Good Examples of Design and Construction Practices for Enhancement of Productivity in Public Works Projects

Works Branch
Development Bureau
April 2020

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1. Introduction

The Total Construction Worker Manpower Strategy, encompassing comprehensively the relevant initiatives and measures to enhance the construction worker manpower resources in a coordinated manner, was endorsed at the WPCC meeting on 10 June 2012. As one of the measures, consideration at planning and design stage of works projects is taken to minimise the demand for skilled workers in trades with projected shortage.

The Steering Group for Enhancing the Manpower Resources of Skilled Workers in Public Works Projects ("SG") was established and the 1st SG meeting was held on 14 September 2012. At the meeting, it was identified that there was room to reduce the demand of skilled workers for trades including bar benders and fixers, formwork carpenters, metal formwork erectors, plumbers, pipelayers, metal workers and welders. Guidelines will be promulgated to provide recommendations for design and construction practice, with an aim to enhancing the construction productivity of the above-mentioned trades in public works projects, but not limiting the aesthetic, innovative and functional requirements of the projects, while providing for quality assurance of the products such as rebar couplers.

In order to address the problem of ageing of construction workers in Hong Kong, the Government has been actively promoting, amongst others, the use of prefabricated rebar products for the Hong Kong construction industry. This included the promulgation of a technical circular in 2016 to set up a list of approved rebar prefabrication yards and formulated the technical and quality assurance requirements, followed by a revised technical circular in 2018 to promulgate an Independent Audit Team to monitor and audit the operation of approved yards.

In response to the challenges currently experienced by the construction industry, DEVB has developed Construction 2.0, which rests on three key pillars: Innovation, Professionalism and Revitalisation. For innovation, a series of actions are being implemented that aim to change the innovation landscape for the industry, which included the establishment of the Construction Innovation and Technology Application Centre, Building Information Modelling (BIM), and Off-site

construction using Design for Manufacture and Assembly (DfMA) and Modular Integrated Construction (MiC).

The "designated workers for designated skills" requirement of the Construction Workers Registration Ordinance (CWRO) has been implemented since 1 Apri 2017. However, through deliberation within the industry, there are opportunities for registered skilled workers of certain designated trade divisions to work across similar skills, and for small scale construction works that are carried out by general workers to be exempted from the "designated workers for designated skills" requirements under the CWRO.

This document shares some good examples of the design and construction practices for reducing the demand on skilled workers and enhancing productivity as developed by the SG.

2. Approach

Desktop study was conducted to identify key work activities involved in construction sites for the trades. With the concerted effort made by various Works Departments (WDs) including Architectural Services Department, Civil Engineering and Development Department, Drainage Services Department, Highways Department and Water Supplies Department, Working Groups were formed to review design of engineering works, workmanship requirements and construction practices with an objective to minimizing the labour demand of the identified trades. Meetings were held amongst Working Groups members including professional staff in the Development Bureau / WDs and relevant stakeholders (including relevant trade associations and trade unions) to review feasible and effective measures to reduce the demand of skilled workers. Draft guidelines were prepared and agreed at the 2nd SG meeting held on 13 December 2012

3. General Principle

The general principle is to illustrate the 3S concept (Standardization, Simplification and Single Integrated Element) adopted in design with examples and other specific measures in construction process for individual trades.

Design to enhance the construction productivity

(i) Standardization

Designer should in the first place, consider adopting standardized design details including repetition of grids, standardized types, sizes of components, and connection details as far as practicable. These help enhance efficiency of work execution. An example of standardization of structural beam is shown on **Photo 1**.

(ii) Simplification

Designer should use non-complicated building construction systems and installation details such as reducing the nos. of joints formed, avoiding design of different member sizes and details to simplify the relevant works involved during both the fitting and fabrication processes. Special design involving high workmanship requirements (e.g. curvatures) should also be avoided **(Photo 2)**.

(iii) Single Integrated Element

Taking into account existing site constraints as well as the transportation / handling requirements, designer should consider adopting structural form and design that could allow combining related components together into a single element for prefabrication in the manufacturing factory to enhance working efficiency and to minimize the need for field works **(Photos 3 and 4)**.

