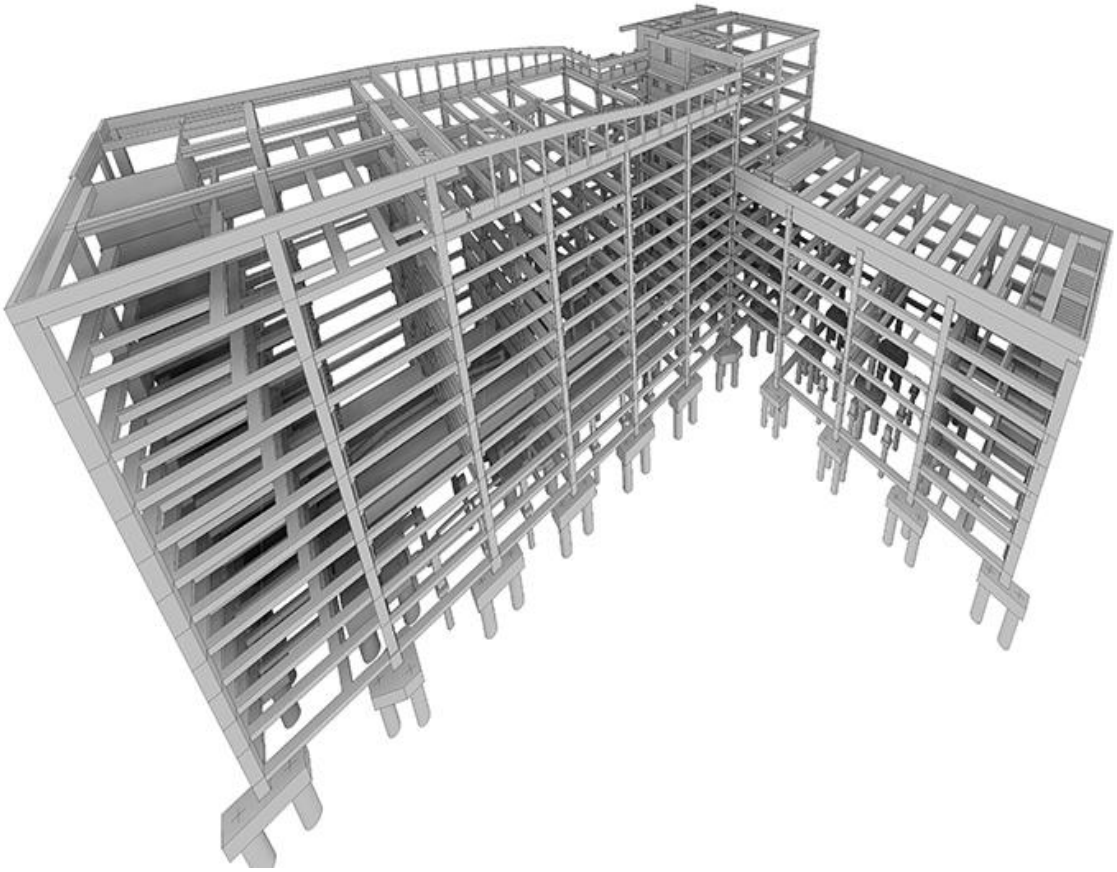
Building and Construction Authority

BIM Essential Guide

For C & S Consultants



BCA acknowledges the leadership provided by the BIM Steering Committee in support of the production of the BIM Essential Guides

The BIM Essential Guides have been drafted by the Centre for Construction IT on behalf of BCA and the BIM Steering Committee.

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Contents

CEO's Message

Dear readers,

Building Information Modelling (BIM) has gained much traction in recent years as digital construction technology that will fundamentally transform the building and construction industry practice in the delivery of an excellent built environment. It is a game changing technology that will improve the construction productivity as well as the level of integration and collaboration across the various disciplines in the construction value chain. It is therefore important for the industry to embrace the technology with clarity.

The BIM Essential Guides are part of the industry's efforts to demystify BIM and to give clarity on the requirement of BIM usage at different stages of a project.

Under the leadership of the BIM Steering Committee chaired by Er Lee Chuan Seng, Emeritus Chairman, Beca Carter, and comprising of leaders in BIM, the BIM Managers Forum has contributed much time and effort to compile the various best practices to make this Guide possible over a short span of time. We would like to thank them for their contribution.

We hope that every BIM user can truly reap the benefits of BIM by integrating it into his/her day-to-day workflow – from feasibility study to facility management. We hope that BIM users can use these guides as a platform to jumpstart their BIM adoption, before they leap to greater heights, innovating and transforming their workflow.

BIM is a journey. We envisage that it will grow with time and will inspire more advanced and innovative use of BIM. I would like to encourage all BIM practitioners to join in this industry effort to grow this Guide into a wealth of BIM knowledge.

Dr John Keung

ACKNOWLEDGEMENTS

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Hybrid Structural Detailing	JTC Consultants
Structural BIM Model	AECOM
Structural BIM Model	P&T Consultants
Secondary Structural Elements Model	CityTech Consultants

OBJECTIVES

The objective of this Essential Guide is to assist C&S (Civil & Structural) to develop models in their BIM project, including New Construction and A&A Projects. It is a graphical guide that shows the possible use-cases of BIM for various Design Stages of the project.

This is a general document that covers a few typical buildings and not an extensive document that covers all scenarios that might arise based on specific projects. Users are allowed to edit/change accordingly to suit their needs.

This Essential Guide is not based on any particular BIM software and does not cover any explanation or steps on its usage. For help and guide for your specific BIM software, please refer to your software user manual.

Based on the project requirement, type and time line choose the BIM use and implement in the project.

Suggested BIM Deliverables

STAGE	SUGGESTED BIM DELIVERABLES (STRUCTURAL ONLY)
1. Preparation & Conceptual Design	a. Soil profile & foundation options b. Material use: concrete, steel, aluminium, etc… c. Construction method: in-situ, precast, prefab, etc. d. Design code to be used: ACI, BS, EN, etc.
2. Schematic Design	a. Preliminary Model based on Architectural Massing models b. Design Criteria / Brief, Framing Options & Alternate Design c. Preliminary structural analytical model d. Preliminary Design Coordination Report b/w Architectural & Structural models e. Preliminary cost estimate for Structural models
3. Detailed Design	a. Final Structural Model to produce ST & CD submission drawings b. Final structural analytical model and calculation report c. Clash detection & resolution report b/w Architectural, Structural & MEP d. Spatial Validation Report e. Detailed cost estimate, BOQ, tender docs prepared by QS
4. Construction	a. Design Validation Report (depth of piles, temporary structures, site restrictions, etc.) b. RFI Resolution & Constructability Report c. Contractor Model to produce Shop & Fabrication Drawings (rebar & steel) d. Single Services Drawings (SSD) & Combined Services Drawings (CSD) e. Detailed schedule of materials & quantities
5. As Built	a. As constructed drawings from Consultant b. Verification checks using laser scanners, survey data, etc…
6. Facility Management	a. As built Structural Model from Contractor

Note: Regulatory BIM e-submissions are excluded from the above list because the timing of submission may vary due to individual project requirements.

Concept Design Stage

UNDERSTANDING CLIENT REQUIREMENTS AND DESIGN PARAMETERS

Both the client and the engineer should reach an understanding on the purpose of BIM to fulfil Client's Requirements.

Example of some questions that can be asked to understand the Client's Requirements.

- What are the overall goals in this BIM project?
- What are the specific goals that have to be achieved by BIM in this BIM project
- What are the possible ways to achieve the specific BIM goals?
- Is the client aware and agreeable that the design team may use a different way achieve the specific BIM goals?

Suggested BIM Deliverables:

1) Prepare design criteria and project brief
2) Study soil report and explore foundation options.
   The Qualified Person (QP) the Professional Engineer (PE) shall identify what type of foundation best suit existing soil conditions.
3) Identify material (concrete; steel; timber; aluminium; glass) and grade to be used
4) Identify construction method: in-situ, precast, prefab etc.
5) Identify the code of practice (BS or EN) for structural design
6) Identify the extent of civil/external works but not limited to: road alignment; water supply; sewer and drainage; existing utilities survey; earthworks like soil excavation or backfill and electrical and communication supply enclosures

The preliminary Structural BIM Model could be referenced from the Architectural BIM model and serves as a preparation for the Detailed Design stage. Before starting the actual modelling, it is recommended to go through proper planning and preparation.

There are no BIM models under this stage.

Schematic Design Stage

PRELIMINARY STRUCTURAL MODEL

The Preliminary Structural Model (PSM) shall be based from the equivalent Architectural BIM model and serves as a reference for the next evolution of into Detailed Design stage. Before starting the actual modelling, it is recommended to go through proper planning and preparation by completing the BIM Execution Plan or BEP.
The PSM is suggested to include the following:

1) Initial sizes of all load bearing elements with indicative dimensions.
   Load bearing elements are defined as supporting a load of the structure above including its own weight shall be modelled. The QP/PE can exclude/ignore all non-load bearing elements like:
   - Doors & Windows
   - Dry Walls
   - Furniture
   - Curtain Systems like glass or precast cladding
   - Roof excluding Trusses
   - Planter Boxes and Drains
   - Prefabricated Bathroom Units (PBU)
   - Bay Windows, Parapets and Ledges
   - Staircase Railings
   - MEP Pipes, Ducts, Cable Trays, Fixtures, Terminals and Fittings

