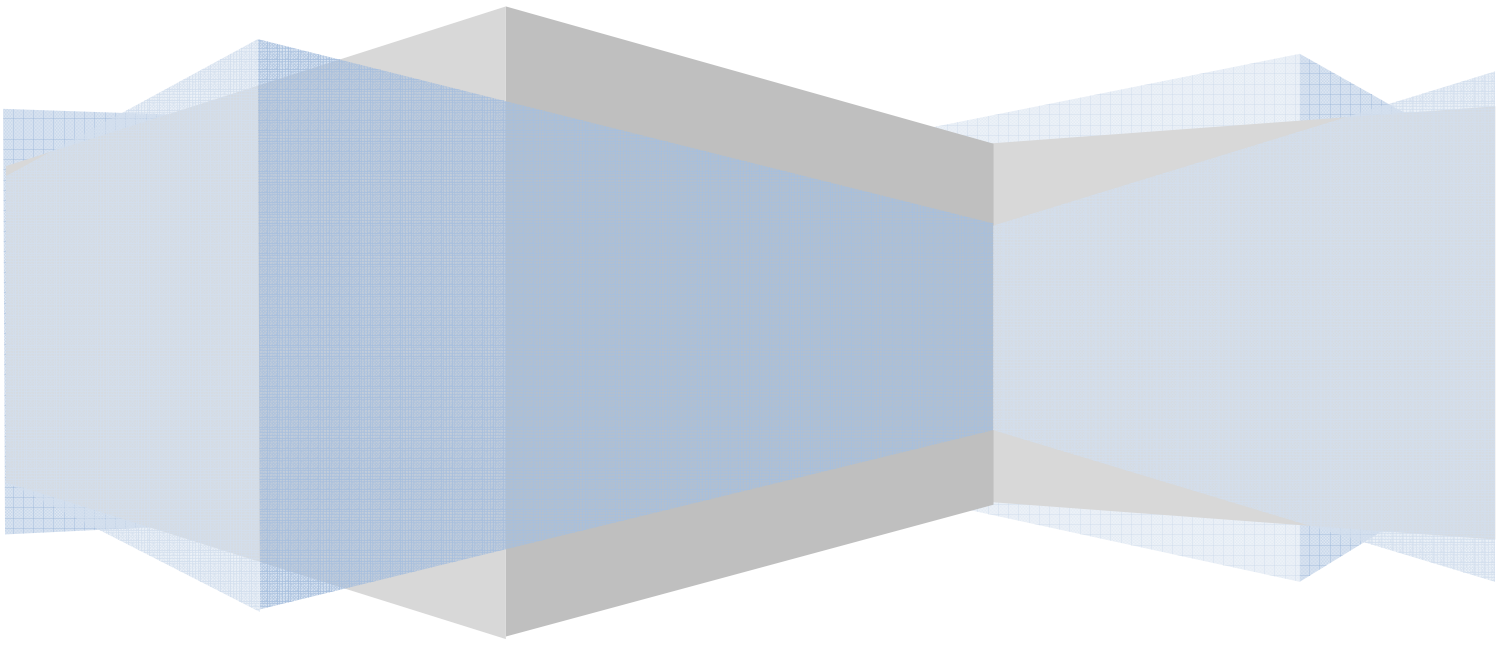
Building and Construction Authority

CODE OF PRACTICE ON

Buildability

April 2011



The Code of Practice on Buildability is electronically published by the Building and Construction Authority.

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CODE OF PRACTICE

ANNEX

Introduction

The legislation on Buildability was introduced by the Building and Construction Authority (BCA) in 2001 under the Building Control Act to promote buildable design through greater adoption of prefabricated, modular and standardised building components. Under the legislation, building designs are required to comply with a minimum buildable design score. Various editions of the Code of Practice on Buildable Design had been published by BCA, namely in December 2000, June 2002, January 2004 and September 2005 to reflect the revisions made to the buildable design requirements through the years and to accelerate the pace of adoption of labour-efficient designs.

While the industry has gained more experience with buildable designs, more could be done to enhance buildability and further reduce labour usage. Good buildable designs will have to be complemented by the adoption of labour-efficient technologies and methods to improve productivity at the construction stage. To achieve this, the Buildability framework has been strengthened to require designers to deliver more buildable designs upstream, and builders to adopt more labour-saving construction methods / technologies downstream. Builders will have to comply with a new minimum Constructability Score downstream which encourages the use of construction technologies, methods and processes that reduce the industry's reliance on foreign workers.

To reflect the development of Buildability concept beyond design, the Code of Practice on Buildable Design has been renamed as Code of Practice on Buildability. This Code sets out the requirements of minimum Buildable Design Score, minimum Constructability Score and their submission procedures. It also sets out the method of determining the Buildable Design Score and the Constructability Score. Some amendments and revisions may be expected from time to time.

If you need clarification on any aspect of this Code of Practice, please contact the Building and Construction Authority, Singapore.

1 SCOPE

This Code sets out the requirements of minimum Buildable Design Score and minimum Constructability Score for buildings and their submission procedures. It also sets out the method for determining the Buildable Design Score and the Constructability Score of building works.

2 DEFINITIONS

For the purpose of this Code, the following definitions shall apply:

Buildability	The extent to which the design of a building facilitates ease of construction as well as the extent to which the adoption of construction techniques and processes affects the productivity level of building works.
Buildable Design Score	The score for buildable design computed in accordance with Buildable Design Appraisal System (BDAS) as set out in the Code of Practice.
Constructability Score	The score for constructability computed in accordance with the Constructability Appraisal System (CAS) as set out in the Code of Practice.
Minimum Buildable Design Score	The lowest Buildable Design Score allowed under a particular category of development stipulated in this Code.
Minimum Constructability Score	The lowest Constructability Score allowed for the relevant gross floor area of the development stipulated in this Code.
Gross Floor Area	The gross floor area is calculated using the definition by the Urban Redevelopment Authority (URA).
Labour Saving Index (LSI)	A value given to a particular building system which reflects the relative difference in site labour productivity associated with the various structural and wall systems. In certain instances, the LSI could be further lowered to discourage the use of labour intensive elements or components. A LSI is also given for the use of prefabricated reinforcement/cages in cast in-situ components.
Qualified Person (QP)	The Qualified Person shall be as defined in the Building Control Act, Chapter 29, Part I, Section 2.

Type of Use	This refers to the use of the building/development, e.g. residential use or commercial use.
Type of Building Work	This refers to new building work, repairs, alterations or additions to an existing building (whether carried out within or outside the existing building).

3 STATUTORY REQUIREMENTS

3.1 Act and Regulations

The following Act and Regulations have relevance:

a. The Building Control Act.

b. The Building Control Regulations.

c. The Building Control (Buildability) Regulations.

3.2 Responsibility

3.2.1 It is the responsibility of the developers, architects, engineers, builders and others engaged in the design and construction of buildings to be conversant with the statutory requirements pertaining to the Buildability Framework. Designers and builders should familiarise themselves with the Buildable Design Appraisal System (BDAS) and Constructability Appraisal System (CAS) respectively to enable them to consider a wider range of construction systems, methods, technologies, materials and products to meet the requirement for minimum Buildable Design Score and Constructability Score.

3.2.2 The developer shall engage the appropriate Qualified Persons (QPs) to carry out buildable design. The QP for building works and the QP for structural works shall be responsible for ensuring that the Buildable Design Score requirement is met. The QPs shall jointly declare the Buildable Design Score achieved. The QPs shall also jointly declare the As-built Buildable Design Score achieved.

3.2.3 The builder shall be responsible for ensuring that the Constructability Score requirement is met. The builder shall declare the Constructability Score achieved. The builder shall also declare on the certificate of compliance of Constructability Score.

4 CATEGORIES OF BUILDINGS

The various types of building development are categorised in Table A. Buildings listed under the First Schedule are exempted from both the buildable design and constructability requirements.

Table A Categories of Building

CATEGORIES	TYPES OF DEVELOPMENT
Residential (landed)	• Terrace house • Semi-detached house • Bungalow • Clustered housing
Residential (non-landed)	• Condominium • Flat • Service apartment • Apartment • Dormitory • Hostel
Commercial	• Bank • Departmental store • Shopping centre • Office building • Supermarket • Restaurant • Hotel • Conventional hall and facilities • Exhibition hall
Industrial	• Factory • Warehouse • Godown • Brewery • Cold storage building • Packaging and processing plant • Printing plant • Sub-station
School	• Primary school • Secondary school

Table A **Categories of Building *(continued)***

CATEGORIES	TYPES OF DEVELOPMENT
Institutional and others	• Library • Hospital • Home for the aged • Childcare centre/Nursery • Research building • Educational facilities • Terminal building • Campus • Medical centre • Camp • Embassy • Museum • Crematorium and Columbarium • Club house • Cinema/Theatre • Sports/Recreational facilities • Public transport station

The above list shall not be exhaustive. The QP/builder is advised to seek clarification with BCA if his type of development is not stated in the above list.

5 BUILDABLE DESIGN SCORE REQUIREMENTS

5.1 Buildable Design Score

5.1.1 The Buildable Design Score of the building design shall be determined using this Code of Practice and the Buildable Design Appraisal System (BDAS) which is given in Annex A of this Code. BDAS may, from time to time, be amended, modified or replaced with a new edition.

5.1.2 Summary of the three areas of scoring
The Buildable Design Score of a project is made up of 3 parts:

Part 1 - Structural System (maximum 50 points). Points are awarded for various types of structural system used.

Part 2 - Wall System (maximum 40 points). Points are awarded for various types of wall system used.

