Mass concrete in Indian Metros

Design and Execution engineered

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Functional requirements of Mass Raft Structure

- Larger in size yet monolithic in nature
- As homogeneous as possible though concrete is heterogenous
- Fully compacted mass devoid of pores, voids and cracks having a volume that is equivalent to a residential apartment or more, with rebar cage

Mass concreting of Raft Structure has twin challenges in India

- Mitigating Temperature effects
  - Controlling Peak temperature & Temperature difference

- Making the structure as monolithic as possible
  - Planning & execution of sequence of casting

Challenge in Mass Concreting in Indian Metros – constraints

- Capacity of Plants – lower per hour production capacity
- Predominantly line pump utilization with very few Boom placers in use
- Transit mixers deployment, based on daily average, would be less in number to cater to the added volume required for mass concreting
- Need to use multiple plants for delivery that in turn results in scarcity of high-skilled Quality Control personnel
- Lower stock capacity to store materials required for mass concreting
- Issues with traffic ➔ Restricted timing, routes, Congestion, etc
- Possibility of abrupt stoppage of delivery of concrete for various reasons
- Site location and its narrow accessibility result in limited scope for multi-front delivery of concrete loads

Capabilities abroad - Achievements

- 20,246 cum in 62 hours in Sharjah (April 13 to 16 2017)
- 19,624 cum in 49 hours (Lakhta Centre Tower, Russia in March 1 2015)
- 16,208 cum in 18.5 hours in Los Angeles (February 16 2014)
- 5500 cum of M80 grade in 37 hours Singapore (April 2019)
  – M80 requires more time to produce and it is a very sensitive concrete

Capabilities abroad – USA, better resources & accessibility

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Capabilities abroad – Russia, better resources & accessibility

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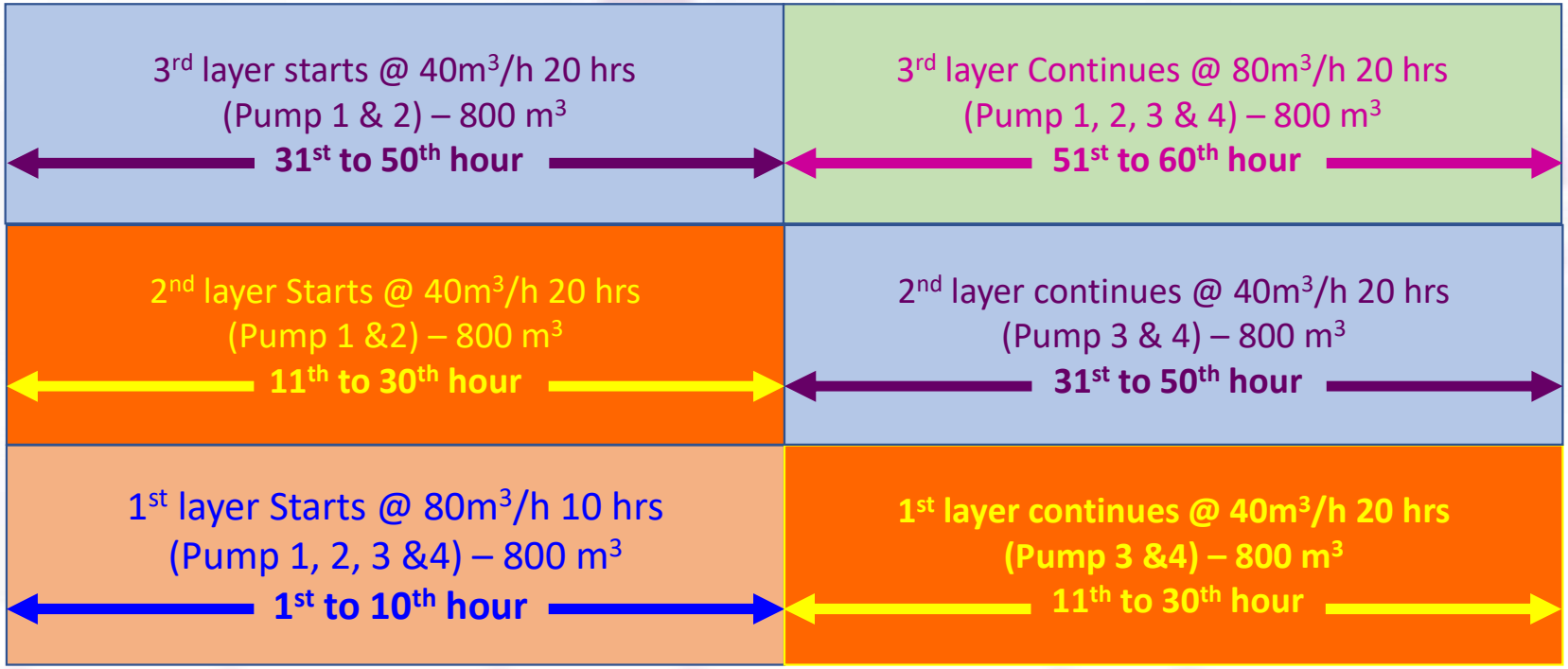
Scenario in India