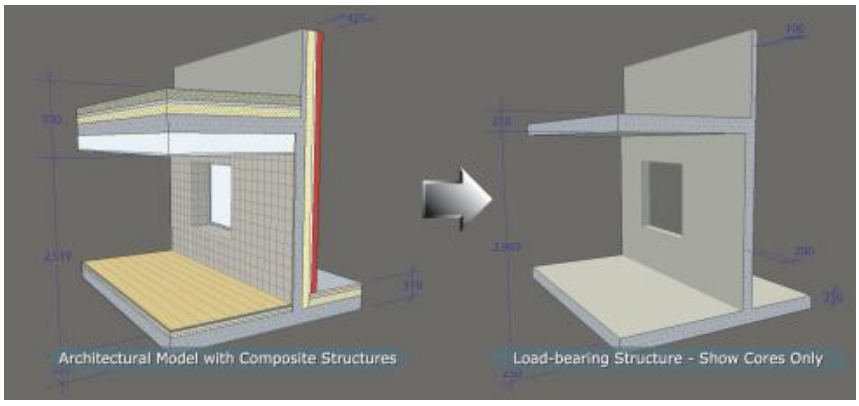


Fig. 1: Load Bearing Elements Only

2) Foundation elements like the following but not limited to:
    - Bored Piles
    - Spread/Isolated Footing
    - Retaining & Diaphragm Walls
    - Continuous Bored Piles (CBP) Walls
    - Mat Slabs or Raft Foundation
    - Soil Stabilization like Jet Grouting Columns and Micro Piles

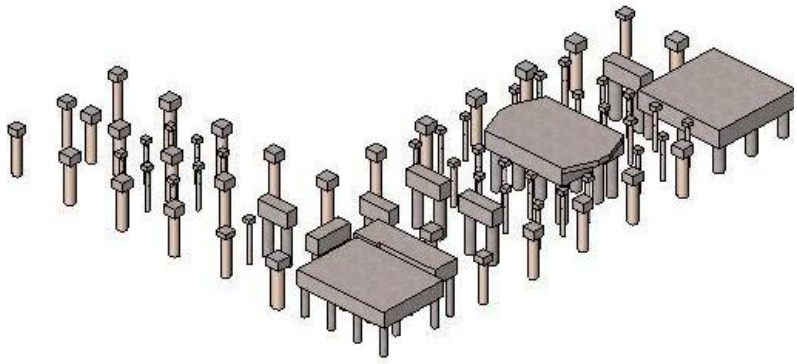


Fig. 2: Foundation Elements (Image courtesy of RSP)

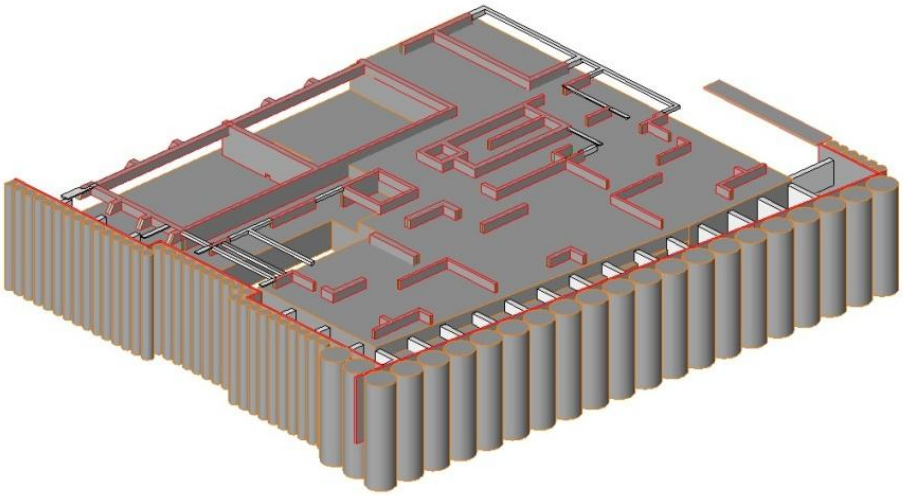


Fig. 3: Continuous Bored Pile (CBP) wall and Mat Foundation (Image courtesy of TYLin)

3) Digital Terrain Model (DTM) showing existing soil conditions and properties; soil contour and profile.

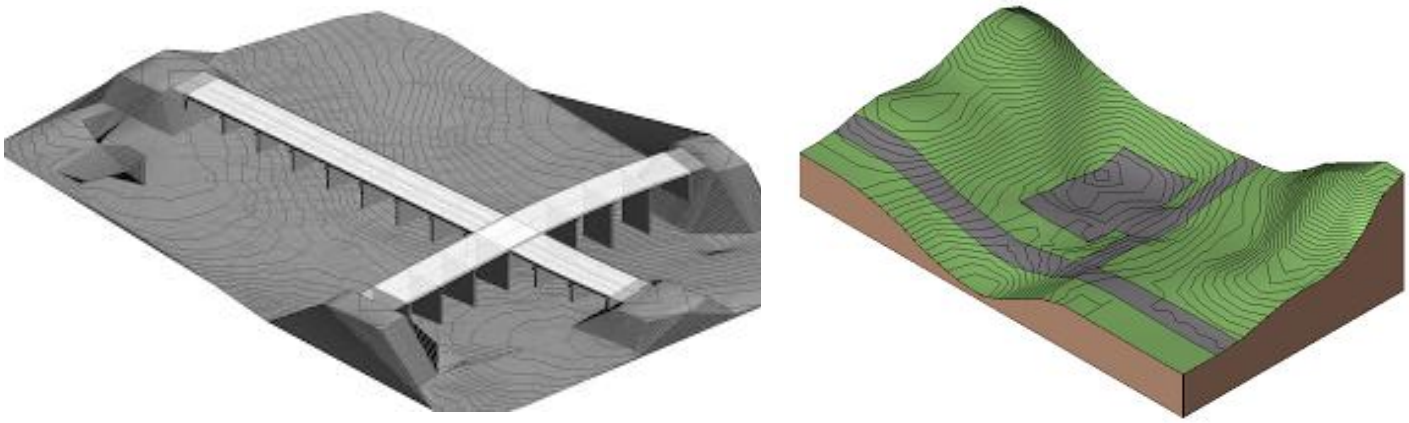


Fig. 4: Digital Terrain Model (Image courtesy of CCIT)

4) Design Object Library (DOL) of commonly used elements including unique objects like precast, post-tension and built up steel sections cut from plates.

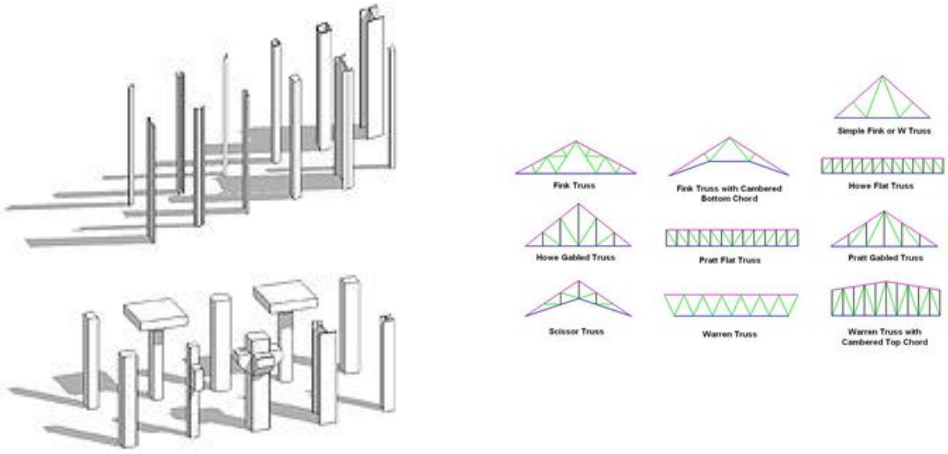


Fig. 5: Structural Objects-Columns and Trusses (Image courtesy of CCIT)

5) Modelling of primary load bearing elements:
    - Structural Columns
    - Structural Girders
    - Structural Floors (Suspended, Composite and Precast)
    - Structural Walls
    - Structural Foundations (Grade Beams, Piles & Pile Caps)
    - Tunnel Structures greater than 6.0 meters in depth and 1.0 in diameter
    - Structural Trusses
    - Crane and Hoisting Structures
    - Civil Defence (CD) Shelter
    - Bridge Piers

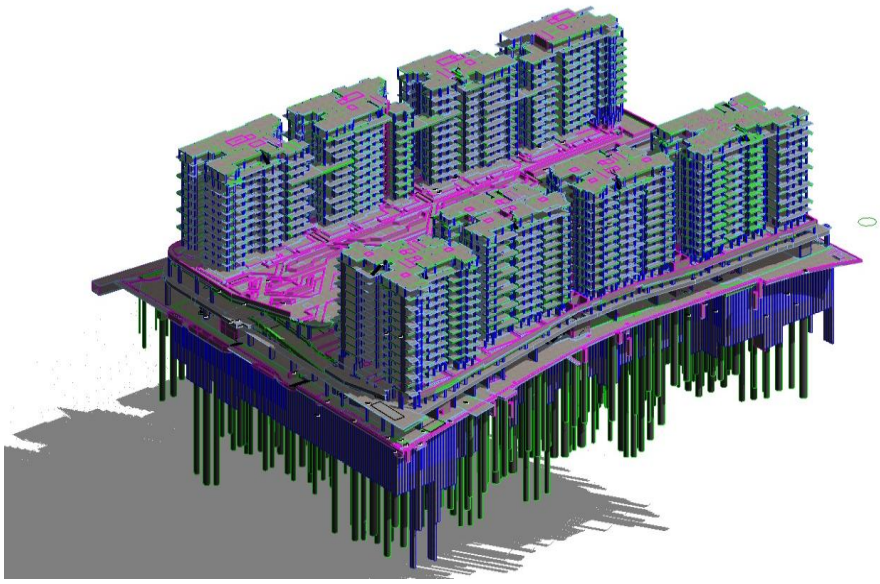


Fig. 6: Capitaland Bedok Mixed Development Model (Image courtesy of AECOM)

All objects shall be accurately classified into its correct construction material and category. For example, columns can either be made of reinforced

concrete or steel. Category refers to the classification system employed by the BIM authoring tool.

Fig. 7: Eco Sanctuary Superstructure Model (Image courtesy of P&T Consultants)

For example, avoid defining a column into a wall category. Downstream application like quantity take off and time scheduling are dependent on the defined categories of objects.

