Code of Practice for Structural Use of Concrete 2013

The Buildings Department (BD) has set up a Technical Committee (TC) to, among others, collect and consider the views and feedback from the building industry arising from the use of the Code of Practice for Structural Use of Concrete 2013 (Concrete Code 2013). The current Concrete Code 2013 (2020 Edition), which was promulgated in December 2020, incorporated the amendments made and promulgated through circular letters dated 13 June 2017 and 24 November 2020. Taking into account the advice of the TC, the following amendments to the Concrete Code 2013 (2020 Edition) have been promulgated and uploaded to BD website www.bd.gov.hk:

(a) Appendix A – February 2022; and

(b) Appendix B – June 2023.

(YU Po-mei, Clarice)
Building Authority

Ref.: BD GR/1-50/76

This PNAP is previously known as PNAP 296
First issue June 2007
This revision June 2023 (AD/NB2) (General revision)

Appendix A
(PNAP APP-142)

Amendments to the Code of Practice for Structural Use of Concrete 2013 (2020 Edition)

(February 2022)

Legends:

Amended

Deleted

(6/2023)

Amendments to the Code of Practice for Structural Use of Concrete 2013 (2020 Edition) in February 2022 included:

(a) clause 6.2.3 and Figure 6.18b – addition of design requirements for plain concrete linings;

(b) clause 10.3.4.2 and Table 10.2 – revision of the requirements on the use of 100 mm and 150 mm concrete cubes;

(c) clause 11.7.5.4 and Table 11.2 – addition of general guidelines on monitoring early compressive strength of insitu concrete by maturity method; and

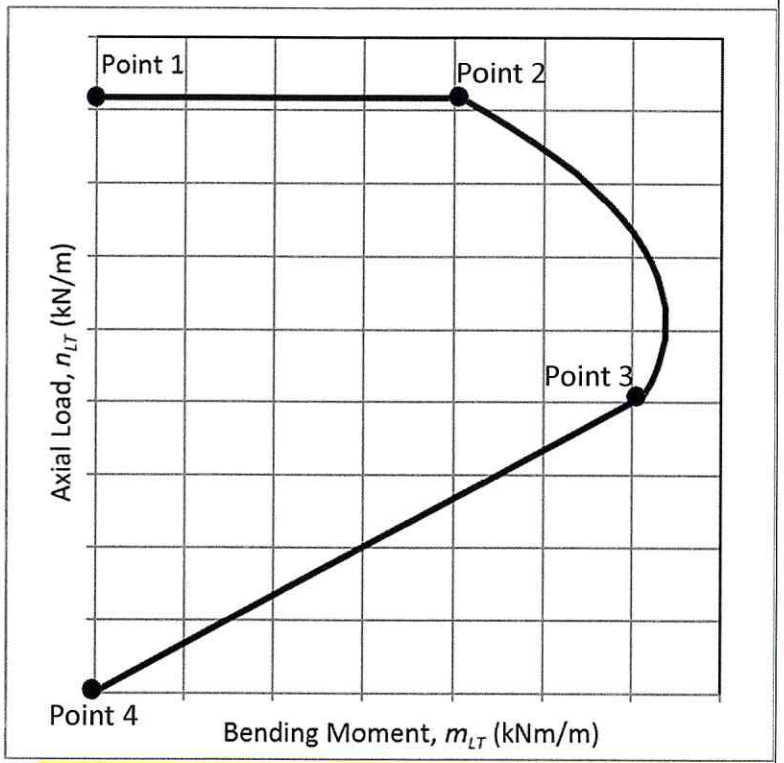
(d) Annex A – addition of ASTM C1074-19$^{\varepsilon 1}$ corresponding to the new clause 11.7.5.4.