- Supplying 1000 cum/day is considered good
- 2000 cum/day is considered as the best effort with 3 or more plants supplying
- Hence, casting of a raft structure with a volume of 5000 cum would require about minimum 3 days duration
- Cold joints are unavoidable, though manageable
- If planned for horizontal joint over vertical joint, there are distinct advantages

Scenario in India - Casting 65.0 m X 41.0 m X 1.8 m size raft

- Raft with a volume of about 4800 cum of concrete is to be cast in 3 days
- Temperature controlled concrete is to be used, with addition of Ice, Chilled water, Supplementary Cementitious Material and Retarding admixture. Super-plasticizer is to be added for workability
- With three layers, expected time lapse between the successive layers is from 10 to 20 hours
- Horizontal layering, a proven practice, is preferable compared to casting thicker layers that would leave vertical joints, especially at the bottom (refer to Pics)
- Temperature Controlled Mass concrete, invariably cast with Fly Ash / GGBS and with retarder component is expected to exhibit a final setting time of more than 12 hours

A typical Casting Scenario – 4800 m^3 @ 80 m^3/hr with 4 pumps in operation – 3 X 0.6m layers



- Time lapse between 1st and 2nd layer initially 10 hours and finally 20 hours
- Time lapse between 2nd and 3rd layer initially 20 hours and finally 10 hours

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Casting in Layers

- Necessity, Concerns and Solutions

Casting in Layers - Necessity

- It is not possible to compact a layer which is more than 600mm thick with needle vibrators as the vibration would not travel deeper
- Slump value of 180 – 200 mm is required to ensure fresh concrete flows below and within the bottom rebars that are in two or more layers
- More importantly, spreading the thickness in layers of 0.5 to 0.6m would make compaction much easier, and visual inspection of a flat compacted surface is much more effective
- When cast in thicker layer (>0.60m) fresh concrete would slide with varying contour profile for a wider area (refer to Pics)
- Very often, the portions spread with varying thickness for a wider area would not get compacted because the focus would be on concrete that is getting pumped in the current portion to build the height

Casting in Layers - Necessity

- Casting in thicker layers/sections would also lead to un-intended and un-noticed vertical cold-joint formation due to concrete spreading in varying contours (refer to Pics)
- Even when a vertical joint is planned, formation of gap at the bottom due to differential shrinkage of hardened concrete on either side of the joint should be taken care of.
- A Vertical joint should be treated or provisioned to ensure that it remains water tight forever. Provision of water proofing membrane at the bottom may not be 100% fool-proof as experienced in the field
- If the thicker layer is poorly compacted due to difficulty in accessibility , resultant weak, porous portions and gaps (due to vertical joint) at the bottom pose great threat to durability as well as strength of the raft

Making the successive layers monolithic - Concern

- Structural Concern
  - ❖ Cold joint formation leading to “Shear slip/failure” between the two successive layers
  - ❖ Shrinkage cracks occurring on the surface of intermediate layer