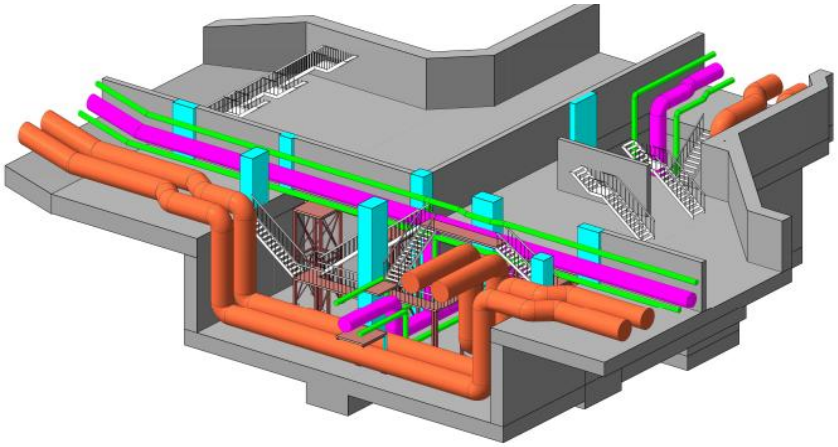


Fig. 8: URA Combined Services Tunnel (Image courtesy of Parsons Brinckerhoff)

6) M

- Structural Joist
- Structural Purlin
- Structural Bracing
- Staircase (Landing Beams; Stringers and Slabs)
- Plinth or Equipment Pads
- Ramps

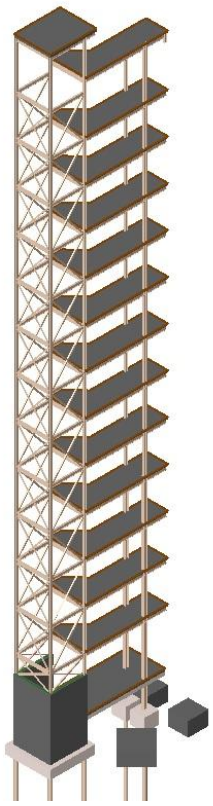


Fig. 9: HDB Lift Upgrading Program

(Image courtesy of CityTech Consultants)

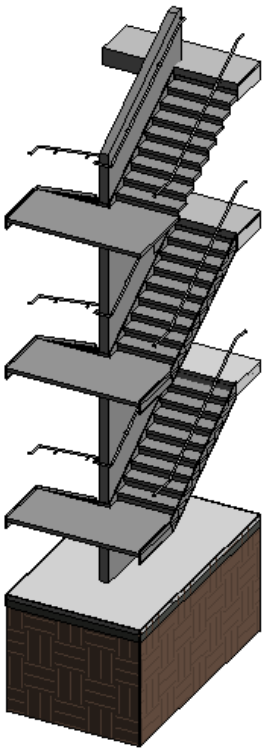


Fig. 10: Staircase Elements

(Image courtesy of CCIT)

Structural Analysis

ANALYTICAL MODEL FOR FOUNDATION DESIGN

Structural drawings are graphical representations of design calculations to the agreed code of practice as per BCA regulations. During the transition stage both the withdrawn British Standards (BS) and upcoming Euro codes (EN) are accepted.

1. Boundary conditions shall be properly defined in the BIM authoring tool for fixed, pinned and user defined supports like springs. Supports can be point for columns, line for wall footings and area for mat foundation and slab on grade.

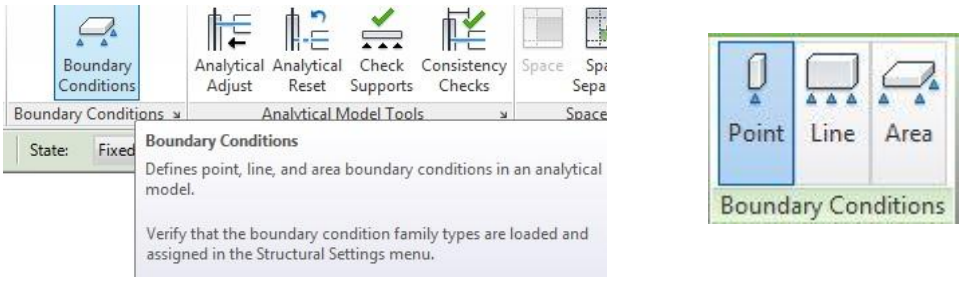


Fig. 11: Support/Boundary Conditions (Point, Line & Area)

2. Soil springs for piles, earth retaining structures shall be properly modelled based on the existing soil condition as described in the geotechnical report.

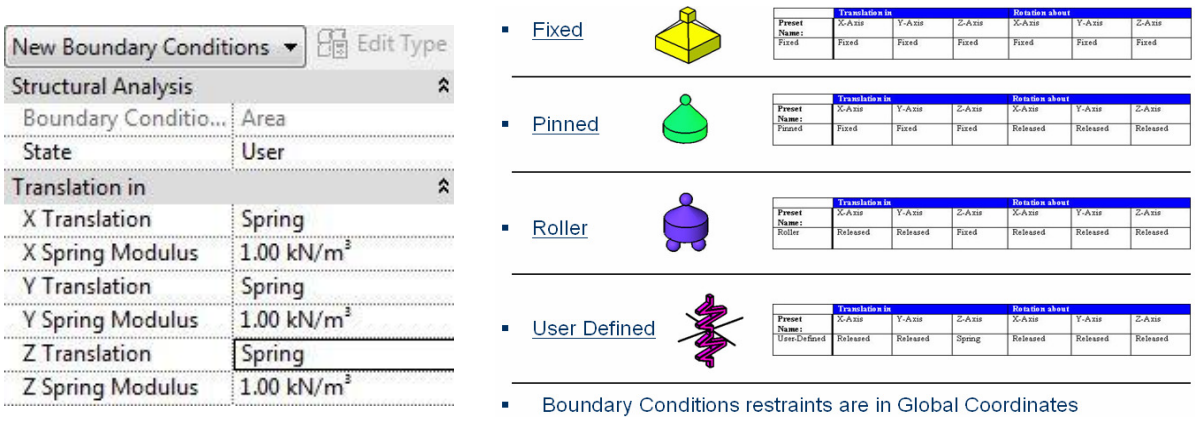


Fig. 12: Soil Spring Supports

ANALYTICAL MODEL FOR SUPERSTRUCTURE & MEMBER DESIGN

BCA encourages QP to synchronize the physical models generated by BIM authoring software with the structural analytical models created simultaneously used for member design.

1. All beams shall be modelled span to span to satisfy criteria for unsupported length in the analytical models

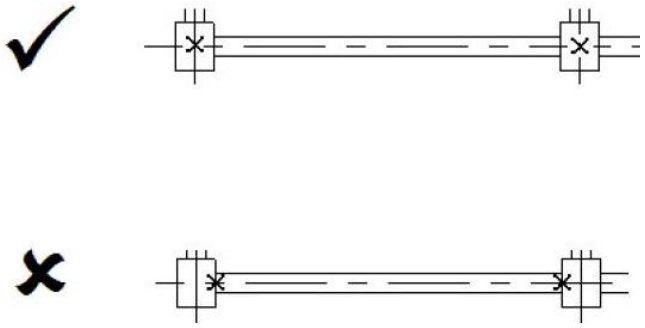


Fig. 13: Framing Elements span to span (Image courtesy of CSC)

2. All columns shall be modelled by level to satisfy criteria for slenderness ratio in the analytical models

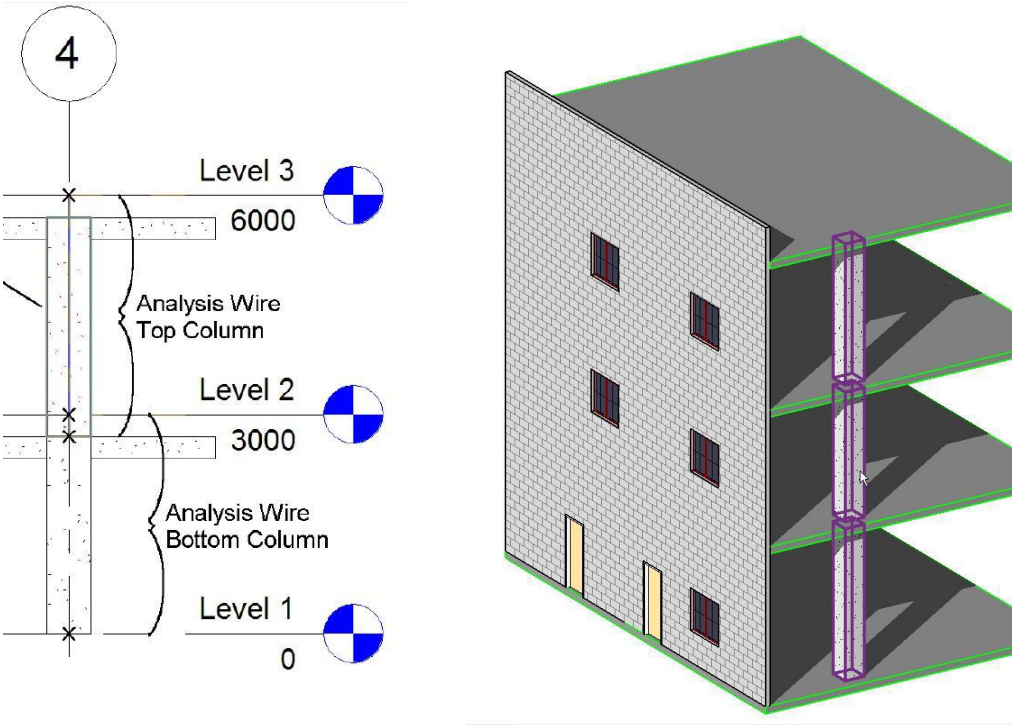


Fig. 14: Columns by Storey (Image courtesy of CSC & CCIT)

3. Slabs shall be modelled for every panel bounded by beams for proper load transfer. Consideration shall be taken for difference in elevation like drops and mezzanine floors. If slabs are modelled as single elements, care shall be exercised when converting to analytical models to make sure loads are decomposed to tributary magnitudes for triangular and trapezoidal load distributions.