Part 3 - Other Buildable Design Features (maximum 10 points). Points are awarded for standardisation, modular dimensions and use of precast/prefabricated components.

In addition to the above, bonus points are obtainable in Part 2 and Part 3 if a project uses off-form external finished wall, single integrated components and/or industry-wide standardisation of floor heights with precast staircases of standardised tread widths and riser heights.

The maximum Buildable Design Score achievable for a project is capped at 100 points.

5.2 Types of Development

5.2.1 The minimum Buildable Design Score requirement shall apply to new building works with Gross Floor Area (GFA) equals to or greater than 2,000 m^2.

5.2.2 The minimum Buildable Design Score requirement shall also apply to building works consisting of repairs, alterations and/or additions (A&A work) to an existing building if the building works involve the construction of new floor and/or reconstruction of existing floor for which their total gross floor area is 2,000 m^2 or more.

5.2.3 For building works with GFA equals to or greater than 2,000 m^2 but less than 5,000 m^2 and for which applications for planning permission were made before 1st January 2004, the minimum Buildable Design Score requirement shall not be applicable.

5.2.4 For buildings not listed in the First Schedule, the QP may apply for exemption if the building has a uniqueness arising from special functional requirements. The exemption will be on a case-by-case basis. The application for exemption is to be submitted to the Commissioner of Building Control.

5.3 Minimum Buildable Design Score

5.3.1 For new building work and A&A work outside existing building (considered as new work), the minimum Buildable Design Score for each category of development, namely residential projects, commercial projects, industrial projects, school projects and institutional and other projects are tabulated in Table B. Different minimum Buildable Design Score requirements are given for 2,000 $m^2 \leq$ GFA < 5,000 m^2, 5,000 $m^2 \leq$ GFA < 25,000 m^2 and GFA $\geq$ 25,000 m^2.

Table B Minimum Buildable Design Score for New Work

CATEGORY OF BUILDING WORK/ DEVELOPMENT	MINIMUM BUILDABLE DESIGN SCORE		
	2,000 m^2 ≤ GFA < 5,000 m^2	5,000 m^2 ≤ GFA < 25,000 m^2	GFA ≥ 25,000 m^2
Residential (landed)	60	65	68
Residential (non-landed)	67	72	75
Commercial	69	74	77
Industrial	69	74	77
School	64	69	72
Institutional and others	60	66	69

5.3.2 For clarity, reference shall be made to the table below for the relevant issue of Code of Practice to be used.

Table C Code of Practice to be Used

Date of planning application	Code of Practice to be used
Before 1st January 2001	Not applicable
1st January 2001 – 31st July 2002	Code of Practice on Buildable Design *December 2000 issue*
1st August 2002 – 31st December 2003	Code of Practice on Buildable Design *June 2002 issue*
1st January 2004 – 31st August 2005	Code of Practice on Buildable Design *January 2004 issue*
1st September 2005 – 14th July 2011	Code of Practice on Buildable Design *September 2005 issue*
On or after 15th July 2011	Code of Practice on Buildability *April 2011 issue*

5.3.3 For A&A work within existing buildings, the minimum Buildable Design Scores for residential, commercial, industrial, school and institutional and other projects are shown in Table D.

Table D Minimum Buildable Design Score for A&A Work

CATEGORY OF BUILDING WORK / DEVELOPMENT	MINIMUM BUILDABLE DESIGN SCORE
Residential (landed)	57
Residential (non-landed)	60
Commercial	62
Industrial	62
School	60
Institutional and others	60

5.3.4 Minimum Buildable Design Score for Mixed Development

The minimum Buildable Design Score for mixed development will be pro-rated according to the GFA of each type of development. For example, the minimum Buildable Design Score for a mixed development comprising 70% residential (non-landed) and 30% commercial is computed as follows:

Table E Computation of Minimum Buildable Design Score for a Mixed Development with GFA between 5,000 m² and 25,000 m²

CATEGORY OF BUILDING	% OF BUILDING GFA	MINIMUM BUILDABLE DESIGN SCORE
		5,000 m^2 ≤ GFA < 25,000 m^2
Residential (non-landed)	70% of GFA	70% of 72 = 50.40
Commercial	30% of GFA	30% of 74 = 22.20
The required minimum Buildable Design Score	100% of GFA	**73 (rounded to nearest integer)**

Table F Computation of Minimum Buildable Design Score for a Mixed Development with GFA 25,000 m² and above

CATEGORY OF BUILDING	% OF BUILDING GFA	MINIMUM BUILDABLE DESIGN SCORE
		GFA ≥ 25,000 m²
Residential (non-landed)	70% of GFA	70% of 75 = 52.50
Commercial	30% of GFA	30% of 77 = 23.10
The required minimum Buildable Design Score	100% of GFA	**76 (rounded to nearest integer)**

5.3.5 Minimum Buildable Design Score for Project with A&A Work

The minimum Buildable Design Score for a project with A&A work to be carried out both within and outside the existing building will be pro-rated according to the GFA of new work outside the existing building and work within the existing building. For example, the minimum Buildable Design Score for an A&A commercial project comprising 20% work within the existing building and 80% new work outside the existing building is computed as follows:

Table G Computation of Minimum Buildable Design Score for an A&A Commercial Project with GFA between 5,000m² and 25,000m²

TYPE OF WORK	% OF GFA	MINIMUM BUILDABLE DESIGN SCORE
		5,000 m² ≤ GFA < 25,000 m²
A&A work within existing building	20% of GFA	20% of 62 = 12.40
Work outside existing building	80% of GFA	80% of 74 = 59.20
The required minimum Buildable Design Score	100% of GFA	**72 (rounded to nearest integer)**

6 SUBMISSION PROCEDURES FOR BUILDABLE DESIGN SCORE REQUIREMENT

Buildable Design Score will be one of the requirements for Building Plan (BP) approval. The BP will not be approved if the submitted Buildable Design Score is lower than the stipulated minimum. The Buildable Design Score is to be submitted by QPs at the following stages:

- BP stage
- ST (Structural plan) superstructural stage
- Temporary Occupation Permit (TOP)/Certificate of Statutory Completion (CSC) stage

6.1 Submission at BP Stage

The QP shall indicate in Form BPD_BP03 (Application for Approval of Building Plans) whether Buildable Design Score calculations are applicable to the proposed building works. If applicable, the Buildable Design Score is to be submitted together with the BP submission using Form BPD_BS01. The Buildable Design Score is to be jointly declared by the QP for Building Works and the QP for Structural Works and the detailed computation of the Buildable Design Score shall be attached. Forms BPD_BP03 and BPD_BS01 can be downloaded from BCA's website at http://www.bca.gov.sg/.

6.2 Submission at ST Superstructural Stage

The current submission procedures allow the ST to be submitted separately from the BP. Where ST submission is made before BP submission, the QP shall indicate in Form BEV/A1 (Application for Approval of Structural Plans) whether Buildable Design Score calculations are applicable to the proposed building works. If applicable, the Structural Buildable Design Score is to be submitted by the QP for Structural Works at the ST superstructural stage using Form BEV/ A1_BS02. The Structural Buildable Design Score is to be jointly declared by the QP for Building Works and the QP for Structural Works. Forms BEV/A1 and BEV/A1_BS02 can be downloaded from BCA's website at http://www.bca.gov.sg/.

6.3 Submission at TOP/CSC stage

6.3.1 Upon project completion, the QP for Building Works and the QP for Structural Works shall compute and declare the As-built Buildable Design Score and submit one set of the computation to BCA using Form BPD_BS03. This submission is to be made before a temporary occupation permit or in a case where no such permit is earlier applied for, a certificate of statutory completion can be granted. Form BPD_BS03 can be downloaded from BCA's website at http://www.bca.gov.sg/.

6.3.2 BCA may conduct site checks during the construction stage.

7 CONSTRUCTABILITY SCORE REQUIREMENTS

7.1 Constructability Score

7.1.1 The Constructability Score of the building works shall be determined using this Code of Practice and the Constructability Appraisal System (CAS) which is given in Annex B of this Code. CAS may, from time to time, be amended, modified or replaced with a new edition.

7.1.2 Summary of the three areas of scoring
The Constructability Score of a project is made up of 3 parts:

Part A - Structural System (maximum 60 points). Points are awarded for various methods and technologies adopted during the construction of structural works.

Part B - Architectural, Mechanical, Electrical & Plumbing (AMEP) System (maximum 50 points). Points are awarded for various methods and technologies adopted during the construction of AMEP works.

Part C - Good Industry Practices (maximum 10 points). Points are awarded for good industry practices adopted on site to improve productivity.

In addition to the above, points are obtainable in Part A and Part B if a project adopts innovative methods, systems, processes, plant and equipment that help to achieve productivity improvement. Innovation points are awarded subjected to BCA's assessment on a case-by-case basis of the impact on labour efficiency of the particular method, system, process, plant and equipment used.

The total points allocated under the CAS is 120 points.

7.2 Types of Development

7.2.1 The minimum Constructability Score requirement shall apply to new building works with Gross Floor Area (GFA) equals to or greater than 5,000 m^2.

7.2.2 The minimum Constructability Score requirement shall also apply to building works consisting of repairs, alterations and/or additions (A&A work) to an existing building if the building works involve the construction of new floor and/or reconstruction of existing floor for which their total gross floor area is 5,000 m^2 or more.