Amendments to the Code of Practice for Structural Use of Concrete 2013 (2020 Edition)

Item	Current version	Amendments
1. Contents	6.2.2 Walls	6.2.2 Walls 6.2.3 Plain concrete linings
2. LIST OF TABLES[1]	Table 11.1 – Objects of production and construction control Table 12.1 – Design flexural tensile stresses for class 2 members: serviceability limit state: cracking	Table 11.1 – Objects of production and construction control Table 11.2 – Correction factor applied to the estimated insitu concrete compressive strength Table 12.1 – Design flexural tensile stresses for class 2 members: serviceability limit state: cracking
3. LIST OF FIGURES[2]	Figure 6.18a - Geometry of the Circular Section Figure 6.19 - Critical section for shear check in a pile cap	Figure 6.18a - Geometry of the Circular Section Figure 6.18b - Interaction Curve for Design of Plain Concrete Lining Figure 6.19 - Critical section for shear check in a pile cap
4. Clause 6.2.3 and Figure 6.18b	-	**6.2.3 Plain concrete linings** *6.2.3.1 General* Plain concrete is suitable for use in structural members with high axial loads and relatively low bending moments. The following criteria can generally be applied to the use of plain concrete lining in tunnels or caverns: (a) the lining curvature is adequate to accommodate axial distribution of external loads; (b) the plain concrete lining is constructed in relatively good rock geology and is always in compression under all load combinations; (c) the effect of imperfection of the concrete lining has been considered by means of rigorous structural analysis of the plain concrete lining; and

[1] Addition of Table 11.2 corresponding to the new clause 11.7.5.4.
[2] Addition of Figure 6.18b corresponding to the new clause 6.2.3.

Item	Current version	Amendments
		(d) an arch section can be formed by plain concrete in conjunction with a reinforced concrete invert provided the junction between the plain and reinforced concrete satisfies the design requirements specified in clause 6.2.3.2. *6.2.3.2 Design of plain concrete lining* (a) Maximum axial load for plain concrete lining The design ultimate capacity of axial load per unit length, n_{LT} and design maximum ultimate bending moment per unit length, m_{LT} ($=n_{LT}\ e_x$) shall be evaluated using the interaction curve as shown in Figure 6.18b. (i) The first section (Point 1 to Point 2) of the interaction curve as shown in Figure 6.18b, the highest axial force, is applicable when the eccentricity of the thrust force is less than or equal to 0.1h. The ultimate capacity is calculated using a rectangular stress block over the whole section; For $e_x \leq 0.1h$ $n_{LT} \leq 0.32hf_{cu}$ 6.63a (ii) The second section (Point 2 to Point 3) of the interaction diagram is based on a rectangular stress block approach and is applicable for eccentricity between 0.1h and 0.3h. The stress block is acting over part of the section, and reduces as the eccentricity increases. For $0.1h < e_x \leq 0.3h$ $n_{LT} \leq 0.4\ (h\text{-}2\ e_x\ )f_{cu}$ 6.63b where:

Item	Current version	Amendments
		e_X is the resultant eccentricity of load at right angles to the plan of the lining. (iii) Cracking restriction limits the use of the strength design method to a maximum eccentricity of 0.3h. The third section (Point 3 to Point 4) of the interaction curve is a straight line down to the point $n_{LT} = 0$, $m_{LT} = 0$, as shown in Figure 6.18b.  **Figure 6.18b – Interaction Curve for Design of Plain Concrete Lining**

Item	Current version	Amendments
		(b) Shear strength The design shear stress in the plain concrete lining subjected to shear and axial compression without shear reinforcement can be calculated in accordance with clause 6.1.2.5(k). The design shear resistance of plain concrete lining can be checked in accordance with clause 6.2.2.3(r).
5. Clause 10.3.4.2(a)	10.3.4.2 Concrete Cube Tests During Construction (a) Concrete Cubes The compressive strength of concrete shall be determined by testing 100 mm or 150 mm cubes 28 days after mixing. A representative sample shall be taken from fresh concrete to make test cubes and each sample shall be taken from a single batch. The rate of sampling shall be at least that specified in Table 10.1 and at least one sample shall be taken from each grade of concrete produced on any one day.	10.3.4.2 Concrete Cube Tests During Construction (a) Concrete Cubes The compressive strength of concrete shall be determined by testing 100 mm cubes, or 150 mm cubes if the maximum aggregate size of concrete exceeds 20 mm, 28 days after mixing. A representative sample shall be taken from fresh concrete to make test cubes and each sample shall be taken from a single batch. The rate of sampling shall be at least that specified in Table 10.1 and at least one sample shall be taken from each grade of concrete produced on any one day.