Enhancing the efficiency of work execution on construction sites

Designers and contractors should apply effective resource planning and work execution procedure to enhance the work sequence and site management to help

better deployment of labour resources. Suggested measures include the followings –

- deploy efficient tools and equipment;
- schedule workers to carry out similar activities in sequence to facilitate their early familiarization with the work and hence enhance their productivity;
- manage resource effectively by focusing on the critical path works;
- implement good site management to minimize idling of workers e.g. ensure timely arrival of materials and efficient workforce planning, etc.;
- adopt modularization, prefabrication, pre-build in shops i.e. do as much work in vendor's shops e.g. modularized skids, etc as possible to minimize site works;
- consider specific contractual arrangement such as design and build contract to allow flexibility for contractors' use of prefabricated structures, alternative materials or innovative design for projects involving large-scale structures;
- issue drawing details in timely manner to allow sufficient time for contractors to carry out planning and preparation works; and
- deploy consistent construction crew.

***** *The proposed measures that would contribute to minimise the demand of skilled labour should be carefully considered on a case-by-case basis in planning and design stages, taking into account the special site conditions, complex functional or architectural requirements as well as their implications on design creativity, time and cost of individual project. In addition, sufficient time should be allowed for the construction stage to avoid large demand of skilled workers arising from tight construction programme.*

The following sections will provide the design examples and other specific measures for the trades mentioned in Section 1.

4. Bar Benders and Fixers

Design stage - adoption of 3S concept

(i) ***S****tandardization*

- Keep floor to floor height uniform to avoid complicated bar bending works. Level difference across floor may be made up by filling rather than by rise/drop of the structural floor slabs. Nevertheless, the additional dead load on the structural floor system should be considered.

- Adopt typical and symmetrical arrangements of structural members of uniform size to streamline the cutting and bending works.

- Avoid irregular shape reinforced concrete members including, e.g. curved/cranked beams, non-prismatic beams/columns, architectural features, etc., which involve complicated/congested steel reinforcement fixing details.

- Keep the width of multi-span beams uniform along its length to avoid complicated curtailment of longitudinal reinforcement bars.

- Avoid frequent changes of column size with floors.

- Use standard shape codes for steel reinforcing bars to BS8666 as far as practicable.

(ii) ***S****implification*

- Promote bar couplers to connect longitudinal bars in columns and walls to avoid the difficulties encountered in fixing of congested reinforcement bars arising from conventional bar lapping. This is subject to stringent compliance with the relevant requirements on supervision, record keeping, and technical compliance to ensure delivery of the design intent in construction.

- Avoid complicated or precise reinforcement detailing with little tolerance for fixing, e.g.

- avoiding hooking shear reinforcements around the bottom layer of longitudinal bars in flat slabs, transfer plates and pile caps, which demands precise cutting, bending and fixing of the shear reinforcements due to congested reinforcements and the requirement to provide adequate concrete cover (**Figure 1**); and
- avoiding slotting longitudinal bars for beams into congested column reinforcement cages (**Figure 2**)

- Simplify reinforcement details by means of design refinement, by e.g.

  - column vertical bars to be lapped at floor level rather than at height to reduce the difficulty in fixing the bars (**Figure 3**);
  - reducing the difficulty in fixing shear reinforcements at the junctions of columns and beams (**Figure 4**); and
  - adopting larger size and spacing main bars and open shear links for columns (**Figure 5**).

- Consider steel mesh fabric in lieu of conventional two-way reinforcement bar layer for slab and wall construction.

(iii) ***S****ingle Integrated Element*

- Dry construction

  Consider using dry construction where appropriate such as concrete block wall or precast wall instead of in-situ reinforced concrete partition walls (**Photo 5**). This may also speed up the construction process.

- Adoption of precast construction (**Photos 6 and 7**)

  Consider precast construction for secondary members like window frame, façade and staircase flight.

Other specific measures

Structural design

- Adopt flat slab/large panel slab construction (**Photo 8**)

Minimize the number of beams as far as possible because reinforcement bars at beams are usually congested and are interlaced with the column bars, which affect the production efficiency of bar benders and fixers.

- Adopt composite structure (**Photos 9 to 11**)

  Reduce the workload of bar benders and fixers on construction sites by, e.g. adopting composite floor, composite columns, etc.

- Transfer structures (**Photo 12**)

  Avoid transfer structures which usually require heavy and complicated steel reinforcement arrangement. If unavoidable, adequate size and detailing of the transfer structures should be well considered to facilitate reinforcement bending and fixing.