7.3 Minimum Constructability Score

7.3.1 The minimum Constructability Score for each category of development, namely residential projects, commercial projects, industrial projects, school projects and institutional and other projects are tabulated in Table H. Different minimum Constructability Score requirements are given for 5,000 $m^2 \leq$ GFA < 25,000 m^2 and GFA $\geq$ 25,000 m^2.

7.3.2 In addition to meeting the minimum Constructability Score requirements, projects must also achieve a minimum score under the Structural System component of the CAS as shown in Table H.

Table H Minimum Constructability Score

CATEGORY OF BUILDING WORK / DEVELOPMENT	MINIMUM CONSTRUCTABILITY SCORE	
	5,000 m^2 ≤ GFA < 25,000 m^2	GFA ≥ 25,000 m^2
Residential (landed)	40 (Minimum 25 points from Structural System)	50 (Minimum 35 points from Structural System)
Residential (non-landed)		
Commercial		
Industrial		
School		
Institutional and others		

8 SUBMISSION PROCEDURES FOR CONSTRUCTABILITY SCORE REQUIREMENT

8.1 Submission of Constructability Score

The builder is required to submit the Constructability Score which shall not be lower than the stipulated minimum at either one of the following stages:

- at the time of application for permit to carry out structural works (Permit), or
- within 3 months (for non-Design and Build projects) or 6 months (for Design and Build projects) after the permit has been issued in the event that the builder requires more time to plan for the type of construction methods and technologies to be adopted in the project.

8.1.1 Submission at Permit Stage

The builder shall indicate in Form BCA-BE-PERMIT (BEV/B1) (Joint Application for Permit to Carry out Structural Works) whether Constructability Score calculations are applicable to the proposed building works. If applicable, the Constructability Score is to be submitted together

with the permit application using Form BEV_CS01. The Constructability Score for the proposed building works and the detailed computation of the Constructability Score is to be declared by the builder. Forms BCA-BE-PERMIT (BEV/B1) and BE_CS01 can be downloaded from BCA's website at http://www.bca.gov.sg/.

8.1.2 Submission within 3 months/6 months after Permit Issuance

The builder shall indicate in Form BCA-BE-PERMIT (BEV/B1) that the Constructability Score calculations, where applicable for the proposed building works, would be submitted within the timeframe allowed depending on the type of contract for the building works. The builder shall also provide an undertaking using Form BEV_CS01_Annex when applying for the permit to carry out structural works that the Constructability Score would be submitted within the allowed timeframe.

The Constructability Score and the detailed computation of the Constructability Score as declared by the builder shall be submitted using Form BEV_CS01. Form BEV_CS01_Annex can be downloaded from BCA's website at http://www.bca.gov.sg/.

8.2 Departure and Deviation from Adopted Construction Methods and Technologies

If there are any deviations to the submitted Constructability Score due to changes to the type of construction methods and technologies adopted, the builder shall re-compute the Constructability Score resulting from such changes and submit the revised Constructability Score at least 3 working days before the deviations are carried out at site. The re-submission of the Constructability Score shall be made using Form BEV_CS01 and the revised Constructability Score shall not be lower than the stipulated minimum.

8.3 Submission of Certificate of Compliance of Constructability Score

Upon completion of the building works, the builder shall submit a Certificate of Compliance of Constructability Score using Form BPD_CCS01 declaring that the construction of the building works has been carried out such that the Constructability Score of the building works is not less than the stipulated minimum constructability score. This submission is to be made before a temporary occupation permit or in a case where no such permit is earlier applied for, a certificate of statutory completion can be granted.

BCA may conduct site checks during the construction stage.

9 OTHER REQUIREMENTS

9.1 Site Records

The builder is required to keep and maintain at site the following documents and records as evidences to demonstrate compliance with the minimum Constructability Score requirement:

- a progress report on the types of construction methods, technologies and processes adopted for the building works in accordance with the Constructability Score submitted, including photographs evidencing the adoption of such construction methods, technologies and processes
- records of the construction processes put in place for the building works
- any other documents, reports and records showing the details of the construction methods and technologies adopted

Submittal of the documentary evidences may be required and shall be made in such manner as requested by BCA.

9.2 Construction Productivity Data

The builder is required to submit Construction Productivity Data of the building works to BCA on a monthly basis which would be used to assess the productivity level of the building works. The Construction Productivity Data shall include the manpower usage, construction output and documentation relating to the construction of the building works.

First Schedule

BUILDING WORKS WHICH ARE NOT SUBJECTED TO THE MINIMUM BUILDABLE DESIGN SCORE AND CONSTRUCTABILITY SCORE REQUIREMENTS

The types of development which are not subjected to the minimum Buildability requirement are:

(a) any culvert, bridge, underpass, tunnel, earth retaining or stabilising structure, slipway, dock, wharf or jetty;

(b) any theme park;

(c) any place of worship;

(d) any power station; or

(e) any waste processing or treatment plant.

Annex A

BUILDABLE DESIGN APPRAISAL SYSTEM

1 INTRODUCTION

The Buildable Design Appraisal System or BDAS was developed by the Building and Construction Authority as a means to measure the potential impact of a building design on the usage of site labour. The appraisal system results in a 'Buildable Design Score' of the building design. A design with a higher Buildable Design Score will result in more efficient labour usage in construction and therefore higher site labour productivity.

1.1 Objective

The objective of BDAS is to result in the wider use of buildable design. It is not the intention to adopt buildability at the expense of good architectural design. The need for more varieties and architectural features to satisfy clients' needs is recognised. There are, in fact, many examples of attractive designs that have high buildable design scores.

Neither is the BDAS intended to solely promote prefabrication. Although, in general, prefabrication should give higher buildable design scores, designs using simple cast-in-place construction can also yield reasonably high buildable design scores.

Most importantly, buildable designs will lead to improvements in quality. This is due to the relative ease of construction and the need for fewer skilled tradesmen.

1.2 Principles of Buildable Design

The designer should first consider external factors such as soil condition, access and storage at the site, availability of resources, skills and technology, sequence of operations etc, to determine the most appropriate building system to be used. He can then apply the **3S** principles of *Standardisation, Simplicity* and *Single integrated elements* to achieve a buildable design.

Standardisation refers to the repetition of grids, sizes of components and connection details. A repeated grid layout, for example, will facilitate faster construction whether formwork or precast components are used. Similarly, columns or external claddings of repeated sizes will reduce the number of mould changes whether on-site or in the factory.

Simplicity means uncomplicated building construction systems and installation details. A flat plate system, for example, eases formwork construction as well as reinforcement work considerably. Use of precast components reduces many trade operations on site and should improve site productivity provided the standardisation principles are observed.

Single integrated elements are those that combine related components together into a single element that may be prefabricated in the factory and installed on site. Prefabricated toilets are good examples of this.

1.3 Scope

BDAS therefore looks at the design and computes the extent to which the principles of standardisation, simplicity and single integrated elements are found. It covers the structural system and the major architectural components such as external and internal walls, doors and windows.

Points are awarded based on the types of structural and architectural system used. More points are awarded to the more buildable systems. The points are totalled to give the "Buildable Design Score" of the design.

1.4 Buildable Design Score and Contractor's Productivity

The particular Buildable Design Score for a design does not imply that every contractor will achieve the same level of site productivity when building that design. There are other factors that affect the contractor's output such as his management, quality of his sub-contractors and others. However, a high Buildable Design Score will imply that the same contractor should build that project with less site labour than one with a low Buildable Design Score.

1.5 Rationale on Allocation of Points

The computation of Buildable Design Score for a project involves the summation of Buildable Design Score attained for structural systems, wall systems and other buildable features. The maximum Buildable Design Score achievable for a project is 100 points.

The allocation of points to structural systems, wall systems and other buildable features is based on manpower consumption.

1.6 Rationale on Derivation of Labour Saving Indices

One of the more important factors in the appraisal system is the labour saving index (LSI). A labour saving index is given to each building system and the use of prefabricated reinforcement/cages in cast in-situ components. The building systems and the indices will be updated regularly to reflect the changes in technology.

Projects were identified for each type of building system to undergo studies. Labour productivity, measured in square metres per manday, relating to each building system was analysed. Based on the relative difference in labour productivity, the labour saving index for each building system was derived. In certain instances, the labour saving indices could be further lowered to discourage the use of labour intensive elements or components.

A high index indicates that the design is more buildable and fewer site workers are needed.

1.7 Updates

This Code of Practice on Buildability, April 2011, has included a number of updates.

1.7.1 Structural System

The key changes are listed below:

(a) The use of slab/beam ratio (i.e. slab/beam>15 or slab/beam≤15) for flat plate and flat slab systems (with and without precast columns/walls) has been removed. Instead, flat plate and flat slab systems have been classified by whether such systems have any perimeter beams or if the perimeter beams have beam depth greater or less than 600mm.

(b) The LSIs for "Precast beam and precast column/wall" and "Precast column/wall and precast slab" structural systems have been increased.

(c) The LSIs for "Precast slab only" and "Precast column/wall only" structural systems have been lowered.

(d) "Precast beam only" structural system has been removed.

(e) "One-directional banded beams" has been reworded to "One-directional beams" and its LSI has been lowered.

(f) The slab/beam ratio for "Two-directional beam" system has been removed and its LSI has been lowered.

1.7.2 Wall System

The key changes are listed below:

(a) The LSIs for dry partition wall have been revised.

(b) The LSIs for precast concrete panel/wall, PC formwork and cast in-situ RC wall with plastering, tiled/stone finishes have been lowered.

(c) The LSIs for precision blockwall and brickwall have been lowered.

(d) Bonus points have been given to the use of off-form external finished wall / column (for cast in-situ RC wall and PC formwork).