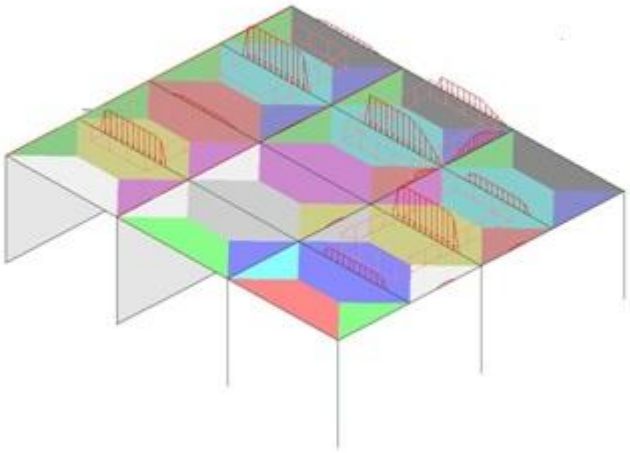


Fig. 15: Floor Slab Load Distribution (Image courtesy of CCIT)

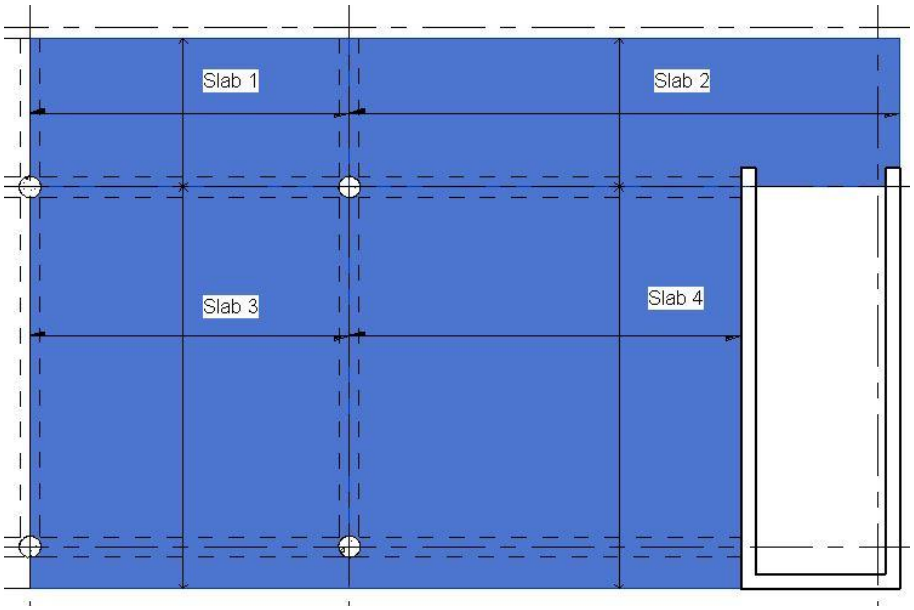


Fig. 16: Floor Slab Panel by Panel (Image courtesy of CCIT)

4. The analytical model created in parallel with the physical models in a BIM authoring software must be fully connected before exporting to 3rd party structural analysis engines. If necessary provide rigid links to connect offset analytical lines to each other.

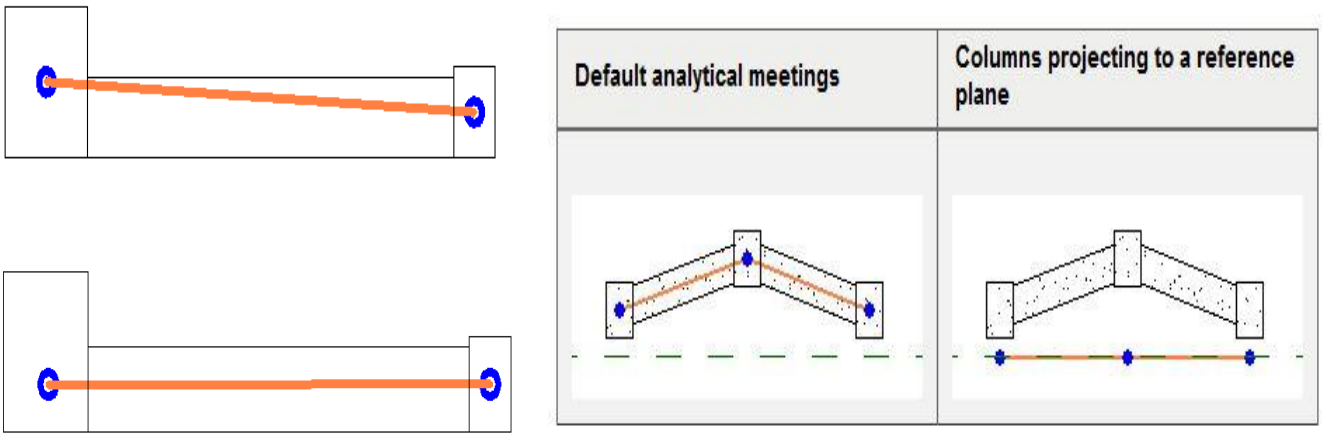


Fig. 17: Beam analytical lines corrected to reflect unsupported length (Image courtesy of CCIT)

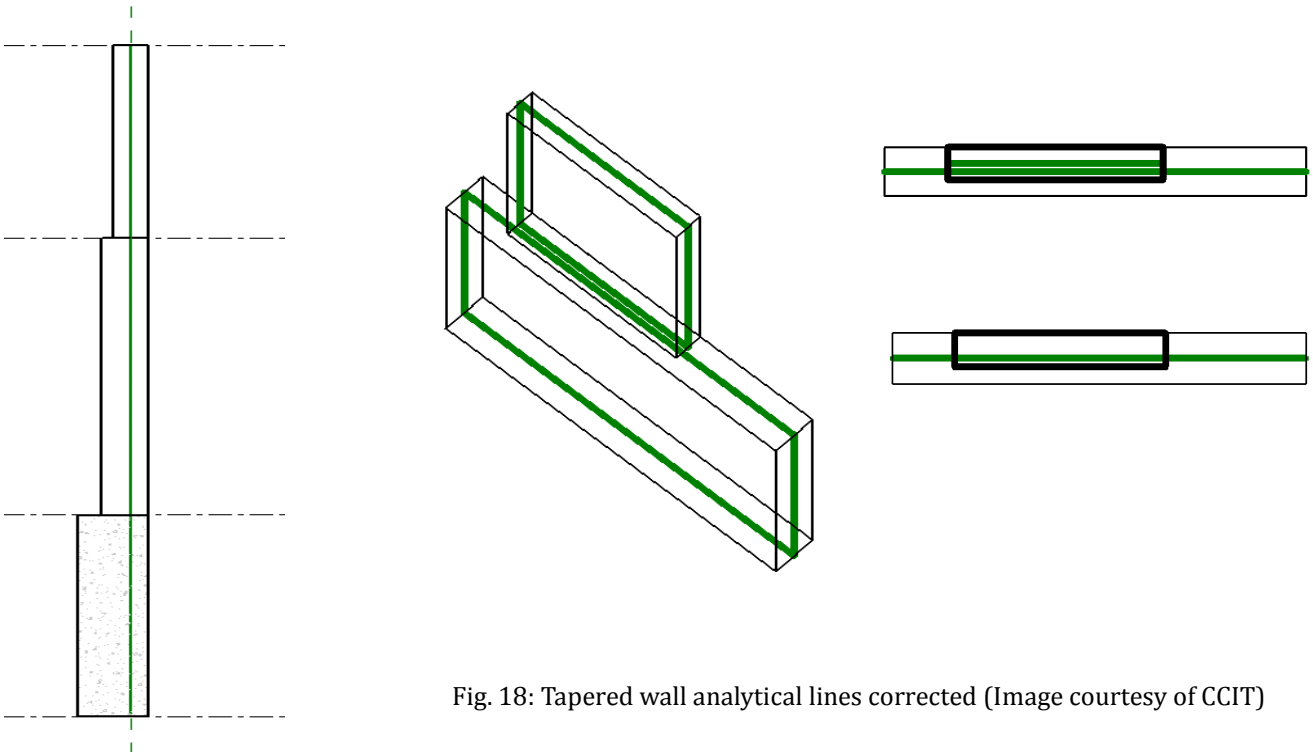


Fig. 18: Tapered wall analytical lines corrected (Image courtesy of CCIT)

Detailed Design Stage

SUBSTRUCTURE MODELLING GUIDELINES

Temporary works or earth retaining and stabilizing structures (ERSS) but not limited to:

1) Diaphragm & Earth Retaining Structures
2) Walers
3) Cofferdams
4) Piling Platform
5) Trenches and Excavations less than 6.0 in depth
6) Temporary slopes and Stockpiles

These structures generally are not required to be modelled unless the structure is intended to be permanently installed and not be disassembled upon completion of the construction.