- Building Information Modelling (BIM)

  To promote the adoption of BIM as far as practicable to carry out rebar modelling for the congested nodes (e.g. junction of multiple beams with a column) to render the design clash-free and buildable.

Construction process

- Promote semi-precast concrete construction for structural elements on site.

  Consider semi-precast elements for the works involving complicated formwork or tedious bar fixing on spot (like staircase flight and water tanks). Full precast method is usually deployed in repeated and easily handled structural members, e.g. building façade, precast bathroom, etc. It is more flexible to adopt semi-precast units in combination with cast in-situ concrete in construction of more massive structures, e.g. use of semi-precast beams and slabs with in-situ concrete fill-in for floor construction (**Photos 13 and 14**).

- Using mechanical plant for cutting and bending of reinforcement bars can help reduce the need of skilled bar benders and fixers (**Photo 15**). Promote

the use of prefabricated rebar products supplied by CEDD's approved rebar prefabrication yards in accordance with DEVB TC(W) No. 10/2018 "Quality Assurance for Use of Off-site Prefabricated Steel Reinforcing Bar Products".

5. Formwork carpenters and Metal Formwork Erectors

Design stage - adoption of 3S concept for building works

(i) ***S****tandardization*

Standardization of architectural design, e.g.

- Standardize
  - the height of each floor;
  - floor details e.g. slab thickness from storey to storey;
  - the size of bays on each floor; and
  - the structural design of slabs, columns, walls, beams and staircases.
- Keep the number of columns optimal.

(ii) ***S****implification*

Simplification of architectural design, e.g.

- Avoid projecting concrete members e.g. concrete bay window, concrete fins or features from external walls of buildings.
- Without affecting the functional operation, mechanical and electrical efficiency and maintenance considerations, avoid designing labour-intensive and time-consuming elements e.g. generator rooms, toilets,

kitchens, etc. in localized areas of a floor. The congested work environment may lead to clashing of work by the different skilled workers. In other words, such facilities should be evenly distributed on each floor as far as possible.

Simplification of structural design, e.g.

- Adopt flat slab instead of conventional structural beams and slab to reduce the work on beam construction.

- Construct small areas near the door frames (i.e. between door frame and ceiling, between door frame and adjacent wall) by non-in-situ concrete materials or precast concrete blocks to avoid labour-demanding formwork (**Photo 16**).

Minimization of special design, e.g.

- Avoid special feature design involving high workmanship requirements, e.g. wall curvatures, sharp corners, etc. unless there is a genuine need for special architectural requirements.

(iii) ***S****ingle Integrated Element*

- Dry construction (**Photo 5**)

  Use dry construction e.g. concrete block wall or dry wall instead of in-situ reinforced concrete partition walls.

- Adoption of precast construction (**Photos 6 and 7**)

  Consider precast units of building facades, curtain walls, glass walls, window frame, staircase flight etc.

Design stage - adoption of 3S concept for civil works

(i) ***S****tandardization*

Standardization of design, e.g.

- Standardize the design of columns and walls
- Consider using claddings to replace concrete architectural finishes.

(ii) ***S****implification*

Simplification of architectural design, e.g.

- Avoid profiled finishes on the external faces of structural features, e.g. retaining walls, bridge abutments, etc. (**Photos 17 and 18**). Provide greening to improve the appearance of the features if appropriate.
- Consider non-in-situ elements for special architectural design of the structural features.

Simplification of structural design, e.g.

- Use less curve profile for the bridge columns and soffits.

(iii) ***S****ingle integrated element*

- Adopt precast concrete units to construct beams and columns.

6. Pipelayers and Plumbers

Specific Measures to Enhance the Construction Productivity for Pipelayers

Planning and Design

- Selection of suitable and proper types of materials

  Consider using —

  Light and durable materials (e.g. polyethylene (PE) pipes) to reduce manpower resources in handling the materials.

  Coils of PE pipes (with nominal size 90 mm and below) to replace the standard straight lengths of PE pipes in order to minimise the jointing work required.

- Adopt straight and direct alignments of pipelines to reduce turns, joints and fittings.

Construction process

- Rehabilitation method

  Consider applying rehabilitation method (e.g. slip-lining of existing water pipes) instead of laying new pipes for repair of damaged water pipes,.

- Trenchless construction methods

  Adopt trenchless construction methods (e.g. horizontal directional drilling, pipe jacking, micro-tunneling, etc.) instead of traditional open-cut method.