1.7.3 Other Buildable Design Features

The key changes are listed below:

(a) Except for buildable design features awarded with bonus points, the percentage of coverage for all other buildable design features has been changed to

(i) ≥ 70% to < 90% instead of ≥ 65% to < 80%
(ii) ≥ 90% instead of ≥ 80%

(b) "Repetition of horizontal grids" has been added as a buildable design feature.

(c) The points awarded for the use of precast meter chambers have been lowered and are only applicable to landed residential developments.

(d) "Non-screed floor" has been reworded to "No screeding for any flooring" with more points given.

(e) "No column stumps", "Precast bay windows" and "Precast planter boxes" have been removed.

(f) More bonus points have been awarded for the use of prefabricated bathroom/toilet units.

(g) Bonus points have been awarded for the use of industry-wide standardised floor heights with standard precast staircase sizes.

1.8 Development of BDAS

The Buildable Design Appraisal System was developed with the assistance of a committee comprising leading local and foreign contractors who provided productivity data inputs from their projects. Inputs from various government agencies, consultants and product manufacturers were also incorporated. The concern for buildability, or the need to integrate design with construction, has also been taken up in developed countries. In Japan, this integration is maximised as most projects proceed on a design-and-build basis. Major Japanese contractors such as Takenaka Corporation, Taisei Corporation and Kajima Corporation have developed their own in-house buildability appraisal systems. BCA's Buildable Design Appraisal System is modelled after Takenaka's system.

2 HOW TO USE THE BUILDABLE DESIGN APPRAISAL SYSTEM (BDAS)

2.1 Components of the Appraisal System

The BDAS provides a method to compute the Buildable Design Score of a design. It consists of three main parts:

(a) the Structural System;

(b) the Wall System; and

(c) Other Buildable Design Features.

Buildable Design Score of the Structural System

A designer could use different structural systems for different parts of the building so as to achieve the best practical design. The Buildable Design Score for a particular structural system is the product of the percentage area covered by the structural system and its corresponding labour saving index available in Table 1. The Buildable Design Scores for the different structural systems adopted are then summed up and multiplied by the weight factor to arrive at the Buildable Design Score of the total structural system. The maximum Buildable Design Score achievable for structural systems is 50 points.

Buildable Design Score of the Wall System

The Buildable Design Score for a particular wall system is computed by multiplying the percentage wall length covered by the wall system and its corresponding labour saving index available in Table 2. The Buildable Design Scores for the different wall systems adopted are then summed up and multiplied by the weight factor to arrive at the Buildable Design Score of the total wall system. The maximum Buildable Design Score achievable for wall systems is 40 points.

Buildable Design Score of Other Buildable Design Features

In this section, the buildability of the design is examined at the detailed level. Three basic design characteristics, namely standardisation of columns, beams, windows and doors, grids and usage of precast components are considered. The use of these buildable design features will be awarded with points directly. The maximum Buildable Design Score that can be achieved in this section is 10 points.

In addition, bonus points would be given for the use of single integrated components such as prefabricated bathroom/toilet units and precast household shelters. The use of industry-wide standardized floor heights with standard precast staircases would also be recognised with bonus points.

2.2 Computation of Buildable Design Score

The Buildable Design Score formula is expressed as:

Buildable Design Score of Building	=	Buildable Design Score of Structural System (including Roof System) + Buildable Design Score of Wall System + Buildable Design Score of Other Buildable Design Features
BDScore	=	$50[\sum(A_s x S_s)] + 40[\sum(L_w x S_w)] + N + \text{Bonus points}$
where A_s	=	A_{sa} / A_{st}
L_w	=	L_{wa} / L_{wt}
A_s	=	Percentage of total floor area using a particular structural system
A_{st}	=	Total floor area which includes roof (projected area) and basement area
A_{sa}	=	Floor area using a particular structural system
L_w	=	Percentage of total external & internal wall length using a particular wall system
L_{wt}	=	Total external & internal wall length, excluding the length of external basement wall for earth retaining purpose.
L_{wa}	=	External & internal wall length using a particular wall system
S_s	=	Labour saving index for structural system (Table 1)
S_w	=	Labour saving index for external & internal wall system (Table 2)
N	=	Buildable Design Score for other buildable design features (Table 3)
Bonus points	=	Bonus points for the use of single integrated components and industry-wide standardized floor heights with standard precast staircases

The Buildable Design Score of a project which consists of more than one building should be computed by multiplying the respective Buildable Design Score of the individual building with its percentage of the total floor area of that building in the project. That is,

$$\text{BDScore}_{\text{project}} = \text{Sum of } [\text{BDScore}_{\text{building}} \times (A_{st})_{\text{building}} / (A_{st})_{\text{project}}]$$

EXPLANATORY NOTES TO BUILDABLE DESIGN SCORE FORMULA

(a) Buildable Design Score of Structural System

The score for the structural system is based on the following:

Method for computation : $50[\sum(A_s x S_s)]$

A_s : The extent to which a particular structural system is used. This is expressed as a percentage of the total floor area of the building.

S_s : A labour saving index for the particular structural system. The labour saving indices for the various structural systems are given in Table 1.

All structural systems used must be accounted for. If a combination of systems is used, then the contribution of each system is computed and summed up to arrive at the score. The maximum Buildable Design Score for the structural system is 50 points.

The total floor area is the total floor area constructed in the project, and includes roof (projected area) and basement area.

(b) Buildable Design Score of Wall System

The score for the wall system is based on:

Method for computation : $40[\sum(L_w x S_w)]$

L_w : The extent to which a particular external or internal wall system is used. This is expressed as a percentage of the total wall length of the building.

S_w : A labour saving index for the particular external or internal wall system. The labour saving indices for the various wall systems are given in Table 2.

All wall systems must be accounted for. If a combination of systems is used, then the contribution of each system is computed and summed up to arrive at the score. The maximum Buildable Design Score for wall system is 40 points.

The total wall length includes all external and internal walls but exclude external basement wall for earth retaining purpose.

(c) Buildable Design Score of Other Buildable Design Features, N value

This section covers other design considerations that contribute to labour saving on site. Points are given for each labour saving method adopted and these are summed up to give the score, up to a maximum of 10 points. The points of various design considerations are given in Table 3.

(d) Buildable Design Score of Single Integrated Components and Industry-wide standardized floor heights with standard precast staircases, Bonus points

Bonus points are given for the use of single integrated components such as prefabricated bathroom/toilet units and precast household shelter, as well as Industry-wide standardized floor heights with standard precast staircases. The points for these components are given in Table 3.

Table 1 Structural Systems – S_s Value

STRUCTURAL SYSTEM	DESCRIPTION	LABOUR SAVING INDEX S_s
Precast Concrete System	Full precast	1.00
	Precast column/wall[2] with flat plate and no perimeter beams	0.95
	Precast column/wall[2] with flat plate and perimeter beams (beam depth ≤ 600 mm) [3]	0.85
	Precast column/wall[2] with flat slab and no perimeter beams	0.90
	Precast column/wall[2] with flat slab and perimeter beams (beam depth ≤ 600 mm) [3]	0.80
	Precast beam and precast slab	0.90
	Precast beam and precast column/wall[2]	0.90
	Precast column/wall[2] and precast slab	0.90
	Precast slab only	0.70
	Precast column/wall only[1][2]	0.70
Structural Steel System *(applicable only if steel decking or precast slab is adopted)*	Steel beam and steel column *(without concrete encasement)*	0.95
	Steel beam and steel column *(with concrete encasement)*	0.85
Cast In-situ System[1]	Flat plate with no perimeter beams	0.90
	Flat plate with perimeter beams (beam depth ≤ 600 mm) [3]	0.80
	Flat slab with no perimeter beams	0.85
	Flat slab with perimeter beams (beam depth ≤ 600 mm)[3]	0.75
	One-directional beam	0.70
	Two-directional beam	0.45
Roof System (non-RC)	Integrated metal roof on steel truss	0.90
	Metal roof on steel truss or timber truss	0.85
	Tiled roof on steel beam or precast concrete beam or timber beam	0.75
	Metal roof on cast in-situ beam	0.60
	Tiled roof with cast in-situ beam	0.55

NOTE:

(1) For cast in-situ floor with cast in-situ transfer beam, an index of -0.10 shall be applied to the entire cast in-situ floor area. This requirement does not apply to cast in-situ floor with transfer beam designed for ramp access.

(2) Precast wall refers to load-bearing walls only.

(3) If flat plate/flat slab is used with perimeter beams with beam depth > 600mm, the corresponding index would be reduced by 0.05. For example, the index for flat plate with perimeter beams (beam depth > 600mm) would be 0.75 (i.e. 0.80 - 0.05).

* An index of 0.03 each would be given if prefabricated reinforcement/cage/continuous stirrup is used in cast in-situ slab, beam and column/wall.

* Indices for other systems not shown in this table shall be determined by BCA on a case-by-case basis. For such cases, the QPs are advised to seek BCA's comments before proceeding with the designs.

EXPLANATORY NOTES TO TABLE 1

(a) Table 1 has been arranged into 4 main systems of precast concrete system, structural steel system, cast in-situ system and roof system with their respective labour saving indices. In the event when a structural system used for a project is not stated in Table 1, the labour saving index shall be decided by BCA.

(b) For precast concrete system, the labour saving indices are given according to the combinations of precast components (slab, column/wall and beam) used.

(c) Flat plate refers to a slab design which does not have column heads or drop panels. Under BDAS, a flat plate system could be viewed as a floor with flat soffit (with the exception of perimeter beams). From the buildability point of view, such floor with flat soffit would ease formwork construction and reinforcement work at site considerably and helps to improve site productivity.