<table>
<tr><th>Item</th><th>Current version</th><th>Amendments</th></tr>
<tr><td>6. Table 10.2</td><td>
<table>
<tr><th rowspan="3">Specified Grade Strength</th><th rowspan="3">Compliance Criteria</th><th colspan="2">Column A</th><th colspan="2">Column B</th></tr>
<tr><th colspan="2">Average of 4 consecutive test results shall exceed the specified grade strength by at least</th><th colspan="2">Any individual test result shall not be less than the specified grade strength minus</th></tr>
<tr><th>150 mm Cubes</th><th>100 mm Cubes</th><th>150 mm Cubes</th><th>100 mm Cubes</th></tr>
<tr><td rowspan="3">C20 and above

Below C20</td><td>C1</td><td>5 MPa</td><td>7 MPa</td><td>3 MPa</td><td>2 MPa</td></tr>
<tr><td>C2</td><td>3 MPa</td><td>5 MPa</td><td>3 MPa</td><td>2 MPa</td></tr>
<tr><td>C1 or C2</td><td>2 MPa</td><td>3 MPa</td><td>2 MPa</td><td>2 MPa</td></tr>
</table>
Table 10.2 - Compressive Strength Compliance Criteria
</td><td>
<table>
<tr><th rowspan="2">Specified Grade Strength</th><th rowspan="2">Compliance Criteria</th><th>Column A</th><th>Column B</th></tr>
<tr><th>Average of 4 consecutive test results shall exceed the specified grade strength by at least</th><th>Any individual test result shall not be less than the specified grade strength minus</th></tr>
<tr><th></th><th></th><th>100 mm Cubes
(150 mm Cubes)</th><th>100 mm Cubes
(150 mm Cubes)</th></tr>
<tr><td rowspan="2">C20 and above</td><td>C1</td><td>7 MPa
(5 MPa)</td><td>2 MPa
(3 MPa)</td></tr>
<tr><td>C2</td><td>5 MPa
(3 MPa)</td><td>2 MPa
(3 MPa)</td></tr>
<tr><td>Below C20</td><td>C1 or C2</td><td>3 MPa
(2 MPa)</td><td>2 MPa
(2 MPa)</td></tr>
</table>
Table 10.2 - Compressive Strength Compliance Criteria
</td></tr>
<tr><td>7. Clause 10.3.4.2(b)(i)</td><td>(i) Before 40 test results are available, where there is sufficient previous production data using similar materials from the same plant under similar supervision to establish that the standard deviation of 40 test results is less than 5 MPa for 150 mm test cubes or 5.5 MPa for 100 mm test cubes, compliance requirement C2 may be adopted; otherwise compliance requirement C1 shall be adopted.</td><td>(i) Before 40 test results are available, where there is sufficient previous production data using similar materials from the same plant under similar supervision to establish that the standard deviation of 40 test results is less than 5.5 MPa (5 MPa for 150 mm cubes), compliance requirement C2 may be adopted; otherwise compliance requirement C1 shall be adopted.</td></tr>
<tr><td>8. Clause 10.3.4.2(b)(ii)</td><td>(ii) Where the calculated standard deviation of a set of 40 consecutive test results of concrete judged by compliance requirement C2 of Table 10.2 exceeds 5 MPa for 150 mm test cubes or 5.5 MPa for 100 mm test cubes, compliance requirement for checking the test results shall be changed from C2 to C1 on the 35th day after making the last pair of test cubes in the set of 40.</td><td>(ii) Where the calculated standard deviation of a set of 40 consecutive test results of concrete judged by compliance requirement C2 of Table 10.2 exceeds 5.5 MPa (5 MPa for 150 mm cubes), compliance requirement for checking the test results shall be changed from C2 to C1 on the 35th day after making the last pair of test cubes in the set of 40.</td></tr>
</table>