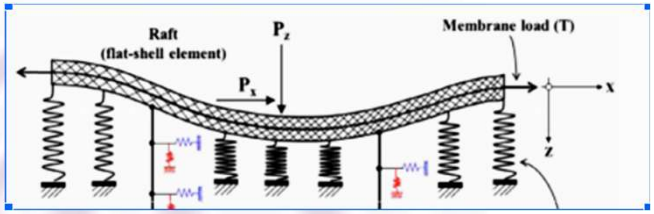
Factors addressing about concern

- ✓ Shear due to lateral force is considered non-critical normally, due to the size of the mass raft, that is considered infinite in design aspect
- ✓ Leaving lateral construction joints, that form cold joints in walls which are pure flexural members, are routine practices in construction.
- ✓ When executed properly the horizontal joint in a raft, which is less critical would not exhibit any sign of slippage or cracking.

Courtesy : Er.Jegatheesan, Buro Engineers

Making the successive layers monolithic - Solution

- Solution
  - Raft is expected to act like a continuous beam with a combination of Sagging (due to column's vertical load) and Hogging Bending moments



  - Rebars of columns act as shear keys in the area around the columns
  - Rebars in the form of Chair rods provided, act as shear keys across the area away from the column rebars
  - Additional vertical hooks can be provided as shear keys, where essential. These vertical hooks shall run from top to bottom.
  - Provision of additional nominal reinforcement in lateral directions, just below the joints would mitigate shrinkage cracks

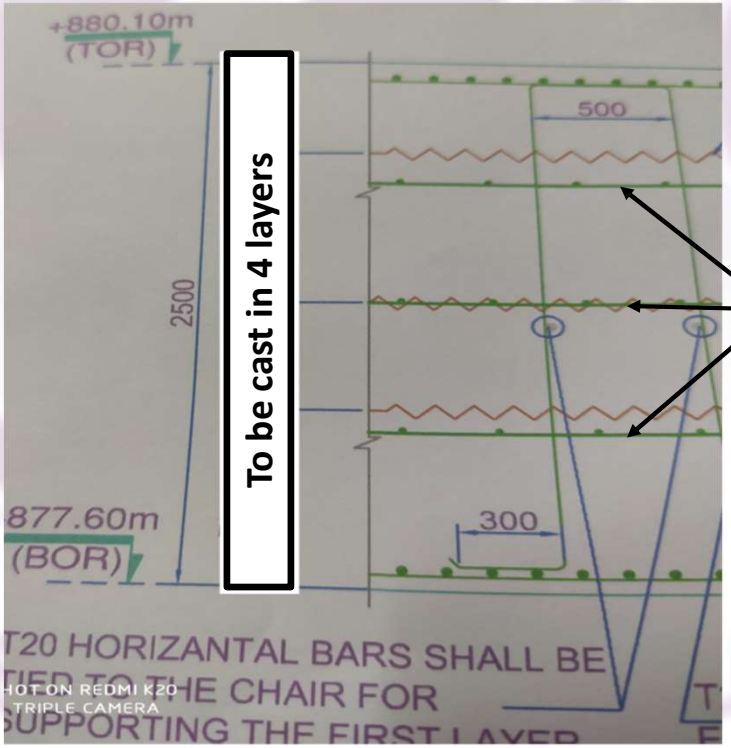
Courtesy : Er.Jegatheesan, Buro Engineers

Making the successive layers monolithic - Solution

Column rebars forming Shear-keys in Raft

Making the successive layers monolithic - Solution

- Solution in the form of structural design



HORIZONTAL JOINTS
(THE JOINTS ARE PROVIDED AT SPECIFIED DEPTHS. THE DEPTH CAN VARY AS PER THE CONCRETE POURING CAPACITY OF THE CONTRACTOR)