Specific Measures to Enhance the Construction Productivity for Plumbers

Planning and Design

- Select durable materials and suitable design for plumbing and drainage installations, e.g.

  - epoxy coated ductile iron pipes instead of cast iron pipes, especially for those installations to be laid under buildings or subject to high water pressure, to reduce future repair and maintenance;

  - quick jointing methods instead of traditional welding techniques; and

  - small diameter coils of PE pipes and pipes in coil to be used instead of the standard straight lengths.

- Use adequate sizes for drainage pipes susceptible to blockage, particularly those embedded underground and those with long pipe run (e.g. for relatively large floor plates in special building types including hospitals and correctional institutional facilities);

- Use direct supply system to minimise the plumbing work on site.

- Standardize plumbing and drainage installations in buildings to enable the plumbing and drainage work to be carried out more efficiently.

- Consider off-site fabrication of pre-jointed pipe sections in Mainland or other areas.

- Adopt straight and direct alignments of plumbing system to reduce turns, joints and fittings.

7. Metal Workers and Welders

Innovative Design to Reduce and Replace On-site Metal Works

- Alternative design

  Adopt alternative design to reduce metal works or welding process , e.g.

  - bolt and nut connection arrangement for both permanent (such as portal frame, roof-top structure) and temporary (such as pile casing, gantry) metal works to replace welding process;
  - mechanical connectors including purposely-made joints for large-scale structures or proprietary products to replace traditional welding or bolting techniques for forming joints; and
  - proprietary methods for parapet installation to improve productivity (**Photos 19 and 20**).

- Alternative materials

  Adopt non-metal materials to minimize metal works, e.g. glass reinforced plastic in handrail, roof panels and water tanks, etc (**Photos 21 to 23**).

- End -

Photo 1 : Standardization of structural beam

Photo 2 : Special design (curvatures) involving high workmanship requirements

Photo 3 : Precast building façade with window frames

Photo 4 : Precast bathroom cum kitchen

Photo 5 : Precast concrete block wall

Photo 6 : Precast façade

Photo 7 : Precast staircase

Photo 8 : Flat slab

Photo 9 : Composite floor comprising steel and concrete structures

Photo 10 : Composite V-shaped columns for building construction

Photo 11 : Connection of composite beam and column structure

Photo 12 : Transfer structure

Photo 13 : Semi-precast beams

Photo 14 : Semi-precast slabs

Photo 15 : Mechanical plant for cutting and bending of reinforcement bars

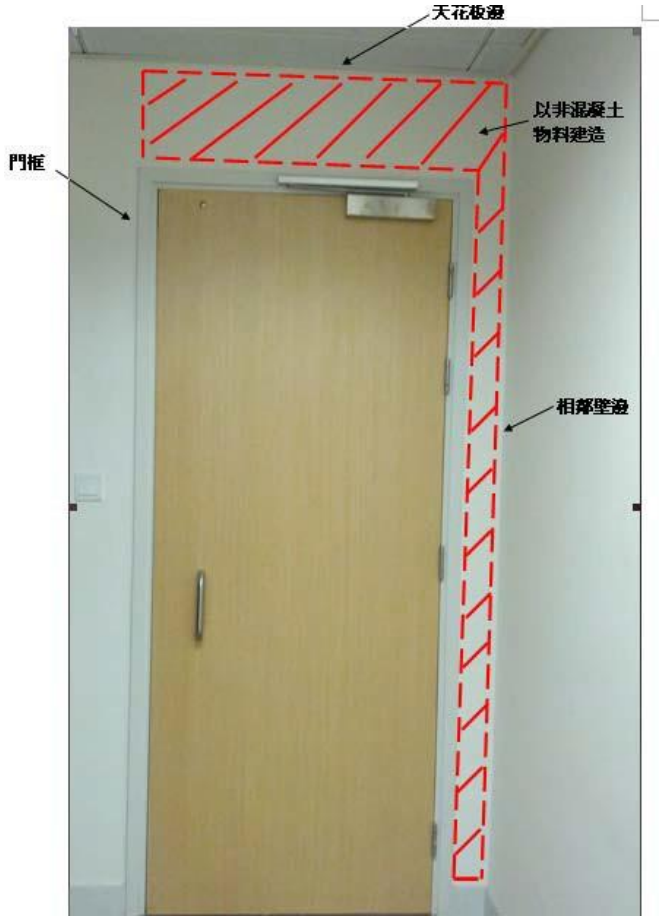

Photo 16 : The small areas between door frame and ceiling, and between door frame and adjacent wall constructed by non-concrete elements

