

In Collaboration With



Our Ref: **APPBCA-2026-22**

9 October 2026

Dear Sir/Madam

For enquiries, please contact:
Building Engineering Group (#12-01)
Our online feedback form at:
<https://go.gov.sg/bca-feedback-form>

JOINT BCA/LTA CIRCULAR

MEASURES AND GOOD PRACTICES FOR ENHANCING DIAPHRAGM WALL QUALITY IN DESIGN AND CONSTRUCTION

Objective

This circular provides guidance to the industry on measures and good practices to enhance the quality, constructability and watertightness performance of Diaphragm Walls ("D-walls") functioning as Earth Retaining or Stabilising Structures ("ERSS") for building works in Singapore.

Background

2. D-walls are extensively employed in deep underground construction in Singapore, being particularly well-suited to the city-state's dense urban environment and challenging ground conditions. These reinforced concrete walls serve dual functions as temporary excavation support during construction and permanent underground structural elements. When executed to proper standards, D-walls provide superior watertightness, effectively controlling groundwater ingress during both the excavation phase and throughout the structure's operational life.

3. Reinforcement congestion can adversely affect concrete placement and compaction, leading to defects such as honeycombing and porosity that may result in water leakage and extensive remedial works. Such leakages compromise the essential functions of underground structures. These deficiencies require extensive remedial works, typically involving injection grouting, and incur additional labour and costs. Hence, the Building and Construction Authority (BCA) and Land Transport Authority (LTA) established a joint working group (WG) to review local practices and with industry inputs, develop the guidance in this circular to improve D-wall construction quality and performance.

4. The WG conducted several engagement sessions with industry professionals and practitioners to gather feedback on the construction practices and carried out a comprehensive review of local and international practices before finalising these measures and good practices.

5. Four key measures were identified. These measures when implemented together with the other complementary good practices in Annex A, would improve the quality of D-wall construction.

Measures	Existing practices	Recommended practices	Intended Effect
Specification of Tremie Concrete	Slump of 170 to 230mm	Slump flow of 400mm to 550mm	More flowable concrete aids in filling the gaps within the tightly spaced reinforcement bars, thus overcoming honeycombing or porosity issues in D-wall
Crack-width Design	0.25mm and 0.30mm	0.30mm ^A	The crack-width of 0.30mm aligns with prevailing code requirements. It is intended to reduce reinforcement congestion, thereby improving concrete placement, enhances overall in-situ concrete quality and delivers better watertightness performance of diaphragm walls in practice.
Concrete Cover	Minimum 90mm	Minimum 75mm	Reducing the concrete cover increases the effective depth of the D-wall which in turn reduces the amount of reinforcement bars required.
Layer of Reinforcement	No guidance	Maximum three layers ^B	Limiting the number of layers of reinforcement will reduce reinforcement congestion issues

^A – See details in Annex A.2

^B – See details in Annex A.4

The details of the above can be found in **Annex A**. Industry can avail themselves to the key measures and good practices in **Annex A** where practical.

6. Notwithstanding this circular, all QPs must exercise sound engineering judgment and conduct thorough evaluations, taking all reasonable steps and exercising due diligence to comply with all relevant requirements and ensure D-wall quality meets the objectives and performance requirements stipulated in the *Fifth Schedule of the Building Control Regulations 2003*, and all relevant standards and codes of practice. Where project-specific conditions warrant, QPs are expected to implement more stringent and additional measures.

7. Should you require any clarification on the guidelines, please submit your enquiry through BCA's Online Feedback Form at <https://go.gov.sg/bca-feedback-form>. Thank you.

Yours faithfully



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MEASURES AND GOOD PRACTICES FOR ENHANCING DIAPHRAGM WALL QUALITY IN DESIGN AND CONSTRUCTION

ANNEX A – MEASURES AND GOOD PRACTICES FOR D-WALL

The following measures and good practices are intended to minimise reinforcement congestion and to improve concrete quality through material specification, design and detailing, and construction practices.