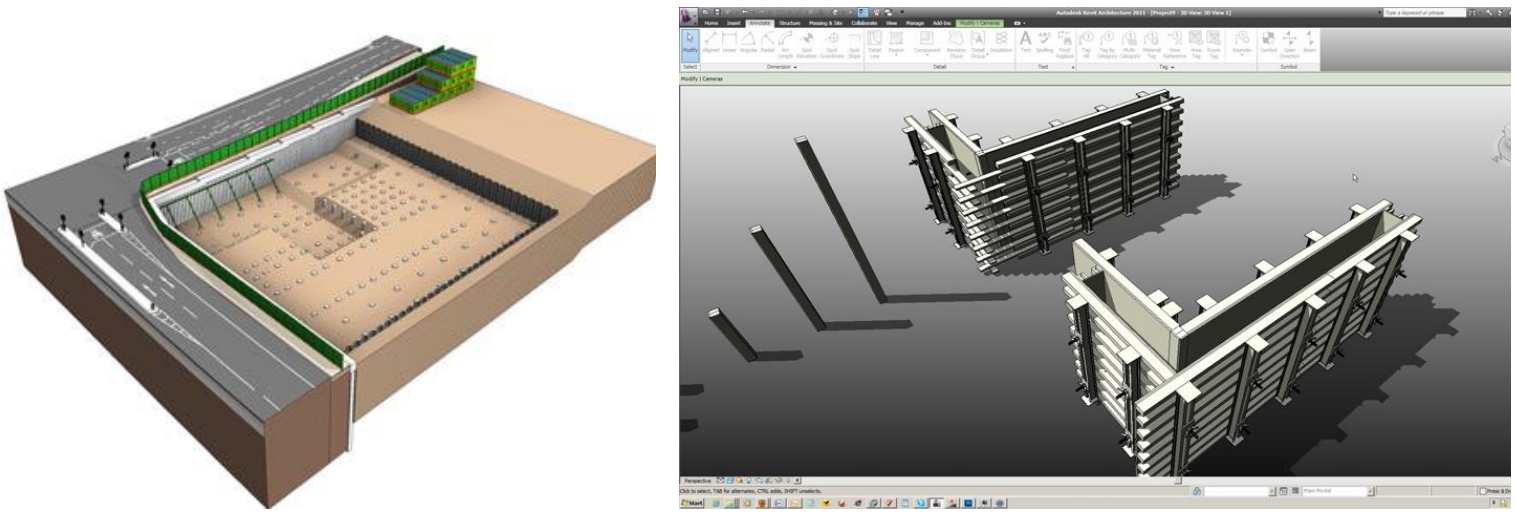


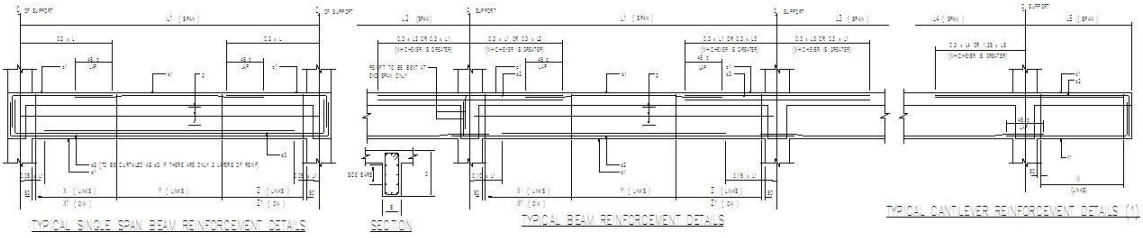
Fig. 19: Temporary Structures (Image courtesy of CCIT)

SUPERSTRUCTURE MODELLING GUIDELINES

1. Structural connections can be done in either 3D or 2D details. Connections can be reinforcing bars for concrete; bolts and welds for steel or steel members.

For rebar connections:

a. Rebar schedules for beam, column, walls and slabs are allowed.



BEAM MARKING	RC BEAM SIZE (BxH)	REINFORCEMENT						LINKS						R-BAR	REMARKS
1-BH81	300X800	3T16	3T16	3T16	3T20			T10-200	T10-200	T10-200					
1-BH82	300X800	3T16	3T16	3T16	3T20			T10-200	T10-200	T10-200					
1-BH83	300X800	3T16	3T16	3T16	3T20			T10-200	T10-200	T10-200					
1-BH84	300X800	3T16	3T16	3T16	3T20			T10-200	T10-200	T10-200					
1-BH85	300X800	3T16	3T16	3T16	3T20			T10-200	T10-200	T10-200					

Fig. 20: Structural Beam Schedule (Image courtesy of JTC)

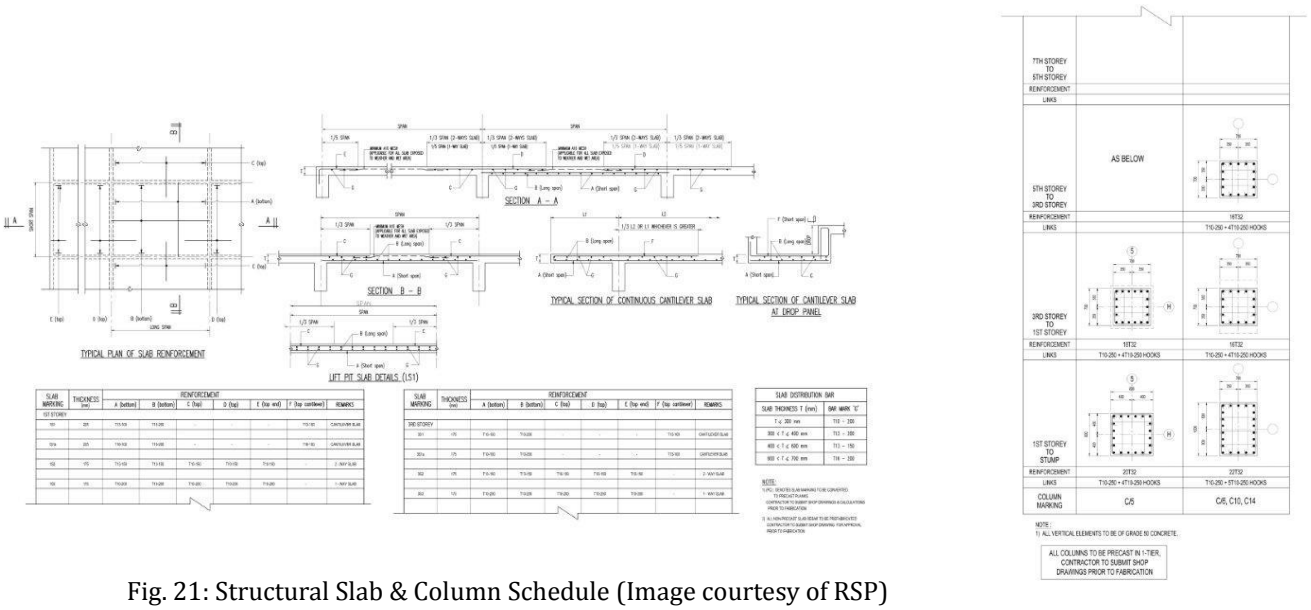


Fig. 21: Structural Slab & Column Schedule (Image courtesy of RSP)

b. Hybrid approach. Element profile generated from BIM objects supplemented with 2D annotations like rebar, dimensions, spacing and curtailment.

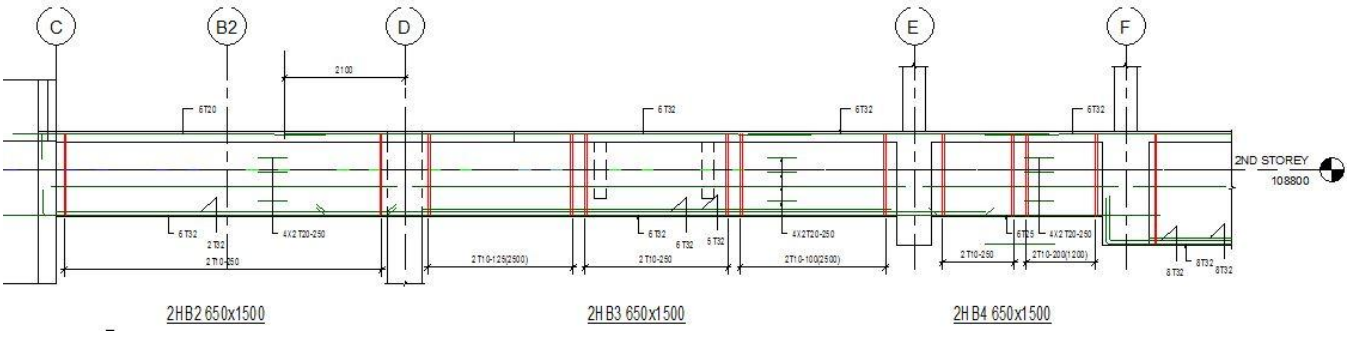


Fig. 22: Structural Beam Detail (Image courtesy of LSW)

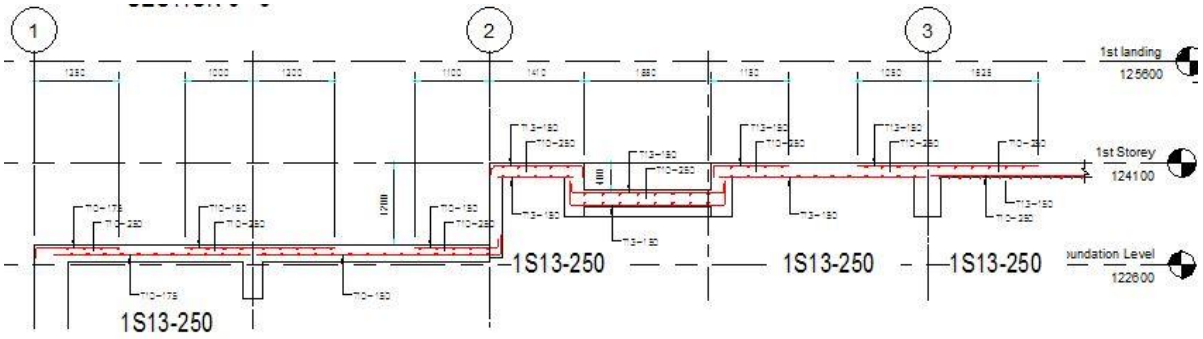


Fig. 23: Structural Slab Detail (Image courtesy of JTC)

c. 3D rebars is encouraged if featured is available. BIM tools like Tekla Structures, Graitec Advance Concrete, Bentley ProConcrete are able to generate 3D structural connections generated from BIM models.