Item	Current version	Amendments
9. Clause 10.3.4.2(b)(iii)	(iii) Where the calculated standard deviation of 40 previous consecutive test results is less than 5 MPa for 150 mm test cubes or 5.5 MPa for 100 mm test cubes, compliance requirement shall be changed from C1 to C2 on the 35th day after making the last pair of test cubes in the set of 40.	(iii) Where the calculated standard deviation of 40 previous consecutive test results is less than 5.5 MPa (5 MPa for 150 mm cubes), compliance requirement shall be changed from C1 to C2 on the 35th day after making the last pair of test cubes in the set of 40.
10. Clause 10.3.4.2(b)(iv)	(iv) For concrete grade not exceeding C60, the calculated standard deviation exceeds 8 MPa for 150 mm test cubes or 8.5 MPa for 100 mm test cubes; or	(iv) For concrete grade not exceeding C60, the calculated standard deviation exceeds 8.5 MPa (8 MPa for 150 mm cubes); or
11. Clause 10.3.4.2(b)(vi)	(vi) The average of the latest 40 cube test results exceeds the grade strength by at least 10 MPa for 150 mm test cubes or 12 MPa for 100 mm test cubes and all individual test results exceeds the grade strength by at least 4 MPa for 150 mm test cubes or 5 MPa for 100 mm test cubes; or	(vi) The average of the latest 40 cube test results exceeds the grade strength by at least 12 MPa (10 MPa for 150 mm cubes) and all individual test results exceeds the grade strength by at least 5 MPa (4 MPa for 150 mm cubes); or
12. Clause 11.7.5.4 and Table 11.2	-	11.7.5.4 *Monitoring early compressive strength of insitu concrete by maturity method* After concrete casting, the development of insitu concrete compressive strength at early age can be monitored by the maturity method. The maturity method can be used for estimating insitu concrete compressive strength through measurement of the temperature-time history of concrete of ages up to 14 days after casting, for the purpose of determining the concrete strength for striking of formwork and falsework[1] in lieu of the minimum periods specified in clause 10.3.8.2. In formulating a proposal adopting the maturity method, reference should be made to the acceptable standard in Annex A. The proposal should cover the following:

<table>
<tr><th>Item</th><th>Current version</th><th>Amendments</th></tr>
<tr><td></td><td></td><td>
(a) choice of an appropriate maturity function and determination of maturity function constants;
(b) apparatuses and their calibration;
(c) procedure for developing strength-maturity relationship;
(d) procedure for estimating insitu concrete strength;
(e) validation of insitu concrete strength;
(f) re-calibration and re-validation; and
(g) quality assurance and supervision.

The concrete mix used in the structure should be the same as that used to derive the strength-maturity relationship.

Taking into account the different conditions between cast insitu concrete and concrete cubes under various curing temperatures in the calibration process, a correction factor as shown in Table 11.2 should be applied to the estimated insitu concrete compressive strength.

<table>
<tr><th>Type of concrete mix</th><th>≤ 48 hours after concrete casting</th><th>> 48 hours after concrete casting</th></tr>
<tr><td>Concrete mix containing pfa or ggbs</td><td>0.7</td><td>0.8</td></tr>
<tr><td>Other concrete mix</td><td>0.8</td><td>0.8</td></tr>
</table>
Table 11.2 – Correction factor applied to the estimated insitu concrete compressive strength
</td></tr>
</table>

Item	Current version		Amendments	
			1 Due to the rapid rate of concrete strength development within 24 hours after concrete casting, the maturity method is not suitable for use in justifying minimum periods before striking formwork and falsework of less than 24 hours.	
13. Annex A[3]	BS EN 13263-1:2005 +A1:2009	Silica fume for concrete. Definitions, requirements and conformity criteria	BS EN 13263-1:2005 +A1:2009 ASTM C1074-19ε1	Silica fume for concrete. Definitions, requirements and conformity criteria Standard Practice for Estimating Concrete Strength by the Maturity Method

[3] Addition of ASTM C1074-19ε1 corresponding to the new clause 11.7.5.4.