Additional nominal rebar below each layer

Courtesy : L.N.Murty, Amara Raja Infra

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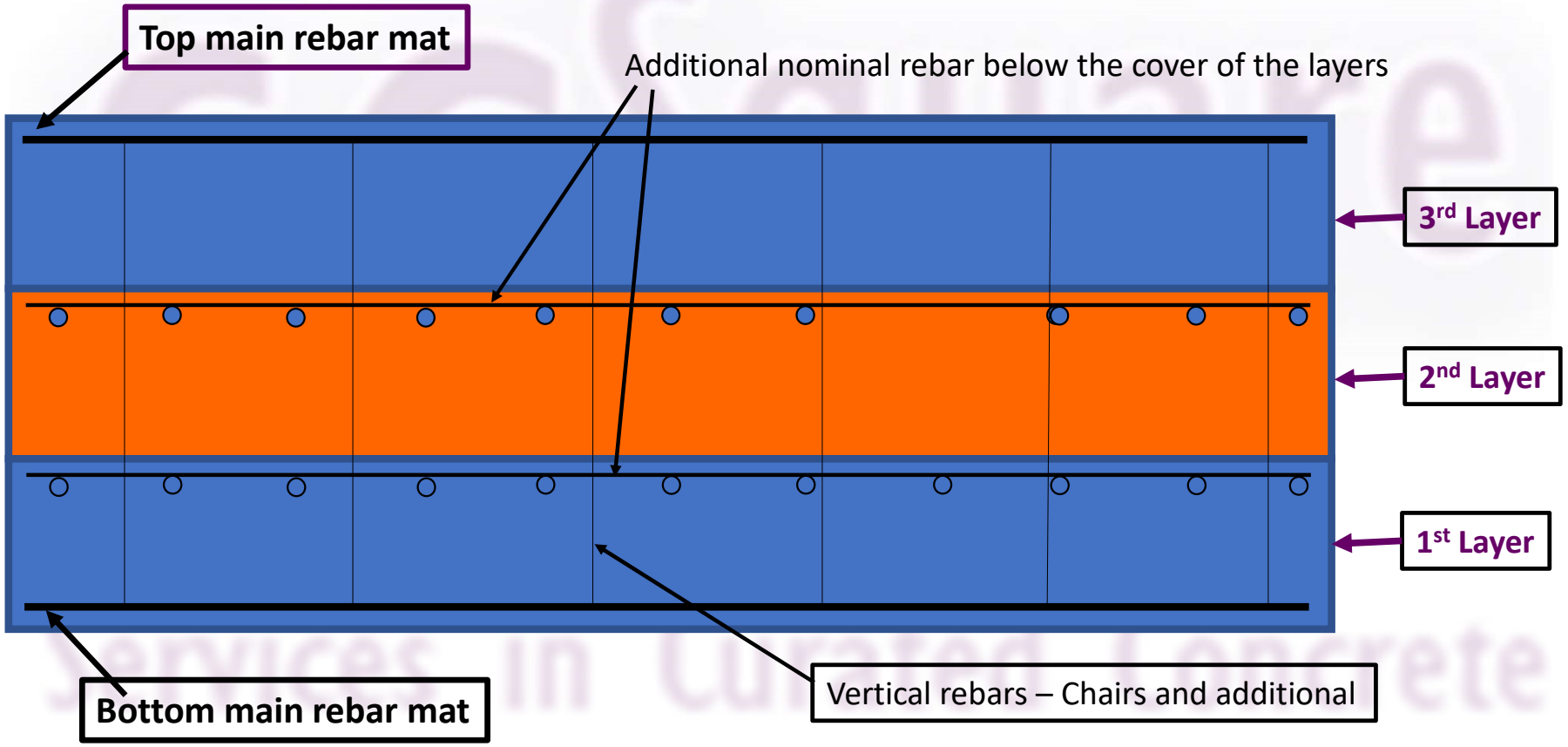
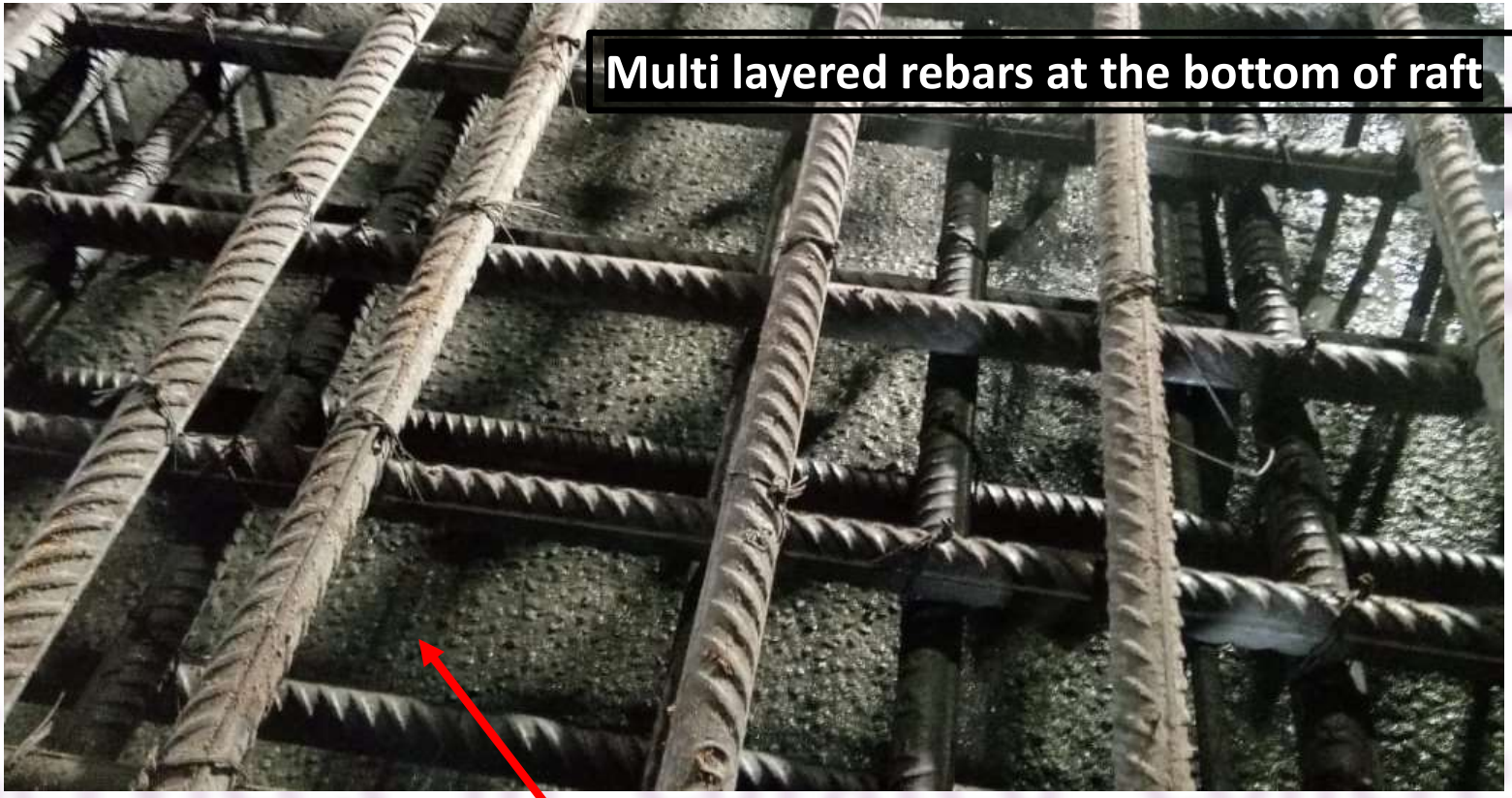
Making the successive layers monolithic - Solution