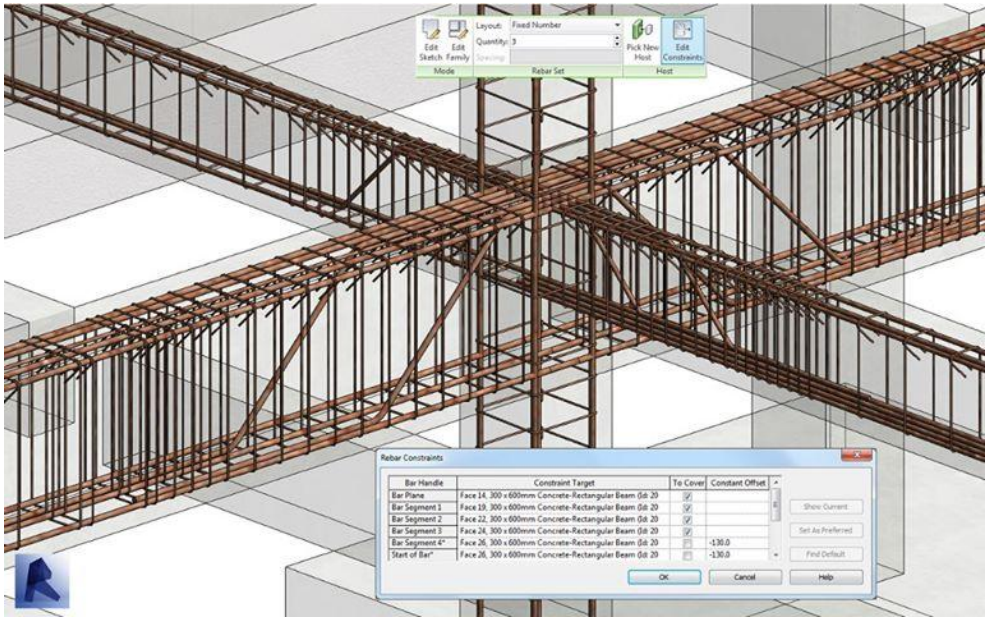


Fig. 24: Structural Beam 3D Rebar (Image courtesy of CCIT)

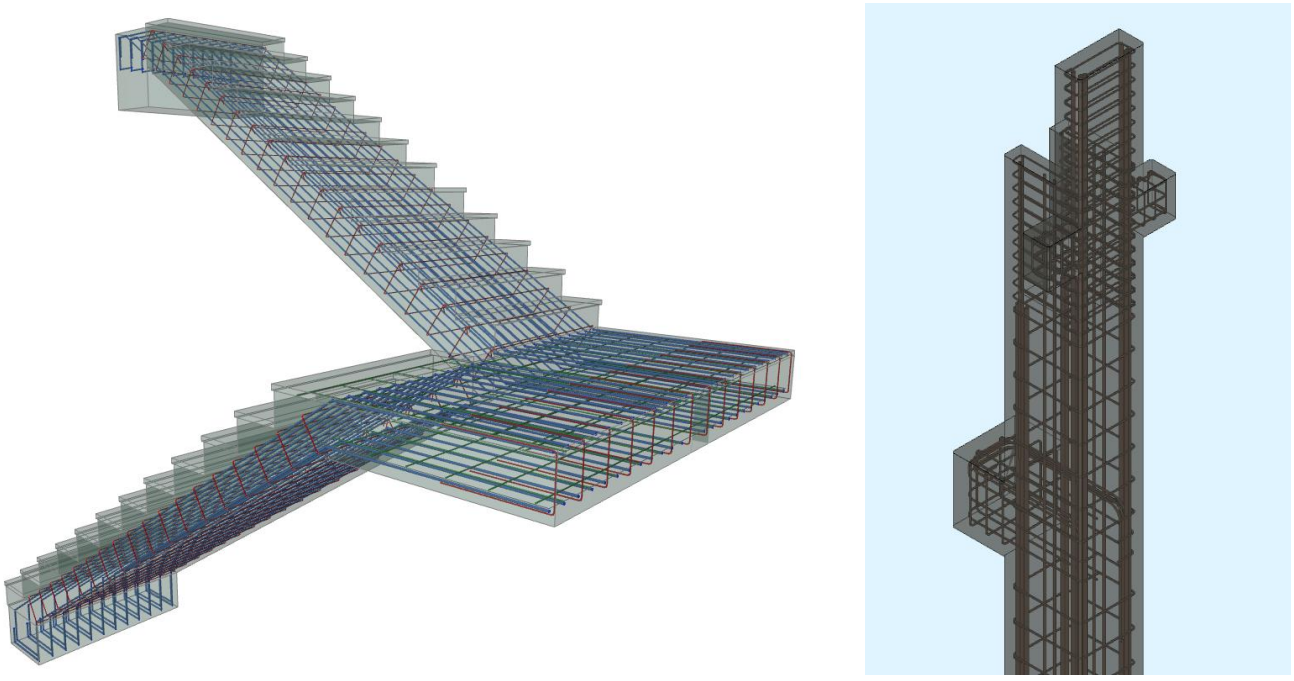


Fig. 25: Structural Staircase and Column 3D Rebar (Image courtesy of CCIT)

d. Specialty works like precast rebar and post tension tendons can be submitted as 2D drawings provided by the specialty consultant/contractor.

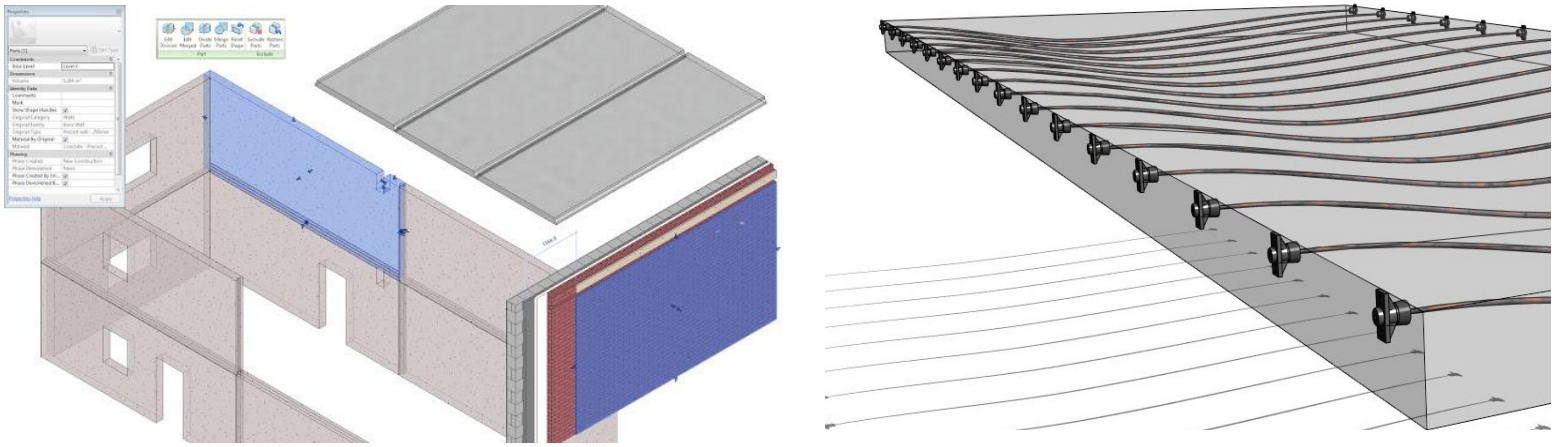


Fig. 26: Revit Precast & Post-Tension Elements (Image courtesy of CCIT)

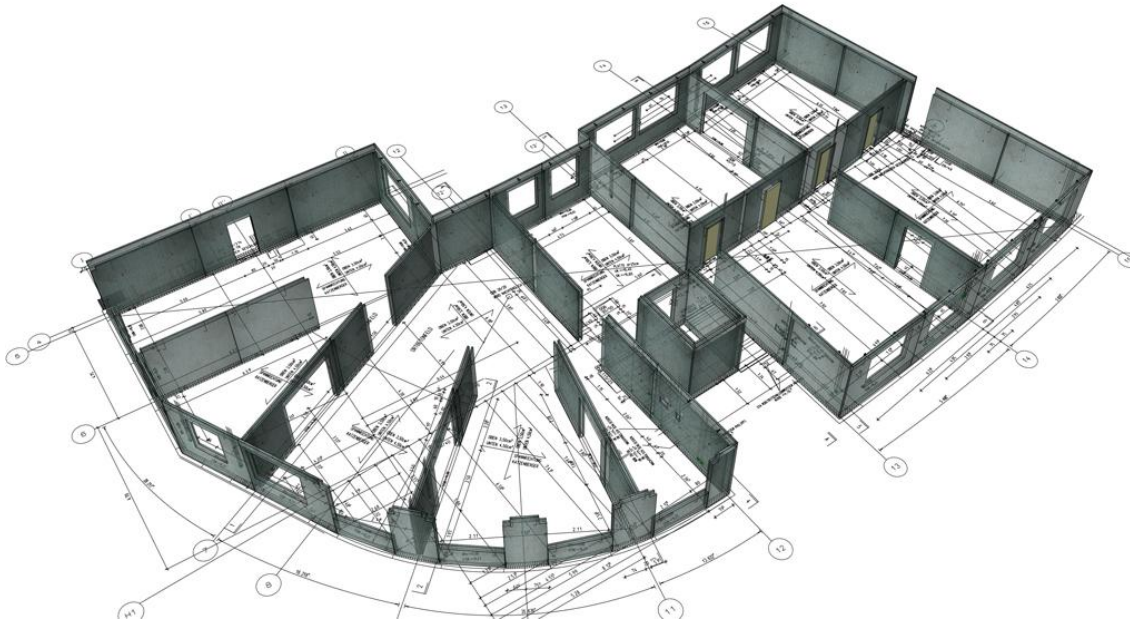


Fig. 27: Nemetschek Allplan Precast Elements (Image courtesy of CCIT)

For steel connections:

a. Pre-qualified steel connections in 2D CAD can be used using drafting or detailed view.

