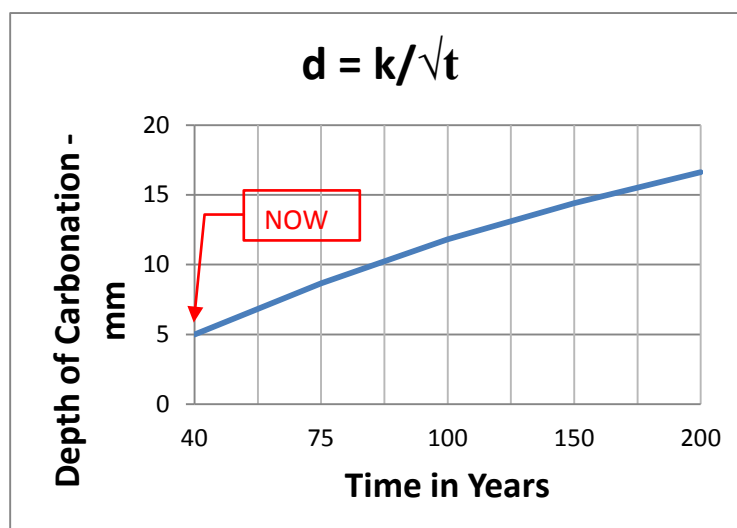


## Notes on Report Letter from WJM dated 4<sup>th</sup> March 2014

While in principle the letter makes some sense we offer the following points:-

- 1 The actual depth of carbonation measured was typically 5mm. The incidence of cover to the steel in the 0 - 10mm range was <1% according to the WJM letter, so the structural relevance is negligible as is the risk of future corrosion affecting the structural performance as a whole. See the plot below. This does not mean that these areas of low cover (or honeycoming or cracking) should be ignored and steps do need to be taken from now on to minimise the risk of further corrosion or at least to monitor and manage the risk from these defects and the possible consequences.
- 2 The steel in the 11-20mm range comprising less than 2% will not be at risk of corrosion until 100 years or so after construction. Regardless of what the specification at the time of construction stated, the proof of the high quality of the concrete is that the depth of carbonation is extremely low, so the structure is still performing as intended by the designers.
- 3 Concrete structures will deteriorate over time if not maintained. This is well known and understood and has been known for many years. Deterioration is inevitable in any building material and when of a minor nature is normally remedied as part of maintenance – brickwork and stone needs occasional repointing to prevent water ingress, old lead often only seems to last a long time because it started out thick and corrodes slowly, stainless steel can look rusty if not cleaned, paint and timber require more frequent attention.
- 4 The defects identified in the present surveys are small in number considering the quantity of concrete in the Barbican. Other concrete buildings from the 1960's and 70's have been demolished or extensively repaired by now, so it is again surprising and a tribute to the quality of the original construction that some issues are only now becoming apparent.
- 5 The cover measured in the surveys would always be to the links assumed to be 10 or 12 mm diameter. Larger links would give a pessimistically low reading because the covermeter would interpret the greater amount of steel as a 10 or 12mm bar closer to the surface. The normal assessment of carbonation depth with time based on 5mm after 40 years is shown below.



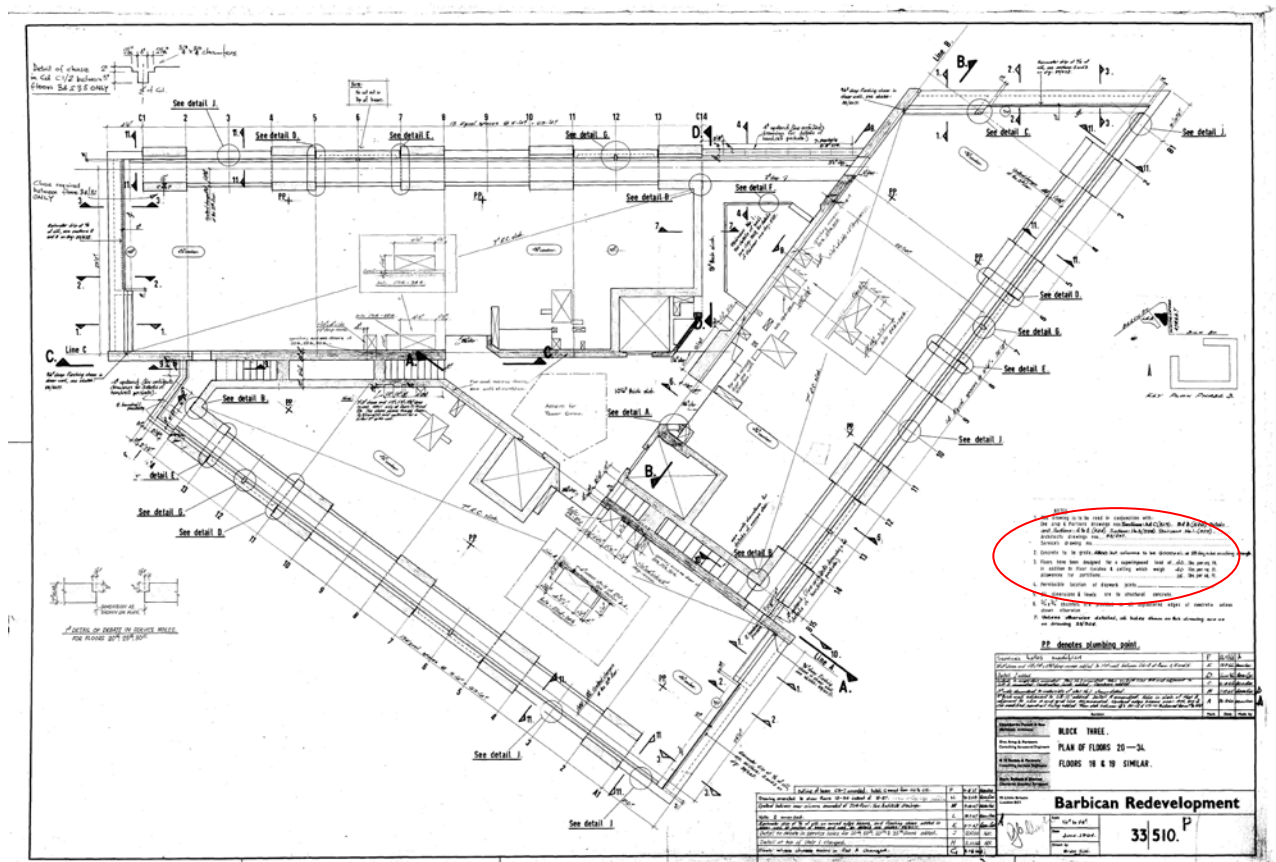
6 Extract from Concrete Practice (C&CA 1975)