Table A: Measures and Good Practices for D-Wall Detailing and Construction

Item	Subject	Description/ Good Practices																																
A.1	Specification of tremie concrete with slump flow of 400mm to 550mm	For projects that are proposing D-walls with reinforcements exceeding (2) layers, tremie concrete achieving a slump flow of 400mm to 550mm and correspondingly a smaller tremie pipe size of maximum 300mm outer diameter is recommended. The recommended tests and frequency of concrete with slump flow of 400mm to 550mm is presented in Table A.1-1. Table A.1-1: Recommended Tests <table><tr><th>Test ⁽²⁾</th><th>Standard</th><th>Acceptable limit ⁽¹⁾</th><th>Testing on-site Frequency ⁽³⁾</th></tr><tr><td>Slump Flow</td><td>BS EN 12350-8 ASTM C1611</td><td>400mm to 550mm</td><td>Each load</td></tr><tr><td>Visual Stability Index (VSI)</td><td>ASTM C1611</td><td>No signs of segregation or bleeding (VSI = 0)</td><td>Each load</td></tr><tr><td>Slump Flow Velocity</td><td>BS EN 12350-8</td><td>10 to 50mm/s</td><td>Minimum 1 / week</td></tr><tr><td>Workability Retention</td><td>BS EN 12350-1</td><td>(Workability retention duration shall be minimum 4 hours). A minimum slump of 150mm at the end of specified retention period ⁽⁵⁾.</td><td>Minimum 1 / week</td></tr><tr><td>Bleeding and Bleeding Rate</td><td>ASTM C232</td><td>≤ 0.1ml/min</td><td>As required ⁽⁴⁾</td></tr><tr><td>Bauer Filtration</td><td>EN ISO 10414-1</td><td>≤ 22ml</td><td>As required ⁽⁴⁾</td></tr><tr><td>Static Segregation</td><td>ASTM C1610</td><td>≤ 10%</td><td>As required ⁽⁴⁾</td></tr></table>	Test ⁽²⁾	Standard	Acceptable limit ⁽¹⁾	Testing on-site Frequency ⁽³⁾	Slump Flow	BS EN 12350-8 ASTM C1611	400mm to 550mm	Each load	Visual Stability Index (VSI)	ASTM C1611	No signs of segregation or bleeding (VSI = 0)	Each load	Slump Flow Velocity	BS EN 12350-8	10 to 50mm/s	Minimum 1 / week	Workability Retention	BS EN 12350-1	(Workability retention duration shall be minimum 4 hours). A minimum slump of 150mm at the end of specified retention period ⁽⁵⁾ .	Minimum 1 / week	Bleeding and Bleeding Rate	ASTM C232	≤ 0.1ml/min	As required ⁽⁴⁾	Bauer Filtration	EN ISO 10414-1	≤ 22ml	As required ⁽⁴⁾	Static Segregation	ASTM C1610	≤ 10%	As required ⁽⁴⁾
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		¹ Acceptance limit to refer to Guide to Tremie Concrete for Deep Foundations by the joint European Federation of Foundation Contractors (EFFC) / Deep Foundation Institute (US) (DFI) Concrete Task Group, 2024 and EN 206-3 ² Tests shall be conducted for trial mix prior to commencement of the actual concreting work. ³ Field test shall be carried out during the execution of the D-wall works. ⁴ For Self-Compacting Concrete (SCC) with SF1 class (550-650mm), the testing frequency of Bleeding, Bauer Filtration and Static Segregation tests shall be carried out at minimum 1 / week ⁵ Workability retention period shall be determined by the contractor based on their concrete supply logistics and maximum anticipated pour duration plus contingencies, with minimum 4 hours workability retention required. Concrete shall retain a minimum slump of 150mm at the end of the specified retention period. Workability retention testing shall be carried out as per BS EN 12350-1, minimum 1 / week at the intervals of 4 hours, and 6 hours or more (based on the required specified retention period).
A.2	Design crack-width of 0.30mm	The crack-width control requirement of 0.30mm aligns with SS EN1992-1-1 standards. Compared to the 0.25mm crack width limit which often requires heavier reinforcement and leads to reinforcement congestion, it is intended to reduce reinforcement congestion, thereby improving concrete placement, enhances overall in-situ concrete quality and delivers better watertightness performance of diaphragm walls in practice. For projects that adopt more stringent crack-width criteria, the Developer and his Designer should consider additional measures to mitigate potential reinforcement congestion and ensure constructability, as set out in this Annex.
A.3	Minimum concrete cover of 75mm	The minimum nominal cover (C_{nom}) is 75mm as specified SS EN 1992-1-1. The designer and diaphragm wall contractor should jointly determine an appropriate construction deviation allowance (Δc) that accounts for the contractor's workmanship standards and construction tolerances, following the guidance provided in footnote B in Tables A.4a to A.4c and Tables A.5a to A.5c of SS 544-1 for exposure classes of XC, XD and XS.
A.4	Maximum layers of reinforcement	To ensure that the quality of concrete of D-walls is not compromised due to reinforcement congestion, the number of longitudinal reinforcement layers on each face should not exceed (6) at lapping areas and (3) at non-lapping areas.