Photo 17 : Profiled finishes on the external faces of slopes to be avoided

Photo 18 : Profiled finishes on the external faces of retaining walls to be avoided

Photo 19 : Proprietary products to replace traditional welding in parapet installation

Photo 20 : Proprietary products to replace traditional welding in parapet installation

Photo 21 : Glass Reinforced Handrail

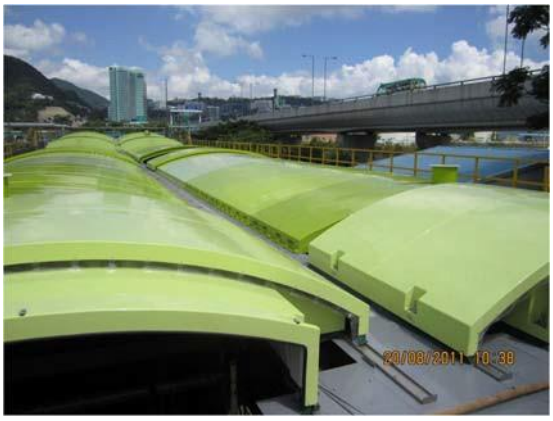

Photo 22 : Glass Reinforced Plastic Roof Panel

Photo 23 : Glass Reinforced Water Tank

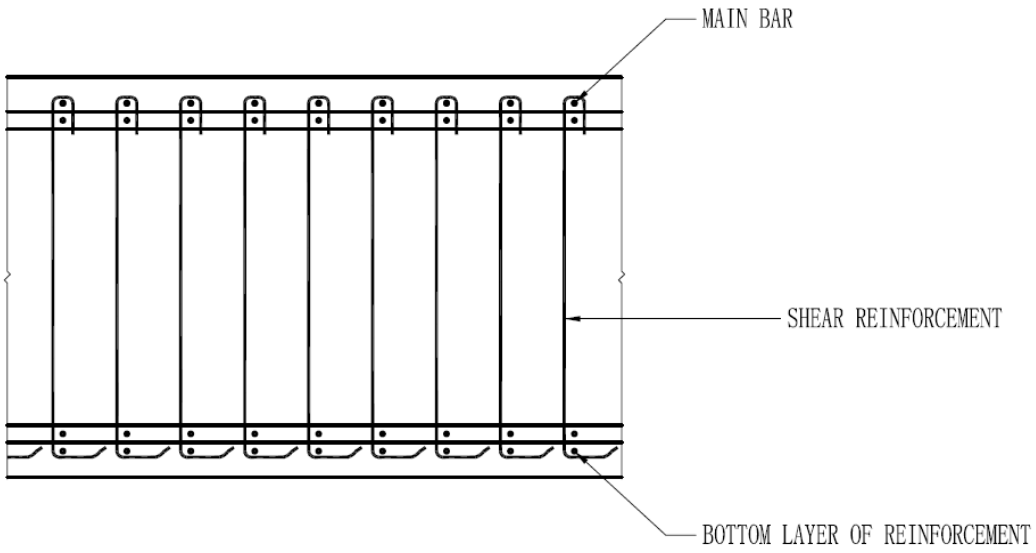

Figure 1 : Shear reinforcement hooked to bottom layer of longitudinal bars to be avoided