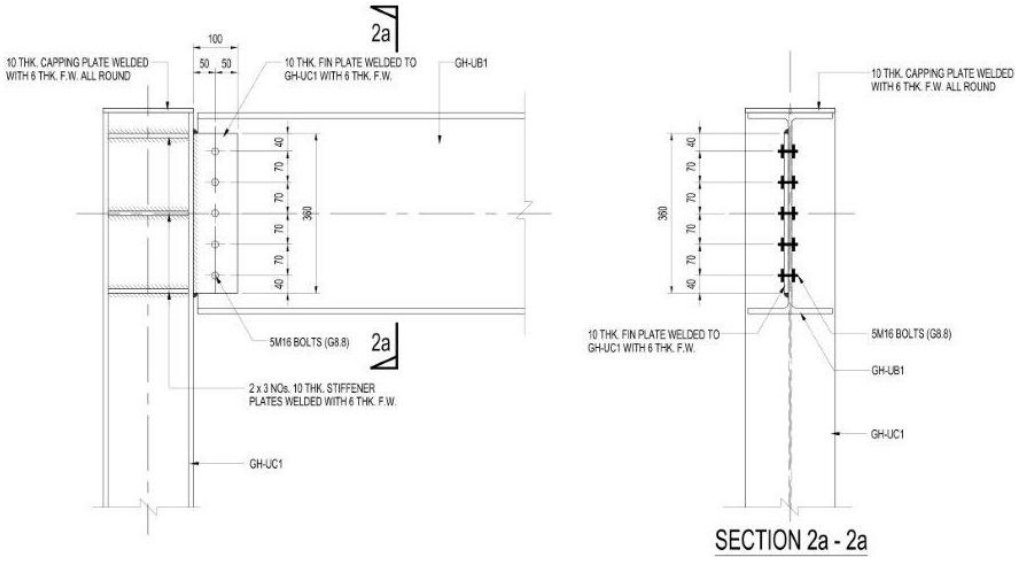


Fig. 28: Structural Steel Connections (Image courtesy of RSP)

b. 3D steel connections. If available, it is recommended to use 3D connections showing bolt, weld and composite connections. Suggested details include all openings/penetrations, shear studs, metal deck, and bracing.

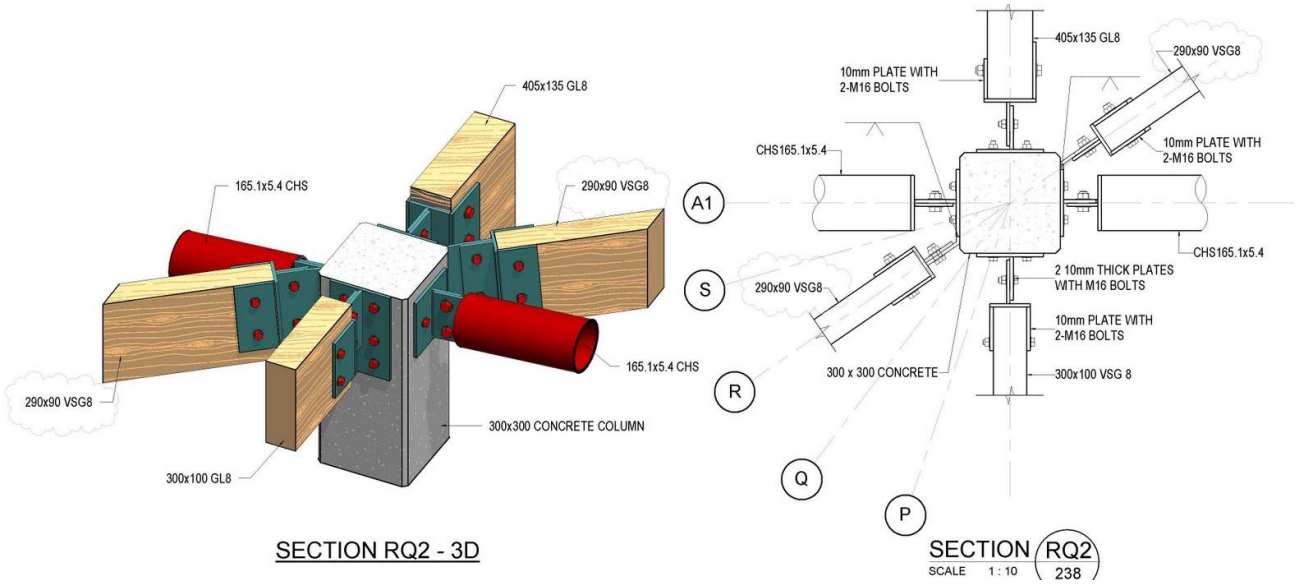


Fig. 29: Structural Steel Connections 1 (Image courtesy of CCIT)

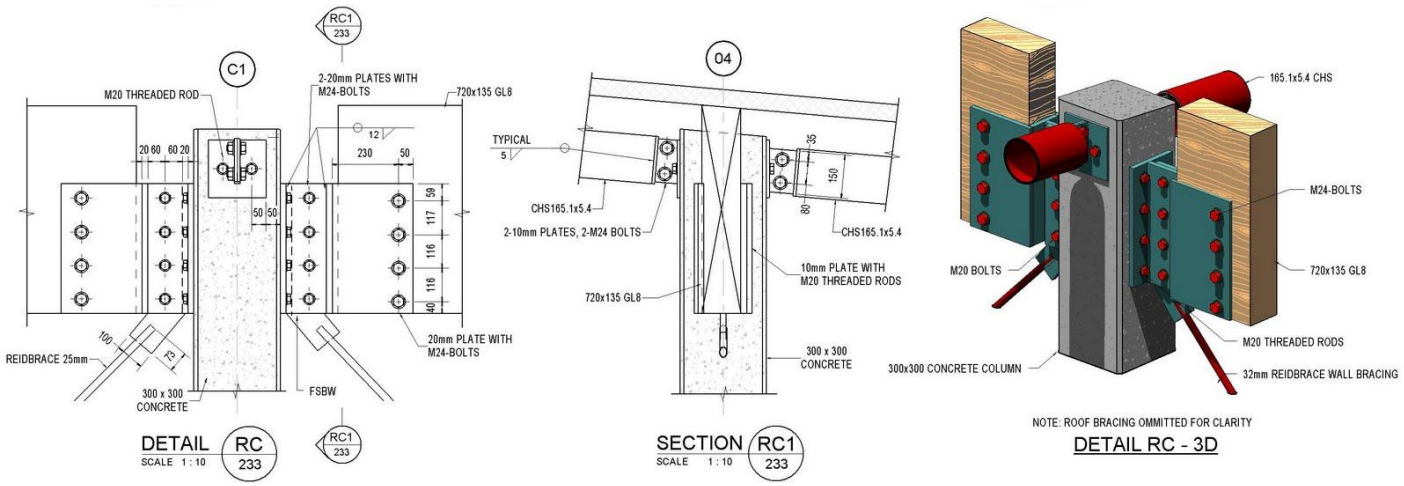


Fig. 30: Structural Steel Connections 2 (Image courtesy of CCIT)

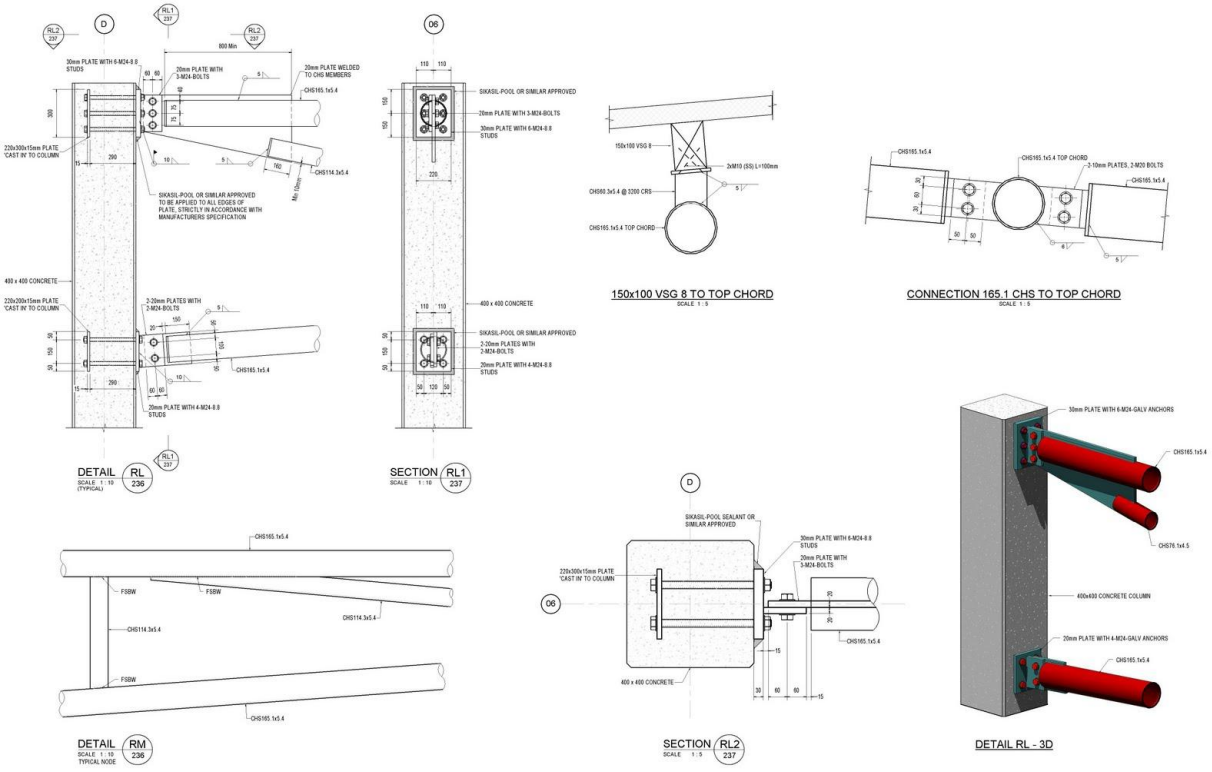


Fig. 31: Structural Steel Connections 3 (Image courtesy of CCIT)

2. Temporary works like formwork, false work, propping, facade retention, needing, edge protection, temporary bridges, site hoarding & signage, site fencing, scaffolding, tower cranes, loading bays and shoring is not required to be modelled except for structures intended to be permanently installed and not dismantled after construction.

3. Construction/erection sequence is not required to be modelled unless required by the client for special projects.

4. Specialty works like curtain walls, CD shelters, tensile fabric roof etc. can be supplemented with 2D CAD drawings inserted as drafting or detailed views. However, load bearing elements of specialty works shall be modelled.