(d) The index for concrete roof depends on the type of structural system used and follow the respective index given under cast In-situ system or precast concrete system.

(e) The integrated metal roof refers to prefabricated roofing system complete with insulation and can be installed as an entire roof section.

(f) A transfer beam refers to a beam that interrupts the paths of load bearing elements from above and distributes the loads sideways to the ends of the beam.

(g) Additional points in the form of labour saving index of 0.03 each would be awarded for the use of prefabricated reinforcement/cages in cast in-situ floor, beam and column.

The use of prefabricated reinforcement/cages must be indicated on plans.

The percentage of coverage for the use of prefabricated reinforcement/cages is to be based on the total floor area or on the total number of columns or total number of beams.

Example of prefabricated reinforcement:

Area of precast floor = 3000 m^2

Area of cast in-situ floor using prefabricated reinforcement (mesh) = 7,000 m^2

Total floor area including roof area = 10, 000 m^2

Percentage of coverage = area of cast in-situ floor using mesh/total floor area

= 7000/10000

= 70%

Therefore, points awarded = 0.03 x 0.70 x 50

= 1.05

Table 2 Wall Systems – S_w Value

WALL SYSTEM	DESCRIPTION	LABOUR SAVING INDEX S_w
Curtain wall / full height glass partition / dry partition wall[2] / prefabricated railing	Curtain wall / Full height glass partition	1.00
	Prefabricated railing	1.00
	Dry partition wall	1.00
	Dry Partition wall with tile / stone finishes	0.90
Precast Concrete Panel / Wall[3]	Precast concrete panel / wall with skim coat	0.90[1]
	Precast Concrete panel / wall with plastering, tile / stone finishes	0.60
PC Formwork[4]	PC formwork with skim coat	0.75[1]
	PC formwork with plastering, tile / stone finishes	0.40
Cast In-situ RC Wall	Cast in-situ RC wall with skim coat	0.70[1]
	Cast in-situ RC wall with plastering, tile / stone finishes	0.40
Precision Blockwall	Precision blockwall with skim coat	0.40[1]
	Precision blockwall with plastering, tile / stone finishes	0.10
Brickwall / Blockwall	Brickwall / blockwall with or without plastering	0.05

Bonus Points

DESCRIPTION	LABOUR SAVING INDEX S_s
Off-form external finished wall/column (for Cast in-situ RC wall and PC formwork) [5]	0.15

NOTE:

(1) These indices also apply to the respective walls with no finishes or finishes done off-site.

(2) Dry partition walls include sandwich panel wall systems, stud and sheet partition wall systems, demountable wall systems.

(3) Precast concrete panels/walls include normal weight concrete panels, lightweight concrete panels, autoclaved aerated concrete panels.

(4) PC formwork refers to precast formwork panel with concrete infill.

(5) Off-form external finished wall/column without the need for additional labour-intensive surface treatment is given additional LSI over and above the LSI given for Cast in-situ RC wall and PC formwork with skim coat.

* Indices for other systems not shown in this table shall be determined by BCA on a case-by-case basis.

EXPLANATORY NOTES TO TABLE 2

(a) Table 2 has been arranged into the various wall systems with their respective labour saving indices. In the event when a wall system used for a project is not stated in Table 2, the labour saving index shall be decided by BCA.

(b) The labour saving index for full height windows and doors is 1.00.

(c) Dry partitions refer to panels that do not require the use of water for erection. Examples are solid composite gypsum boards, cementitious panels or glass panels etc. Precision blocks refer to lightweight concrete blocks that have precised dimensions (± 1mm dimensional tolerance) and can be laid on thin bed adhesive mortar.

(d) Bonus points in the form of additional labour saving index of 0.15 would be awarded for the use of off-form external finished cast in-situ RC or PC formwork wall/column which does not require further concrete treatment. This LSI of 0.15 is given over and above the LSI given for cast in-situ RC wall and PC formwork with skim coat.

Example of off-form finished cast in-situ RC wall:

Total length of cast in-situ (CIS) wall with skim coat = 3, 000 m

Assume part of this wall length is with off-form finish = 500 m

Total wall length of the building = 15, 000 m

Buildable design score of CIS wall with skim coat	= 40 x (3000/15000) x 0.70
	= 5.60 points
Bonus points for CIS wall with off-form finish	= 40 x (500/15000) x 0.15
	= 0.20 points
Therefore, total points awarded for CIS wall	= 5.60 + 0.20
	= 5.80

Table 3 Other Buildable Design Features – N Value

BUILDABLE FEATURES		MODULE	UNIT OF COVERAGE	N VALUE	
				PERCENTAGE OF COVERAGE[4]	
				≥70% TO < 90%	≥ 90%
1. Standardisation					
1.1	Columns (3 most common sizes)	0.5M[2]	no.		2.00
1.2	Beams (3 most common sizes)	0.5M[2]	no.		2.00
1.3	Door leaf openings (width) (3 most common sizes)	0.5M	no.		1.00
1.4	Windows (3 most common sizes)[1]	1M/1M[3]	no.		1.00
2. Grids					
2.1(a)	Repetition of floor-to-floor height (For blocks more than 6 storey) *The repetition should omit bottom floor, top floor and above.*	0.5M	no.	1.50	2.00
2.1(b)	Repetition of floor-to-floor height (For blocks up to 6 storey) *The repetition should omit bottom floor, top floor and above. Only applicable if there are at least 2 floor heights remaining after the floor omission.*	0.5M	no.	0.75	1.00
2.2(a)	Vertical repetition of structural floor layout (For blocks more than 6 storey) *The repetition should omit bottom floor, top floor and above.*		area	1.50	2.00
2.2(b)	Vertical repetition of structural floor layout (For blocks up to 6 storey) *The repetition should omit bottom floor, top floor and above. Only applicable if there are at least 2 floors remaining after the floor omission.*		area	0.75	1.00
2.3	Repetition of Horizontal Grids	6M	no.	1.50	2.00
3. Others					
3.1	Multi-tier precast columns		no.		2.00
3.2	Precast or pre-assembled/ metal staircases		no.		2.00
3.3	Precast meter chambers (for landed residential developments)		no.		1.00
3.4	Precast refuse chutes		no.		1.50
3.5	Precast service risers		no.		1.00
3.6	No screeding for any flooring		area		3.00
Bonus Points		**MODULE**	**UNIT OF COVERAGE**	**PERCENTAGE OF COVERAGE[4]**	
				≥65% TO < 80%	≥ 80%
Single Integrated Components					
A.1	Prefabricated bathroom/toilet units complete with piping/wiring		no.	3.00	4.00
A.2	Precast household shelter		no.	2.00	3.00
Industry Standardisation					
A.3(a)	Typical storeys standardised to either 2.8m, 3.15m, 3.5m, 4.2m or 4.55m height and with precast staircase of riser height of 175mm & tread width of 250mm or 275mm		no.		2.00
A.3(b)	Typical storeys standardised to either 3.15m or 4.2m height and with precast staircase of riser height of 150mm & tread width of 300mm		no.		2.00

NOTE:

(1) Sizes based on dimensions of frames.

(2) The module of 0.5M does not apply to steel columns and beams.

(3) 1M for width and 1M for height (1M = 100 mm).

(4) Percentage of coverage is to be based on total floor area or on total number of components such as columns, beams, doors, windows etc.

* For void on slab that does not serve any functional requirement and is enclosed by walls, 1.00 point will be deducted even if there is only one such void within a block.

* Points for other buildable design features not shown in this table shall be determined by BCA on a case-by-case basis.

EXPLANATORY NOTES TO TABLE 3

(a) Table 3 shows the points given to each buildable design feature that contributes to labour saving on site. Points are summed up to form the Buildable Design Score for this section. The maximum score for this section is 10 points.

(b) For item 1 – Standardisation, the criteria of minimum module must be met before points are given. M denotes 100mm. 0.5M implies that sizes must be in multiples of 50mm. 1M implies that sizes must be in multiples of 100mm.

(c) For item 2 – Grids, the criteria of minimum module must be met before points are given. M denotes 100mm. For repetition of floor to floor height, 0.5M implies that the floor-to-floor height must be in multiples of 50mm. For repetition of horizontal grids, 6M implies that spacing between grids must be in multiples of 600mm

(d) The unit of measurement for each type of design feature is in number or area. This is specified in the column entitled “Unit of Coverage.”

(e) The percentage of coverage of each type of design feature is generally classified into 2 categories:

(i) ≥ 70% to < 90%

(ii) ≥ 90%

In the case of design features awarded with bonus points, the percentage of coverage is classified into the following categories:

(i) ≥ 65% to < 80%

(ii) ≥ 80%

(f) BCA shall determine the points to be awarded or not to be awarded for other buildable features that are not stated in Table 3. For such cases, the QPs are advised to seek BCA’s comments before proceeding with the designs.