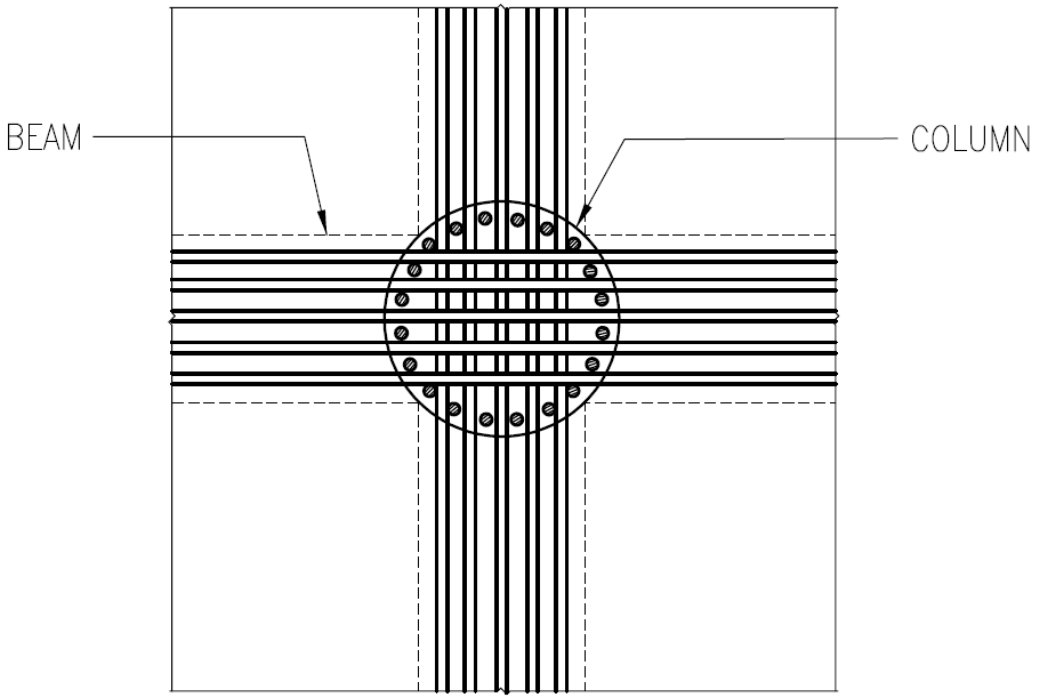

Figure 2 : Longitudinal bars of beams slotted into congested column cages to be avoided

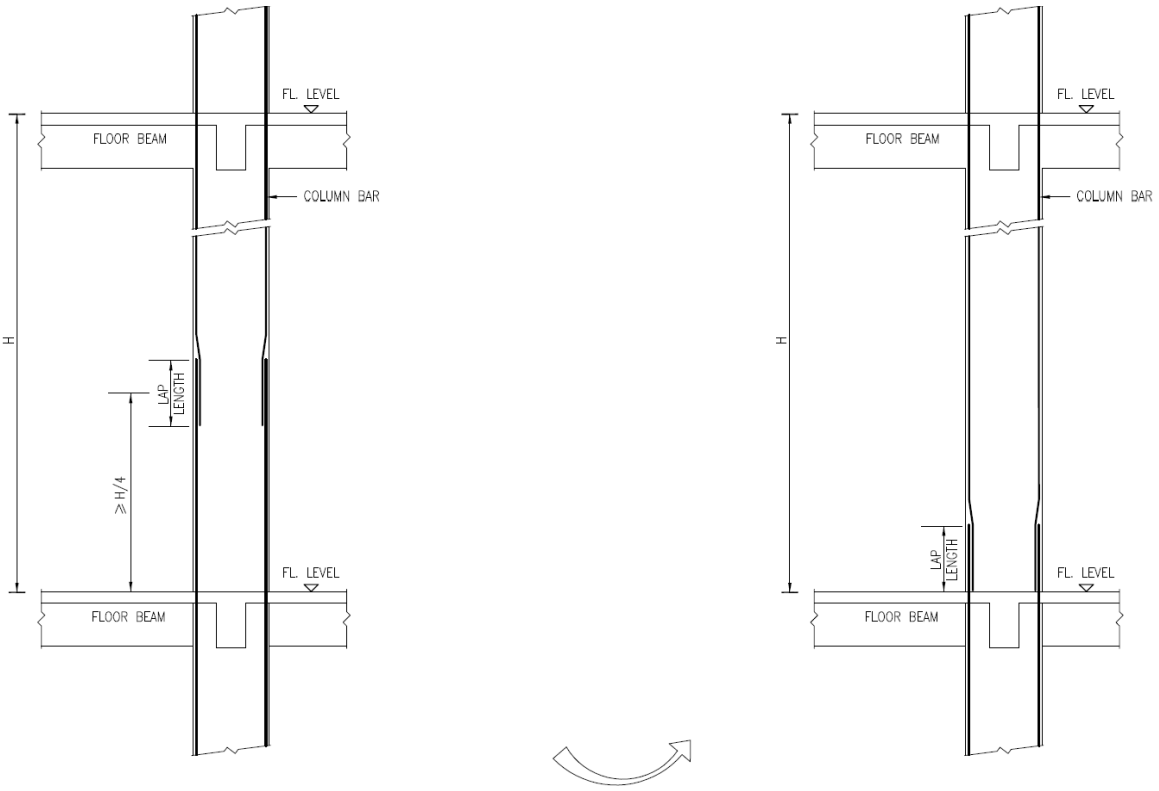

Figure 3 : Column vertical bars to be lapped at floor level rather than at height