**TABLE 12: Required cover for concrete grades and different conditions of exposure (from CP 110).**

Conditions of exposure	Nominal cover									
	Concrete grade									
	20		25		30		40		50 and over	
	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.
Mild: e.g. completely protected against weather, in aggressive conditions, except for brief period of exposure to normal weather conditions during construction	25	1	30	$\frac{1}{4}$	15	$\frac{1}{4}$	15	$\frac{1}{4}$	15	$\frac{1}{4}$
Moderate: e.g. sheltered from severe rain and against freezing whilst saturated with water. Buried concrete and concrete continuously under water	—	—	40	$1\frac{1}{4}$	30	$1\frac{1}{4}$	25	1	20	$\frac{3}{4}$
Severe: e.g. exposed to driving rain, alternate wetting and drying and to freezing whilst wet. Subject to heavy condensation or corrosive fumes	—	—	50	2	40	$1\frac{1}{2}$	30	$1\frac{1}{4}$	25	1
Very severe: e.g. exposed to sea water or Moorland water and with abrasion	—	—	—	—	—	—	60	$2\frac{1}{4}$	50	2
Subject to salt used for de-icing	—	—	—	—	30*	2	40*	$1\frac{1}{4}$	25	1

\*Only applicable if the concrete has crumbled etc.

[CP 110-1:1972. (Code of practice for the structural use of concrete Design, materials and workmanship)]



Concrete in columns 6000psi = 41 N/mm<sup>2</sup> – concrete generally 4800psi = 33N/mm<sup>2</sup>

By the criteria in CP110 the nominal cover to steel in columns should be 30mm (SEVERE exposure), on which there will be a tolerance of about  $\pm\frac{1}{4}$ " (6mm), or possibly as much as  $\pm\frac{1}{2}$ " (12mm).

Drawing dated 1964 – pre-dating CP110 1972 and CP 114:1969 (The structural use of reinforced concrete in buildings). According to CP114 1957 reprinted 1965:-

307. *Cover. Reinforcement should have concrete cover and the thickness of such cover (exclusive of plaster or other decorative finish) should be: [BAP emphasis]*

- 1 *for each end of a reinforcing bar, not less than 1 in, nor less than twice the diameter of such bar;*
  - 2 ***for a longitudinal reinforcing bar in a column, not less than 1½ in, nor less than the diameter of such bar. In the case of columns with a minimum dimension of 7½ in or under, whose bars do not exceeding ½ in diameter, 1 in cover may be used;***
  - 3 *for a longitudinal reinforcing bar in a beam, not less than 1 in nor less than the diameter of such bar;*
  - 4 *for tensile, compressive, shear or other reinforcement in a slab, not less than ½ in nor less than the diameter of such reinforcement;*
  - 5 *for any other reinforcement not less than ½ in nor less than the diameter of such reinforcement.*
- 7 The minimum cover according to CP114 is 1½ inches or 37-38 mm for vertical structural reinforcement and ½ inch or the bar diameter for links. This could therefore be as low as 12 mm for ½ inch links.
- 8 Bearing in mind the percentage minimum cover readings quoted in WJM table 1 are not proportions of the areas surveyed and that they mostly relate to individual link bars or link bar ends and not to groups or whole elements of the structure, the fact is that that 88% of cover measurements have achieved that the specification of cover (be it 38 or 40mm or to CP114 or CP110) for the vast majority of the steel reinforcement.

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**11<sup>th</sup> March 2014**