3 EXAMPLES ON COMPUTING BUILDABLE DESIGN SCORE

3.1 A SINGLE BLOCK BUILDING PROJECT

A. Project Information

- 1 block of 18-storey high residential flat
- No basement
- 5 residential units per storey
- For simplicity, assume typical floor layout for each floor, except 1st storey and roof
- Assume floor-to-floor height of 3.15m, except 1st storey, which is 4m high
- For area of building:

  Total floor area of residential units = 18 x 645.90m² = 11,626.20m²

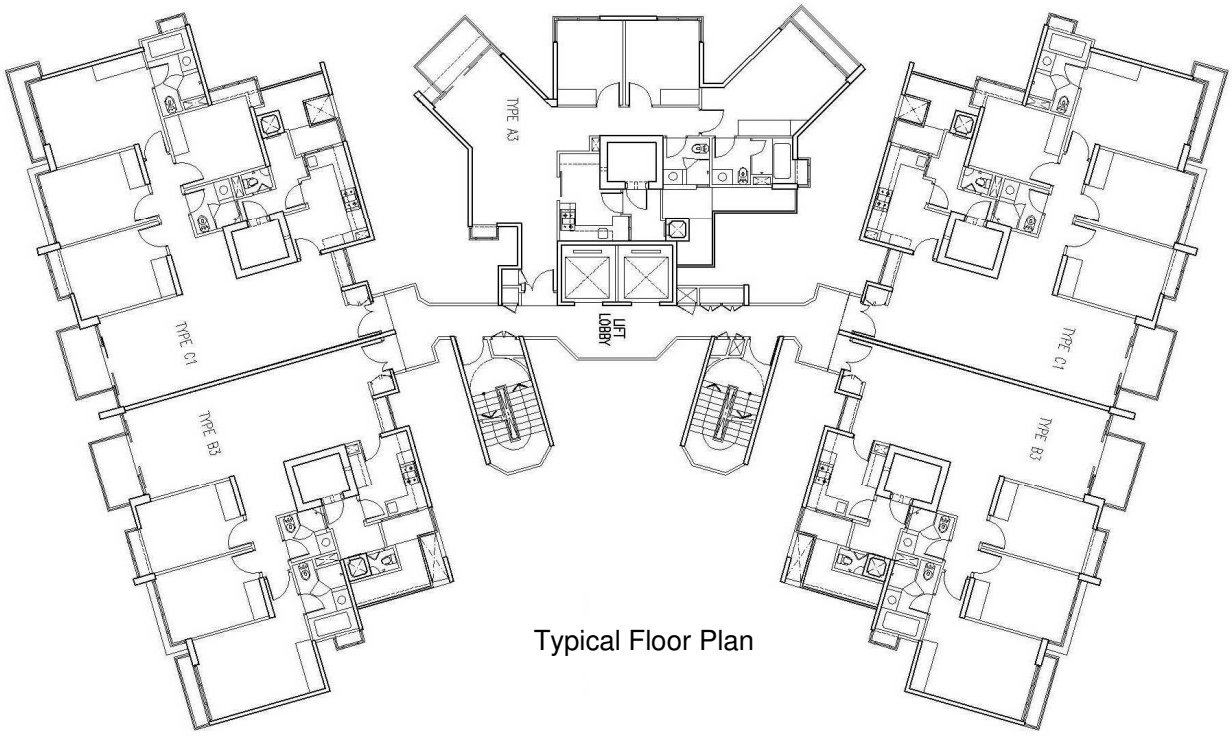
  Total floor area of Lift Lobby = 18 x 102.40m² = 1,843.20m²

  Roof area (assume same as typical floor) = 748.30m²

  A_{st} : Total floor area of building including roof area = 14,217.70m²

B. Buildable Design Score Formula

BDScore = $50[\sum(A_s \times S_s)] + 40[\sum(L_w \times S_w)] + N + \text{Bonus Points}$



Typical Floor Plan

Area of residential units per floor	=	129.18 x 5
	=	645.90 m^2
Lift lobby area per floor	=	102.40 m^2
Typical floor area	=	645.90 + 102.40
	=	748.30 m^2

Design based on flat plate system with cast in-situ columns with wall combination of precast walls and dry wall.

DESCRIPTION	LABOUR SAVING INDEX	AREA(m^2) or LENGTH(m)	COVERAGE (%)	BUILDABLE DESIGN SCORE
Structural System				
(1) Flat plate with no perimeter beams for apartment area + Roof A_{sa} = 19 x 645.90 = 12,272.10m^2 A_{st} = 14,217.70m^2	S_S = 0.90	12,272.10m^2	86.32%	38.84
(2) RC beam/slab for lift lobby area + Roof A_{sa} = 19 x 102.40 = 1,945.60m^2 A_{st} = 14,217.70m^2	S_S = 0.45	1,945.60m^2	13.68%	3.08
Total		14,217.70m^2	100.00%	41.92
Use of prefabricated reinforcement Welded mesh for cast in-situ floor slab 86% of total floor area	0.03		86.00%	1.29
Total (a)				**43.21**
Wall System				
(1) Full height glass and railing	S_w = 1.00	408.60 m	3.86%	1.55
(2) Curtain wall	S_w = 1.00	717.30 m	6.78%	2.71
(3) Precast concrete wall - skim coat and paint finish	S_w = 0.90	5,204.20 m	49.22%	17.72
(4) Cast in-situ RC wall (staircase and lift shaft) - plaster & paint finish	S_w = 0.40	885.00 m	8.37%	1.34
(5) Drywall - no skim coat	S_w = 1.00	1,963.90 m	18.58%	7.43
(6) Drywall - tiled finish	S_w = 0.90	313.60 m	2.97%	1.07
(7) Precision blocks - skim coat and paint finish	S_w = 0.40	1,080.20 m	10.22%	1.64
Total (b)		10,572.80 m	100.00%	**33.46**

DESCRIPTION	LABOUR SAVING INDEX	AREA(m^2) or LENGTH(m)	COVERAGE (%)	BUILDABLE DESIGN SCORE
Other Buildable Design Features				
(1) Standardisation of columns (0.5M) 3S at 95%			95%	N = 2.00
(2) Standardisation of door leaf openings (width)(0.5M) 3S at 90%			90%	N = 1.00
(3) Repetition of floor-to-floor height (0.5M) 100%			100%	N = 2.00
(4) Precast refuse chutes 100%			100%	N = 1.50
Total (c)				**6.50**
Buildable Design Score of Project (a) + (b) + (c)				**83**

3.2 A MULTI-BLOCK BUILDING PROJECT

A. Project Information

This project consists of 8 blocks of buildings:-

- 3 blocks of 3-storey high workshop (Block A, B & C)
- 2 blocks of 2-storey high workshop (Block D & E)
- 1 block of 2-storey high multi-purpose hall (Block F)
- 1 block of 2-storey high classroom (Block G)
- 1 block of 2-storey high classroom cum administration (Block H)

A_{st}, total floor area including roof (projected area), of each building is as below:

- Block A, B & C A_{st} = 2,700m² per building
- Block D A_{st} = 3,000m²
- Block E A_{st} = 2,400m²
- Block F A_{st} = 2,600m²
- Block G A_{st} = 1,000m²
- Block H A_{st} = 3,600m²

  Overall project A_{st} = 20,700m²

B. Buildable Design Score

The Buildable Design Score (BDScore) for the respective blocks is as follows:

- Block A : BS = 79.0 $(A_{st})_{bldg} / (A_{st})_{proj} = 0.13$
- Block B : BS = 79.0 $(A_{st})_{bldg} / (A_{st})_{proj} = 0.13$
- Block C : BS = 79.0 $(A_{st})_{bldg} / (A_{st})_{proj} = 0.13$
- Block D : BS = 79.0 $(A_{st})_{bldg} / (A_{st})_{proj} = 0.14$
- Block E : BS = 79.0 $(A_{st})_{bldg} / (A_{st})_{proj} = 0.12$
- Block F : BS = 77.0 $(A_{st})_{bldg} / (A_{st})_{proj} = 0.13$
- Block G : BS = 59.2 $(A_{st})_{bldg} / (A_{st})_{proj} = 0.05$
- Block H : BS = 57.2 $(A_{st})_{bldg} / (A_{st})_{proj} = 0.17$

The Buildable Design Score of the project is computed as below:

$BDScore_{proj}$ = Sum of $[BDScore_{bldg} \times (A_{st})_{bldg} / (A_{st})_{proj}]$

= **74**

Annex B

CONSTRUCTABILITY APPRAISAL SYSTEM

1 INTRODUCTION

The Constructability Appraisal System (CAS) was developed by the Building and Construction Authority as a means to measure the potential impact of downstream construction methods and technologies on the productivity at site. The CAS results in a 'Constructability Score' of the building works. A project with a higher Constructability Score will result in the use of more labour efficient construction methods and technologies and therefore improve site labour productivity.

1.1 Objective

The objective of CAS is to bring about the wider use of labour-saving construction methods and technologies that can help to reduce the demand for manpower on site.

While the BDAS focuses on the use of buildable designs during the upstream design process, to bring about greater productivity improvements, it is necessary to also tackle improvements in the downstream construction methods. Designers' attention to buildable designs has to be complemented with builders' adoption of labour-efficient construction technologies to bring about greater ease in construction.

The CAS thus impacts on the construction methods used during the construction phase. Through the Constructability Score, the builders' contribution to raising site productivity can be increased by encouraging them to move away from traditionally labour-intensive construction methods and switching to more labour-efficient construction processes.

1.2 Principles of Constructability

The CAS is a performance based system with flexible characteristics that allow builders to adopt the most cost-effective solution to meet the constructability requirement. The constructability of building works is assessed in the areas of *structural works, architectural, mechanical, electrical and plumbing (AMEP) works* as well as *site practices*.

As structural works require the greatest manpower usage for building projects, and is usually along the critical path of construction, a switch to a more labour efficient construction system for structural works is likely to bring about a direct improvement in site productivity.

Besides structural works, manpower is also required for architectural works and M&E works. Hence, site productivity gains could be realised if builders were to embrace the greater use of efficient construction methods and technologies that reduce labour usage for these areas of works.