5. Openings intended for electrical, mechanical, plumbing penetrations are not required to be modelled. However for major penetrations (1/3 of beam depth and or column width; 1.5m for walls and suspended slabs) subject to discretion of the QP/PE, openings for beams, columns, walls and slabs shall be considered.

6. Mechanical and electrical equipments like FCU, antennas, escalator, lifts etc. are not required to be modelled. However, its respective weight shall be considered for loading and equipment pads that support its weight and mitigate vibrations induced while in operation.

7. Structural analytical attributes like member releases, supports conditions, spring coefficients, material grades, loads and load combinations shall be considered if the BIM model is synchronized to create structural analysis and design.

8. Addition and alteration works, only affected members are required to be modelled.

CIVIL DEFENCE SHELTER MODELLING GUIDELINES

1. Model elements of the building with CD shelter structure including all concrete & steel members for shelter protection shall be provided (trellis, canopy, ledge, down hang beams, tie beams, shielding walls etc.)

2. Household shelters, storey shelters and staircase storey shelter have to be modelled.

3. Public/transit shelters like MRT are required to be modelled.

4. Transfer structures (beams, slabs & walls) supporting household shelter shall be modelled. Please take note that the use of transfer beam is allowed for household shelter only.

5. All ventilation sleeves openings regardless of size shall be modelled for CD shelter structures.

EXPECTED OUTPUT FOR ST & CD SUBMISSIONS

4.1 Structural (ST) Submissions

Typical ST e-Submission Package

1. Architectural Drawings (for reference)
2. Structural Drawings
   - -General Assemblies (Floor Plan, Elevation, Section, etc)
   - -Schedules (Beam, Column, Slab etc)
   - -Detail Drawings (connections & rebars)
3. Calculations Report
   - -Foundation Design
   - -Global Frame Analysis
   - -Element Design & Sizing
   - -Connections Design (rebars & steel joints)
   - -Manual Calculations

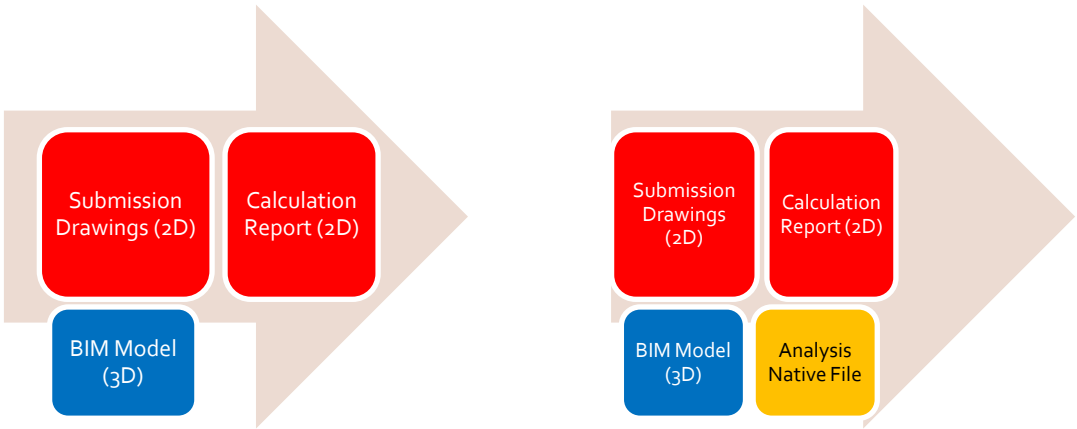


Fig. ?: Current and Future BIM e-Submission (Image courtesy of CCIT)

4.2 Civil Defence (CD) Shelter Submissions

Typical CD e-Submission Package

1. Storey Shelter Drawings

    -Floor Plan

    -Elevation Views

    -Section Views

2. Typical Connection Rebar Details

3. Typical Structural Penetrations/Openings

    -Detail of Embedment

    -Detail of Construction Joints

Collaboration with Other Disciplines

COLLABORATION WITH ARCHITECTS

	INPUT FROM OTHER DISCIPLINE	DELIVERABLES / OUTPUT FROM C&S MODEL
Architecture	Grids	Grids
	Structure Floor Levels (SFL) not FFL	Structure Floor Levels (SFL)
	Column position	Structure Columns
	Ceiling Height	Structural Beams Structural Slab
	Walls position	Structural Walls
	Lift position	Structural Walls
	Cladding	Structural Connections
	Room size usage	Load Case Lad Combinations
	Landscaping (with soil depth / planter sizes, locations)	Structural beams, slabs
	Surface drainage	Structural beams / slabs with drops
	Floor openings	Structural slabs with openings
	Sloped floors / ramps	Structural slabs
	Precast / GRC facades	Structural columns / walls / connections
	Large hanging lighting features	Structural slab
	Building maintenance system (e.g. Gondola)	Structural supports for BMS system (e.g. Gondola plinths)

COLLABORATION WITH CIVIL ENGINEERS /REGISTERED SURVEYORS

	INPUT FROM OTHER DISCIPLINE	DELIVERABLES / OUTPUT FROM C&S MODEL
Civil	Site Plan	Site Plan
	Adjacent Road	Adjacent Road
	Adjacent Properties	Adjacent Properties
	Boundary Lines	Boundary Lines
	Architecture Grids	Architecture & Structure Grids
		Building Layout
		Rotate to True North
	Soil Report	Structural Foundations
	Existing Utilities (gas, electrical, water, drainage, sewer, etc)	Structural Foundations
	Digital Terrain Model	Structural Foundations
	Levels	Earthwork volumes

COLLABORATION WITH MECHANICAL, ELECTRICAL & PLUMBING (MEP)

	INPUT FROM OTHER DISCIPLINE	DELIVERABLES / OUTPUT FROM C&S MODEL
Mechanical	Penetrations / Openings Layout & Number	Std Detail Drawings for Transfer Structures / Check of structural capacities
	Lift	- same as above -
	Escalator	- same as above -
	Mechanical Ventilation	- same as above -
	Air Conditioning	- same as above -
	Equipment Weight & Layout	Equipment Pads / Plinths
	Pipe loaded weight, supports, brackets	Structural supports / connections
	Diesel tank location / size	Structural support / excavation

		volume and retaining system (if underground tank)
	Lift Pit Depth & Hoisting Hook	Structural details (pile cut off levels, slab to take hoisting hook load)
	Weight of chillers	Design live loads
Electrical	Penetrations / Openings	Std Detail Drawings for Transfer Structures
	Equipment Weight	Equipment Pads
	Cable Trays & Hangers	Cable Trays & Hanger Supports
	Light Fixtures	Lighting Fixture Supports
	Underground Cables	Cable
	Lightning protection layout	Structural columns / slabs to embed lightning protector
Plumbing	Penetrations / Openings	Std Detail Drawings for Transfer Structures
	Equipment Weight	Equipment Pads
	Sprinkler positions	Sprinkler Supports
	Potable & Sewer Lines	Pipe Supports
	Pipe loaded weight, supports, brackets	Structural supports / connections
	Water tanks (sprinkler tank, fire tank etc)	Structural supports
	Rainwater harvesting tanks / piping (if any)	- same as above -
	Balancing tank for swimming pools (if any)	- same as above -
	Grease ejector / Ejector / Sump pits	Pit details
	Floor traps	Structural slabs with openings

COLLABORATION WITH CONTRACTOR/FABRICATOR/PRECASTER

	INPUT FROM OTHER DISCIPLINE	DELIVERABLES / OUTPUT FROM C&S MODEL
Contractor	4D Time Structural Model	- none -
	5D Cost Structural Model	- same as above -
	Existing Underground Utilities	Revise structural foundations
	Existing Soil Conditions	- same as above -
	Formworks	Structural BIM Model
Fabricators	Steel Shop Drawings	Centreline of elements Member Forces Member Sizes Support Conditions Bolt Connections Weld Connections
Precasters	Precast / Post Tension Shop Drawings	Centreline of elements Member Forces Member Sizes Support Conditions Tendon Profile Rebar Details Corbel Details

COLLABORATION WITH QUANTITY SURVEYORS & FACILITY MANAGERS

	INPUT FROM OTHER DISCIPLINE	DELIVERABLES / OUTPUT FROM C&S MODEL
QS	Bill of Materials (BOM)	Element Classification
	Unit Cost Analysis	
	Project Costing	
Fabricators	Link to BMS	Material Test Result
		Material Specifications
		As Built Drawings

Others

MODEL VERSION CONTROL

As the project progresses, consequently is the model change. Model will change according to specific requirements needed in every stage. Few factors of having numerous model versions are as follows:

- Design Change
- Authority Submission and Re-submission
- Model Update
- Remote Office Locations

Different model versions are certain. Managing these versions is the possible option that we may implement to avoid having it. Few recommendations listed below will help all project members to avoid confusion.

Organized Folder Structure

- To implemented office-wide.
- Saving the specific file on their corresponding location will be helpful for all, and will also reduce the time spent in searching.
- To avoid duplicating files on their own PC to avoid confusion when working.
- “Backup”, “Superseded” or similar folder name where all backups/ outdated files are located.
- “Archive”, “Published” or similar folder name where all copies of issued files are located.
- “Working”, “WIP” or similar folder name where only “one working model” (varies on project setup) is located.

Keeping “One Working Model”

- Project Server to serve as a central location of model, where every team member can access and work.
- “Tekla BIM Server”, “Revit Server” or similar will allow two or more teams located in remote office locations to update their changes to one central file simultaneously.

NOTE: RECOMMENDATIONS ARE NOT APPLICABLE TO ALL. THESE VARY DEPENDING ON PROJECT AND OFFICE REQUIREMENTS.

This guide is part of the BIM Essential Guide Series

BIM Essential Guide	FOR EACH BIM PROJECT		FOR EACH ORGANIZATION
	WITHIN EACH DISCIPLINE	ACROSS MULTIPLE DISCIPLINES	ALL DISCIPLINES
For Architectural Consultants	●		
For C&S Consultants	●		
For M&E Consultants	●		
For Contractor	●		
Quick Start for BIM Execution Plan		●	
Quick Start for BIM Adoption within an Organization			●

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