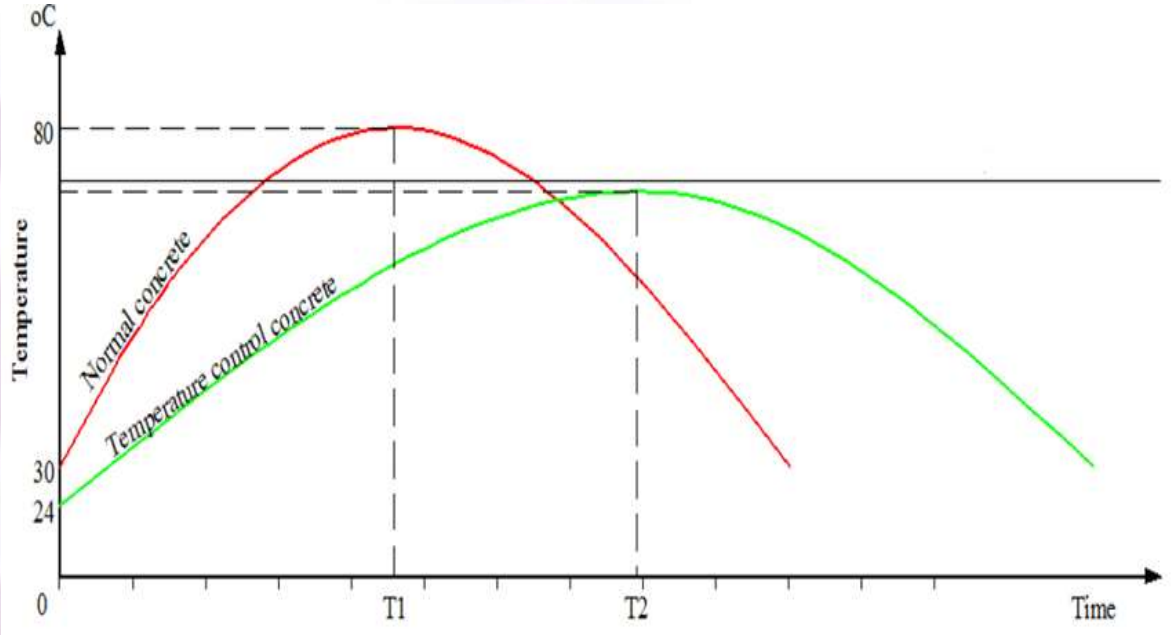


Practices to adopt

Practices to adopt – Better workability to send concrete beneath rebars



Practices to adopt – Addition of Retarding admixture to reduce Peak temperature of concrete



- Addition of retarding admixture shall be made essential in Mass concrete, especially when PCE based admixture is used.
- While PCE based admixture has the tendency to show “sudden withdrawal effect” leading to faster reaction of cement particles, Retarders tends to work to nullify the faster reaction.
- SNF with inbuilt retarder can also be considered.

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Practices to adopt - Layer by layer casting – A way to build a concrete mass

- Layer by layer casting with a slump value of 180mm to 200mm, will make compaction easier and effective
- Horizontal & Flat spread with uniformity in appearance of the compacted surface ensures casting of a solid & water tight structure

Practices to avoid

Practices to avoid – Avoid low slump

- A slump of 120mm would not be adequate even to send the fresh concrete in from the top.
- At low slump the concrete would not reach the bottom of the rebar network, and a proper compaction of a wider area at the depth of >1.0m is impossible.
- End result would be formation of porous structure that leads to seepages / leakages

Practices to avoid – Casting a thick layer (>0.6m)

- Attempt to cast a thicker layer would make fresh concrete spread haphazardly with lesser scope of ensuring compaction for such wider spread
- Unevenly spread concrete for a longer distance that remains uncompacted, would harden leaving weak and porous spots