In addition, the adoption of good site practices, such as good project and site management is also critical to enhancing site productivity performance.

1.3 Scope

The CAS therefore aims at productivity improvements in each of the areas of structural works, AMEP works as well as site practices.

Points are awarded based on the types of construction methods, technologies and processes adopted. Innovative construction technologies, methods, systems and use of advanced plant and equipment that are able to reduce manpower usage and improve site productivity are also awarded with points. The points are totalled to give the "Constructability Score" of the building works.

1.4 Rationale on Allocation of Points

1.4.1 The computation of Constructability Score for a project involves the summation of Constructability Score attained for the Structural component, AMEP component and the component on Good Industry Practices. The total Constructability Score allocated under these three components is 120 points

1.4.2 The highest weightage is given to the Structural component, i.e. 50% or 60 points of the total Constructability Score. The Structural component of the Constructability Score focuses on the builder's choice of external access systems and formwork systems as these take up the bulk of the total manpower needed for structural works.

1.4.3 The other 50% of the Constructability Score is allocated to AMEP and Good Industry Practices, with 50 points given to the AMEP component and the remaining 10 points to the component on good practices. For the AMEP component, points are awarded if builders make a conscious effort to avoid wet works such as screeding and plastering. Builders will also be assessed on their usage of labour efficient pipe works and air-con main ducting such as pre-insulated pipework and prefabricated ducts, as these are labour intensive trades. Similarly, Good Industry Practices focuses on specific good practices such as the use of Building Information Modeling (BIM) and productivity monitoring on site to achieve higher productivity.

1.4.4 The allocation of points to the Structural component, the AMEP component and Good Industry Practices component is to bring about a greater adoption of labour efficient advanced construction methods and processes. In some areas, the traditional construction methods are given much lower points under the Constructability Score to dis-incentivise their use.

2 HOW TO USE THE CONSTRUCTABILITY APPRAISAL SYSTEM

2.1 Components of the Constructability Appraisal System (CAS)

The CAS provides a method to compute the Constructability Score of a project. It consists of three main components:

(a) the Structural System;

(b) the Architectural, Mechanical, Electrical & Plumbing (AMEP) System; and

(c) Good Industry Practices

The Constructability Score is expressed as :

Constructability	=	Constructability Score of Structural System
Score of	+	Constructability Score of AMEP System
Building Works	+	Constructability Score of Good Industry Practices

(a) Constructability Score of the Structural System

A builder could use different external access systems and formwork systems or a combination of each of these systems for different parts of the building so as to achieve the most practical and cost effective approach to meeting the constructability requirement.

The Constructability Score for a particular external access system is the product of the percentage of building perimeter using this external access system and its corresponding allocated points. The Constructability Scores for different external access systems adopted are then summed up to arrive at the Constructability Score of the total external access system. The points allocated to different external access systems are given in Table 1 and the total points achievable under this section are 15 points.

The Constructability Score for a particular formwork system is the product of the percentage of area using the formwork system and its corresponding allocated points. For vertical formwork, the area would be the contact area of the formwork system whereas for horizontal formwork, the area would be the floor area. The Constructability Scores for different formwork systems adopted are then summed up to arrive at the Constructability Score of the total formwork system. All formwork system must be accounted for, except for those used in the basement / sub-structural works. The points allocated to different formwork systems which are classified into various bands are given in Table 1 and the total points achievable under this section are 30 points.

Constructability points are also given to structural innovative methods, systems, processes and plant and equipment that contribute to labour saving on site. Some specific items under this section are given in Table 1. Direct points are awarded if

the usage of these items meets the stipulated criteria and conditions. Points could also be awarded to other innovative construction technologies and methods which reduce labour usage, subject to BCA's assessment. The total points achievable under this section are 15 points.

The contribution of Constructability Scores from the total external access system, the total formwork system and innovation items are summed up to arrive at the Constructability Score of the Structural System. The maximum Constructability Score for Structural System is 60 points.

(b) Constructability Score of AMEP System

Under the architectural portion, Constructability Scores for the use of screed-less floor and unplastered RC / blockwall are given only if these are specifications not stipulated in the tender drawings. For these two items, the Constructability Scores are computed by multiplying the percentage of floor area with no screeding or the percentage of wall length with no plastering works and their corresponding allocated points.

For other AMEP items namely spray painting, pre-insulated pipework, prefabricated ducts, flexible water pipes and mechanical joints, the use of these items will be awarded with points directly if the corresponding stipulated conditions are met. The points allocated to the various AMP systems are given in Table 2 and the total points achievable under this section are 25 points.

Constructability points are also given to AMEP innovative methods, systems, processes and plant and equipment that contribute to labour saving on site. Direct points are awarded if the usage of these items meets the stipulated criteria and conditions. The total points achievable under this section are 25 points.

The points awarded for all the items under the AMEP component are summed up to arrive at the Constructability Score of the AMEP System. The maximum Constructability Score for AMEP System is 50 points.

(c) Constructability Score of Good Industry Practices

In this section, direct points are awarded to good industry practices adopted at site which help to improve construction productivity. Points are given for each good industry practice adopted and these are summed up to give the score, up to a maximum of 10 points. The points allocated to the various good industry practices are given in Table 3.

Table 1 Structural System

STRUCTURAL SYSTEM (MAXIMUM 60 POINTS)		
Construction Technologies / Methods	**Allocated Points**	**Computation Method**
1. External Access System (Maximum 15 points)		
(a) No external scaffold	15	$\frac{\sum(\text{Length with external access system/no external scaffold} \times \text{Allocated pts})}{\text{Total Building Perimeter}}$
(b) Self-climbing perimeter scaffold	15	
(c) Crane-lifted perimeter scaffold / fly cage	14	
(d) Traditional external scaffold	1	
2. Formwork System (Maximum 30 points)		
A. Vertical Contact Area		
(i) No formwork (precast construction)	15	$\frac{\sum(\text{Vertical Formwork Contact Area} \times \text{Allocated points})}{\text{Total Vertical Formwork Contact Area}}$
(ii) Traditional timber/metal formwork	1	
(I) Vertical Formwork[1]		
(i) System Formwork (Band 1)	15	
(ii) System Formwork (Band 2)	14	
(iii) System Formwork (Band 3)	13	
(iv) System Formwork (Band 4)	11	
(v) System formwork (Band 5)	8	
B. Floor Area		
(i) No formwork (precast construction)	15	$\frac{\sum(\text{Floor Area} \times \text{Allocated points})}{\text{Total Floor Area}}$
(ii) Traditional timber/metal formwork	1	
(I) Horizontal Formwork[1]		
(i) System Formwork (Band 1)	15	
(ii) System Formwork (Band 2)	14	
(iii) System Formwork (Band 3)	13	
(iv) System Formwork (Band 4)	11	
(v) System formwork (Band 5)	8	
3. Structural Innovative Methods, Systems, Processes, Plant & Equipment (Maximum 15 points)		
(a) Use of self compacting concrete	2	Points are given if usage ≥ 5% of total superstructure concrete volume
(b) Use of hydraulic stationary placing boom for concreting	2	Points will be given once used
(c) Use of tower crane (tip load ≥ 10 tonnes at maximum reach)	3	Points will be given once used
(d) Strut free deep basement construction[2]	4 (max)	Applicable for projects with restricted site access. Normal earth slope with or without concrete lining is excluded.
(e) Any other innovative methods, systems, processes, plant & equipment	Points to be awarded only for high impact items that improve labour efficiency[3]	

NOTE:

(1) System formwork are grouped into bands in their respective classification according to their productivity output assessed through productivity demonstration. Each band is allocated different Constructability Points to reflect the relative efficiencies of the different system formwork. System formwork not assessed would be deemed to have the same productivity as those under the lowest band (i.e. Band 5) and be accorded with the lowest Constructability Points for system formwork.

(2) BCA will assess the extent of the strut free basement construction and determine the number of points to be awarded.

(3) BCA will assess the impact of the innovative method, system, process, plant & equipment on labour usage and determine the number of points to be awarded.

EXPLANATORY NOTES TO TABLE 1

(a) Table 1 has been arranged into 3 main sections of external access system, formwork system and innovative methods, systems, processes, plant & equipment with their respective point allocation.

(b) Different system formwork have varying efficiencies in terms of productivity performance. To determine the productivity of each system formwork, BCA will carry out a productivity assessment exercise for each system formwork using a standard layout template. The various system formwork are classified into vertical formwork or horizontal formwork. Depending on the productivity outcome, the different system formwork are then grouped into bands in their respective classification. Each band is allocated different Constructability Points to reflect the relative efficiencies of the different system formwork. In the event that a particular formwork system has not been assessed on its productivity, this system formwork shall be taken to have the same productivity as system formwork classified under Band 5 and be awarded with the lowest Constructability Points.

For ease of reference, BCA will publish the bands and allocated Constructability Points of the various system formwork which have been assessed on their productivity performance on BCA's website. The published data will be updated regularly.

(c) Some specific items with points allocated have been listed in Table 1 under Structural Innovative Methods, Systems, Processes, Plant & Equipment. For any other innovations proposed by the builder that are not stated in Table 1, BCA shall determine the points to be awarded or not to be awarded. For such cases, the builder is advised to seek BCA's comments.