		Sections of D-Wall away from congestion zone (i.e. interface with slabs) may adopt up to (4) layers on one face provided practicality of concreting is not adversely impacted and no lapping is envisaged.
A.5	Location of vertical reinforcement lapping	To avoid reinforcement congestion, the Designer should position the lapping of D-Wall vertical reinforcement away from the locations of connection with slabs and other element where the provision of interface or starter reinforcement with anchorages and couplers are located.
A.6	Use of bundled reinforcement	Bundled reinforcement shall be adopted only when: a) Staggered lapping is adopted in accordance with SS EN 1992-1-1 Cl 8.9.3 (3) b) For non-staggered lapping, the clear spacing between any bundled bars at lapping locations shall not be less than the equivalent bar diameter to ensure proper bonding between reinforcement and concrete
A.7	D-wall reinforcement detailing	The Designer should consider the following constructability aspects for D-wall reinforcement detailing during the design phase and indicate in ST submission drawings: a) Code requirements such as horizontal clear spacings of least 100mm between vertical reinforcements, vertical clear spacings of at least 200mm between horizontal reinforcements etc; b) Dimensions and tolerances of stop-end pipe(s)¹ and overcut dimensions for primary and secondary panels; c) Effective width, cage length, number of cages per panel, number of bars and starter reinforcement or coupler per layer, and number of layers within each cage; d) Any other D-wall provisions that may affect reinforcement detailing, such as tremie pipe positioning and permanent elements like king posts. ¹ The size of stop-end pipes, dependent on the depth of the D-wall, could range from 300mm to 500mm. Reference should be made to SS EN 1992-1-1 and BS EN 1538 for reinforcement detailing requirements. Figures A.7-1 to A.7-2 below shows the illustration of effective cage placement for rebars, considering the stop-end pipes.

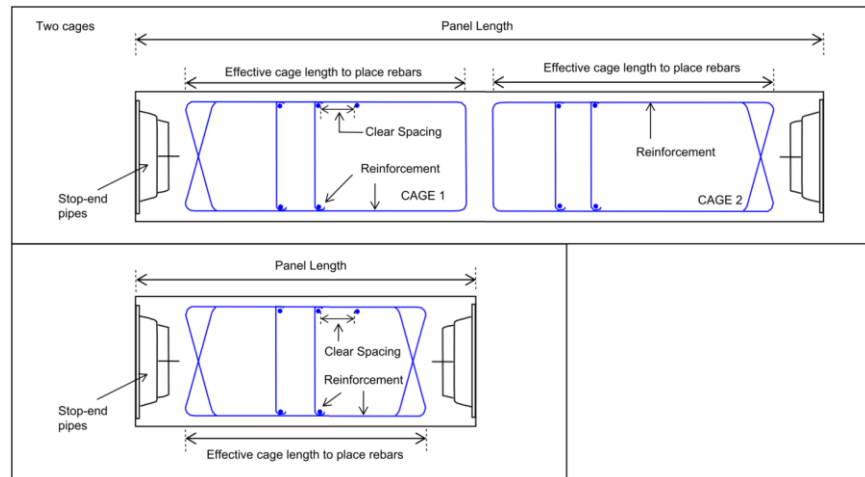


Figure A.7-1 – Primary panel with stop-end pipe on both sides

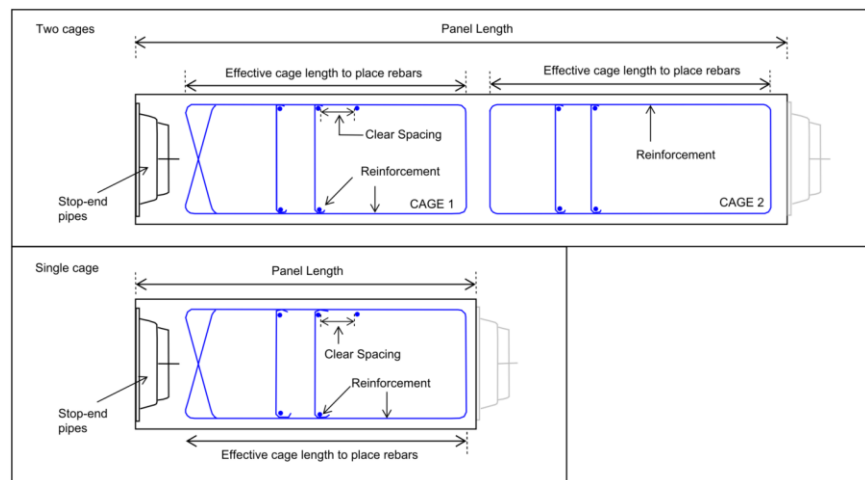


Figure A.7-2 – Secondary panel with stop-end pipe on one side

A.8	Protection of couplers during casting	The size and extent of using timber or polystyrene to protect the couplers during D-wall casting is recommended to be minimised to improve the flowability of concrete.  Figure A.8-1: Protection of top and bottom rows of couplers using a single large piece of timber (Not recommended)  Figure A.8-2: Protection of top and bottom rows of couplers minimised using two separate strips of timber (Recommended)
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