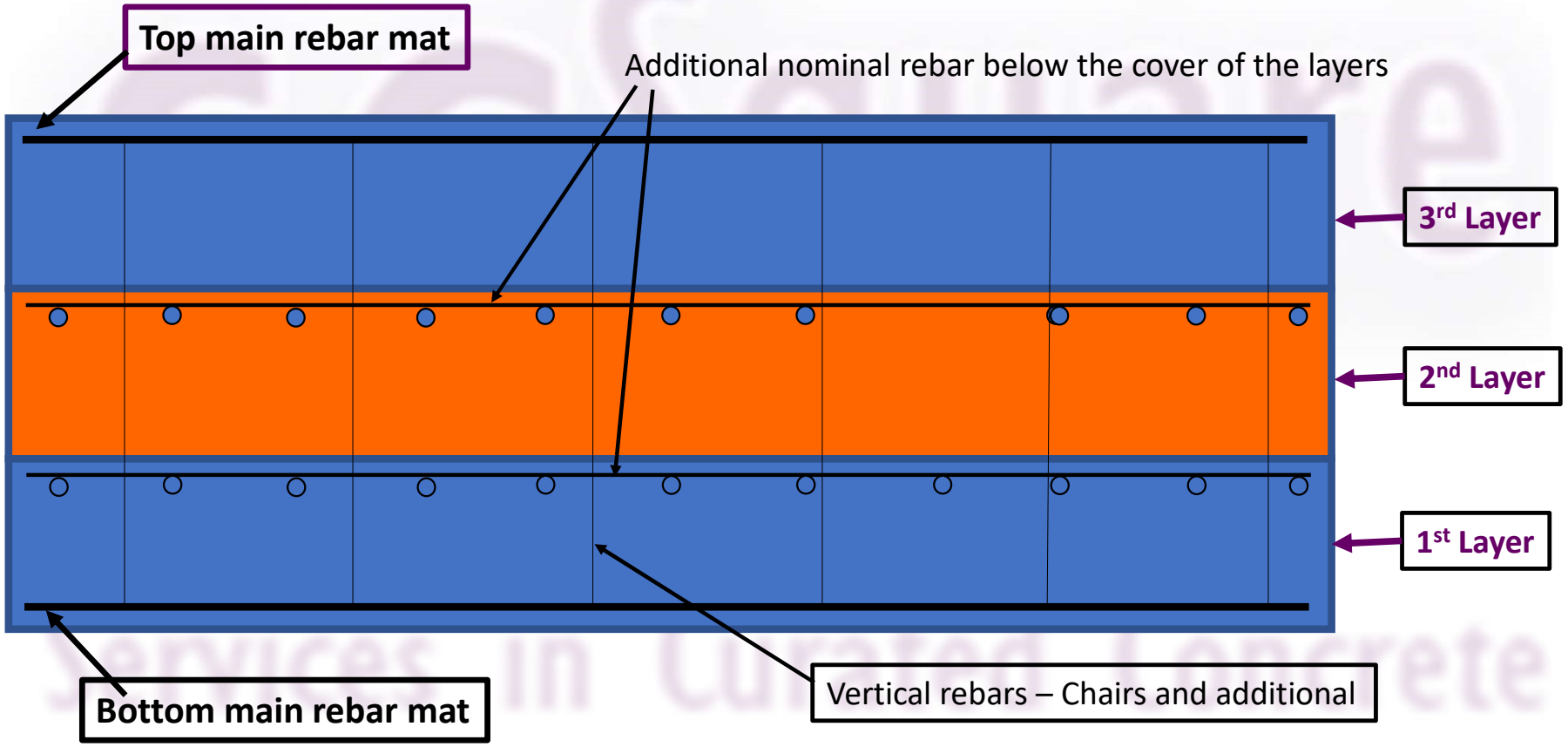
Practices to avoid – Casting a thick layer (>0.6m)

- An image of uneven spread of concrete when attempted to cast a thicker layer (>0.6m)
- Concrete getting hardened in some places before compaction, creating porous and weak spots

Practices to avoid – Casting a thick layer (>0.6m)

- An image of uneven spread from a thicker layer (>0.6m) hardening before compaction
- Creation of un-intended vertical joint at the bottom as well as porous and weak spots

Layered concrete – Measurable approach with additional rebars between the layers



- Construction is a layered approach
- Let it start from the foundation

- G.Sivakumar

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