Table 2 Architectural, Mechanical, Electrical & Plumbing System (AMEP)

ARCHITECTURAL, MECHANICAL, ELECTRICAL & PLUMBING SYSTEM (AMEP) (MAXIMUM 50 POINTS)		
Construction Technologies / Methods	**Allocated Points**	**Computation Method**
1. Architectural		
(a) No screeding on floors (not stipulated in tender drawing): (i) To immediately receive tile/stone finish using thin bed adhesive (ii) Carpet or raised floor finishing	5	Floor Area with no screeding x Allocated points Total Area (excluding wet areas[1])
(b) Off form RC walls to receive (not stipulated in tender drawing): (i) Tile/ Stone (ii) Wallpaper (iii) Paint (skim coat allowed)	5	RC Wall* Length with no plastering x Allocated points Total RC Wall Length* * *Refers to RC walls with finishing including tile/ stone, wallpaper & paint*
(c) Use of spray painting	3	Points are given if usage ≥ 50% of total internal painted area
2. Mechanical, Electrical & Plumbing (MEP)		
(a) Pipe Works (i) Pre-insulated chilled water pipes	3	Points are given if usage ≥ 80% of total pipe length
(b) Air-Con Ducting (i) Prefab ducts OR (ii) Prefab & Pre-insulated ducts	3 6	Points are given if usage ≥ 80% of total duct length
(c) Use of flexible pipes[1] for domestic water system	3	Points are given if usage ≥ 80% of total pipe length
(d) Use of mechanical joints for M&E piping	2	Points are given if usage ≥ 80% of total pipe length
3. AMEP Innovative Methods, Systems, Processes, Plant & Equipment (Maximum 25 points)		
(a) Use of ceiling inserts	2	Points are given if once used for at least one complete floor
(b) Prefab plant / piping modules	3	Points are given once used for at least one plant room
(c) Use of scissor lift and/or personnel lift in lieu of traditional scaffold for AMEP works	2	Points will be given once used
(d) Use of boom lift in lieu of traditional scaffold for AMEP works	2	Points will be given once used
(e) Any other innovative methods, systems, processes, plant & equipment	Points to be awarded only for high impact items that improve labour efficiency[3]	

NOTE:

(1) Wet areas shall include bathroom, kitchen, utility room and balcony areas

(2) Flexible pipes include Crosslinked Polyethylene (PEX) pipes

(3) BCA will assess the impact of the innovative method, system, process, plant & equipment on labour usage and determine the number of points to be awarded.

EXPLANATORY NOTES TO TABLE 2

(a) Table 2 has been arranged into 3 main sections of architectural system, mechanical & electrical and plumbing system and innovative methods, systems, processes, plant & equipment with their respective point allocation.

(b) Ceiling inserts refer to cast-in brackets or steel sections for supporting piping, conduits, cables and other M&E fittings.

(c) Prefab plant / piping modules refer to plant, pipes or ducts that are pre-fabricated off-site, assembled and installed in modules.

(d) Some specific items with points allocated have been listed in Table 2 under AMEP Innovative Methods, Systems, Processes, Plant & Equipment. For any other innovations proposed by the builder that are not stated in Table 2, BCA shall determine the points to be awarded or not to be awarded. For such cases, the builder is advised to seek BCA's comments.

Table 3 Good Industry Practices

GOOD INDUSTRY PRACTICES (MAXIMUM 10 POINTS)	
Description	**Allocated Points**
(a) To use Building Information Modelling (BIM) for whole project duration to: (i) Check for clashes between M&E services, structural provision and architectural objects (ii) Produce M&E Coordination Drawings, Architectural Shop Drawings and Concrete Body Plan for construction purposes (iii) Simulate construction schedules and resource planning	5
(b) To adopt a trade productivity monitoring system for whole project duration to: (i) Establish "workers' productivity norms" (ii) Conduct work studies on the processes if the productivity levels deviate from the norm (iii) Implement measures to improve productivity whenever possible	2
(c) To produce and distribute step by step work manuals for all trades and set up site mock-ups to show how works should be done properly for whole project duration for: (i) Wall installation (ii) Waterproofing (iii) Suspended ceiling installation (iv) Window installation	2
(d) To conduct monthly work study sessions, to scrutinise and improve the work process on site, as well as minimising wastage and improve productivity	2
(e) To use tools like CCTV to conduct real time monitoring on site to study resource flow, schedule and work process flow	2
(f) To conduct the following daily: (i) Tool box meeting (every worker to be informed on his task for the day) (ii) Sub-contractors coordination meeting (to coordinate on work process & resource allocation)	1

EXPLANATORY NOTES TO TABLE 3

(a) Points would only be awarded to a builder when any of the good industry practices listed in Table 3 has been adopted the practices throughout the duration of the project.

3 EXAMPLES ON COMPUTING CONSTRUCTABILITY SCORE

3.1 A residential non-landed development with 2 basements and GFA ≥ 25,000 m^2

<table>
<tr><th>Construction Technologies / Practices</th><th>Computation</th><th>Score</th></tr>
<tr><td colspan="3">Structural System (Max 60 Points)</td></tr>
<tr><td>1. External Access System (max 15 points)</td><td>• Self-climbing scaffold used for entire building perimeter
Score = 100% x 15 points = 15 points</td><td>15</td></tr>
<tr><td>2. Formwork System (max 30 points)</td><td>• Vertical formwork contact area (Band 2) is 4,000m^2
• Horizontal formwork floor area (Band 3) is 36,000m^2
• Precast columns were adopted at certain areas, with a total vertical contact area of 2,500m^2
<table>
<tr><th></th><th>Types of System</th><th>Contact area/ Floor area (m^2)</th><th>Working</th><th>Pts</th></tr>
<tr><td rowspan="2">Vertical Contact Areas</td><td>Vertical Formwork (Band 2 – 14 points)</td><td>4,000</td><td>$14 \times \frac{4000}{4000+2500}$</td><td>8.62</td></tr>
<tr><td>Precast Columns (15 points)</td><td>2,500</td><td>$15 \times \frac{2500}{4000+2500}$</td><td>5.77</td></tr>
<tr><td>Horizontal Floor Areas</td><td>Horizontal Formwork (Band 3 – 13 points)</td><td>36,000</td><td>$13 \times \frac{36000}{36000}$</td><td>13.00</td></tr>
<tr><td colspan="4">Score</td><td>27.39</td></tr>
</table></td><td>27.39</td></tr>
<tr><td>3. Structural innovative methods, systems, processes, plant & equipment (max 15 points)</td><td>- Strut free deep basement construction</td><td>4</td></tr>
<tr><td colspan="2">Sub-total for A (max 60 points)</td><td><u>46.39</u>
<u>≥ 35 (min)</u></td></tr>
</table>

Construction Technologies / Practices	Computation	Score
Architectural, Mechanical, Electrical & Plumbing System (AMEP) (Max 50 Points)		
1. Architectural		
(a) No screeding on floors (not stipulated in tender drawing): (i) to immediately receive tile/stone finish using thin bed adhesive, (ii) carpet or raised floor finishing	• *Floor area without screed to receive tile finish is 20,000m^2* • *Floor area with screed (excluding wet areas) is 8,000m^2* Total floor area = 20,000 + 8,000 = 28,000m^2 **Score** = (20000/28000) x 5 points = 3.57 points	3.57
(b) Use of spray painting	• *Spray painting is used for more than 50% of total internal painted area*	3
2. Mechanical, Electrical & Plumbing (MEP)		
(a) Use of flexible pipes for domestic water system	• *Flexible water pipes were used for more than 80% of total pipe length*	3
3. AMEP innovative methods, systems, processes, plant & equipment (max 25 points)	• *Use of scissor lift in lieu of traditional scaffold for MEP installation*	2
	Sub-total for B (max 50 points)	**11.57**
C. Good Industry Practices (Max 10 points)		
To adopt a trade productivity monitoring system for whole project duration to: (i) Establish "workers' productivity norms" (ii) Conduct work studies on the processes if the productivity levels deviate from the norm (iii) Implement measures to improve productivity whenever possible		2
To produce and distribute step by step work manuals for all trades and set up site mock-ups to show how works should be done properly for whole project duration for: (i) Wall installation (ii) Waterproofing (iii) Suspended ceiling installation (iv) Window installation		2
To conduct monthly work study sessions, to scrutinise and improve the work process on site, as well as minimising wastage and improve productivity		2
To conduct the following daily: (i) Tool box meeting (every worker to be informed on his task for the day) (ii) Sub-contractors coordination meeting (to coordinate on work process & resource allocation)		1
	Sub-total for C (max 10 points)	**7**
Total Constructability Score = Sub-total (A) + Sub-total (B) + Sub-total (C)		**65**

3.2 A MULTI-BLOCK BUILDING PROJECT

A. Project Information

This project consists of 3 blocks of buildings:-

- 1 block of 30-storey high office building (Block A)
- 1 block of 40-storey high residential building (Block B)
- 1 block of 45-storey high residential building (Block C)

A_{fw}, total formwork system floor area, is as below:

- Block A A_{fw} = 20,000m²
- Block B A_{fw} = 25,000m²
- Block C A_{fw} = 35,000m²

  Overall project A_{fw} = 80,000m²

B. Constructability Score

The Constructability Score (CScore) for the respective blocks is as follows:

- Block A : CScore = 65 $(A_{fw})_{bldg} / (A_{st})_{proj}$ = 16.25
- Block B : CScore = 60 $(A_{fw})_{bldg} / (A_{st})_{proj}$ = 18.75
- Block C : CScore = 64 $(A_{fw})_{bldg} / (A_{st})_{proj}$ = 28.00

The Constructability Score of the project is computed as below:

$CScore_{proj}$ = Sum of [$CScore_{bldg}$ x $(A_{fw})_{bldg} / (A_{fw})_{proj}$]

= **63**