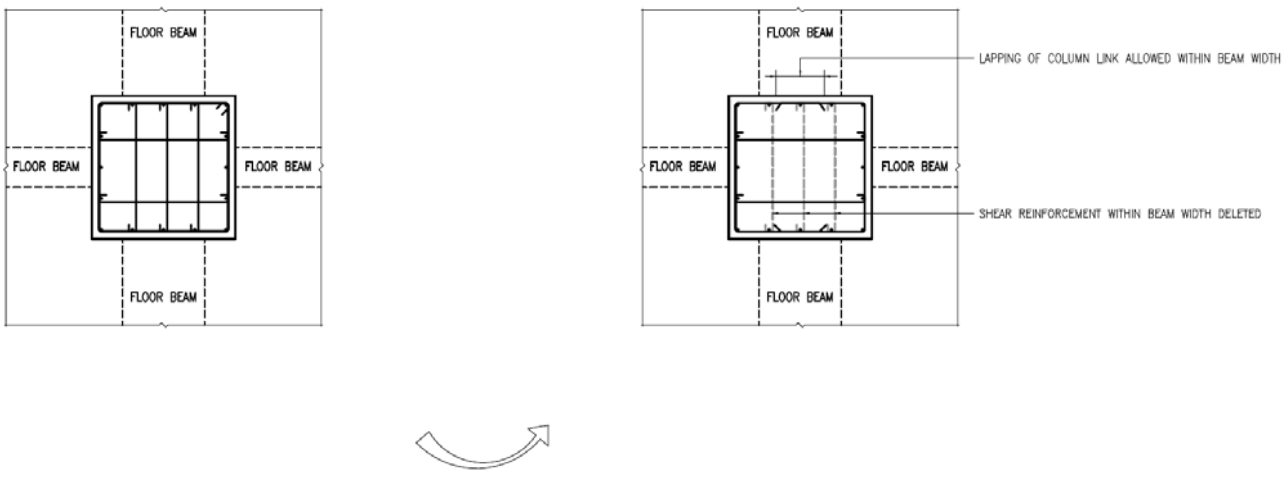

Figure 4 : Difficulty in fixing shear reinforcements at the junctions of columns and beams to be reduced

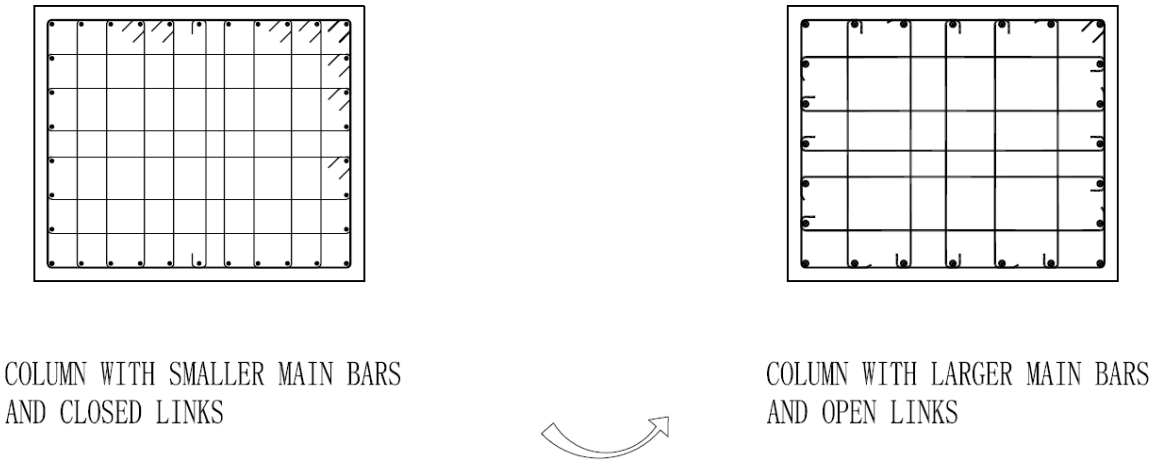

Figure 5 : Adopting larger size main bars and open shear links for columns