Appendix B
(PNAP APP-142)

Amendments to the Code of Practice for Structural Use of Concrete 2013 (2020 Edition)

(June 2023)

Legends:

Amended

Deleted

(6/2023)

Amendments to the Code of Practice for Structural Use of Concrete 2013 (2020 Edition) in June 2023 included:

(a) Clause 3.2.8.3 and Annex A – Addition of referenced standard ISO 15835-2 for the test method on mechanical coupler; and

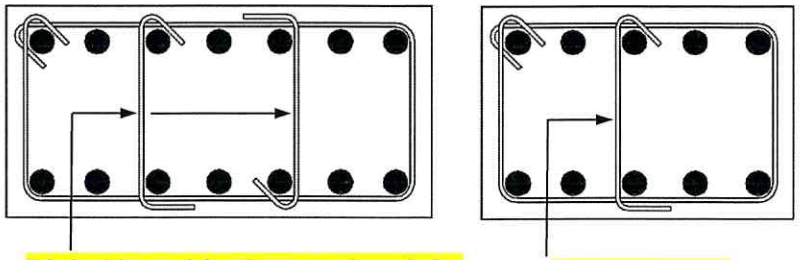
(b) Clause 9.9.1.3(b) and Figure 9.6a – Addition of alternative arrangement for links/ties for beam.

Amendments to the Code of Practice for Structural Use of Concrete 2013 (2020 Edition)

Item	Current version	Amendments
1. List of Figures	Figure 9.6 - Typical corbel detailing..... Figure 9.7 - Typical confinement in beam.....	Figure 9.6 - Typical corbel detailing..... Figure 9.6a - Alternative arrangement for links/ties for beam Figure 9.7 - Typical confinement in beam.....
2. Clause 3.2.8.3[1]	3.2.8.3 Performance of type 1 mechanical couplers Type 1 mechanical coupler satisfying the following criteria may be used as an alternative to tension or compression laps: (a) when a representative gauge length assembly comprising reinforcement of the diameter, grade and profile to be used, and a coupler of the precise type to be used, is tested in tension the permanent elongation after loading to $0.6f_y$ should not exceed 0.1 mm; and ……	3.2.8.3 Performance of type 1 mechanical couplers Type 1 mechanical coupler satisfying the following criteria may be used as an alternative to tension or compression laps: (a) when a representative gauge length assembly comprising reinforcement of the diameter, grade and profile to be used, and a coupler of the precise type to be used, is tested in tension the permanent elongation after loading to 0.6fy should not exceed 0.1 mm[1]; and …… [1] Reference may be made to clause 5.4, excluding sub-clause 5.4.4, of ISO 15835-2 for the test method.
3. Clause 9.9.1.3(b)[2]	(b) Anchorage Links should be adequately anchored by means of hooks with bend not less than 135° in accordance with clause 8.5. Anchorage by means of welded cross bars is not permitted. Where ……	(b) Anchorage Links should be adequately anchored by means of hooks with bend not less than 135° in accordance with clause 8.5. Alternatively, links/ties should be adequately anchored by means of hooks bent through an angle of not less than 135° at one end and 90° at the other end, and should be alternated end for end along the longitudinal bars (see Figure 9.6a). Anchorage by means of welded cross bars is not permitted. Where ……

[1] Addition of referenced standard ISO 15835-2 for the test method on mechanical coupler.

[2] Addition of alternative arrangement for links/ties for beam.

Item	Current version		Amendments	
4. Figure 9.6a			 Figure 9.6a - Alternative arrangement for links/ties for beam	
5. Annex A	AC 133:2008	Acceptance Criteria for Mechanical Connector Systems for Steel Reinforcing Bars	AC 133:2008	Acceptance Criteria for Mechanical Connector Systems for Steel Reinforcing Bars
	BS EN 197-1:2011	Cement. Composition, specifications and conformity criteria for common cements	ISO 15835-2:2018	Steels for the reinforcement of concrete – Reinforcement couplers for mechanical splices of bars – Part 2: Test methods
			BS EN 197-1:2011	Cement. Composition, specifications and conformity criteria for common cements