



Department of Civil and Environmental Engineering
UNIVERSITY COLLEGE LONDON
Gower Street, London WC1E 6BT

James G A Croll FREng, FICE, FStructE, FRSA, FIMA
Professor of Civil Engineering

Report on the Structural condition of Blackburn Meadows Cooling Towers

Prepared for Carbon Media Ltd by James G A Croll, based upon the following information:

- Documentation supplied on 8 June, 2006, by Mr David McFarlane, Group head Civil Engineering, Power Technology. This comprised: 6 original Mouchel working drawings dated circa 1938; 4 plots dated 8.6.06 of geometry and crack surveys undertaken seemingly in 2002 on towers 6 and 7;
- Visit to the Sheffield site to observe from ground level the condition of the two towers;
- On-site meeting on the 15 June, 2006, with the following staff from e.on:
Mr David McFarlane, Group Head Civil Engineering, Power Technology
Mr Mark Maisey, Property Manager, e.on
Ms Rebecca Middleton, Senior Press Officer, e.on
and accompanied by Lucy Evans and Neil Smith, Carbon Media Ltd.

Terms of reference:

To provide independent specialist advice to Carbon Media Ltd regarding the structural integrity of the two Blackburn meadows cooling towers. To provide an intermediary, technical translation, role in the dialogue between Carbon Media Ltd and the tower owners, e.on. To explore whether there are compelling structural safety reasons why the towers should be demolished. To advise as to whether with appropriate remedial works the cooling towers could be made sufficiently safe to form the focus of the intended “big art” project.

Background:

The two cooling towers adjacent to the Tinsley Viaduct are all that remains of the Blackburn Meadows electricity generating station. Were it not for the close proximity of the Tinsley viaduct, carrying the M1 motorway, it is almost certain that these two towers would also have been demolished after the decommissioning of the generating station. Following a recent programme of structural strengthening of the Tinsley Viaduct the tower owners (e.on) are of the view that demolition could now take place without risk of damage to the viaduct. Trial blasts have already been undertaken to test the resilience of the support columns and the shell, as part of the preparatory work for demolition scheduled to take place on an as yet unspecified date but apparently before the end of 2006. The owners are keen for the largely derelict site to be redeveloped.

Carbon Media Ltd, a production company working for Channel 4, has over the past year or so undertaken public consultations throughout the UK to identify sites and proposals for the creation of “big art” projects. One of the most widely supported schemes, both amongst the local Sheffield population and the adjudicators of the various Channel 4 proposals, was that based upon the reuse of the Blackburn Meadows cooling towers near Sheffield. E-on had indicated that there was no alternative but demolition.

I was asked to try to establish whether or not there are compelling structural considerations that make demolition necessary. Even if the present condition would not allow safe adoption of the towers as part of the project, I was also asked to provide preliminary views as to

whether appropriate strengthening could be undertaken to bring the towers into a structural condition that might allow such re-use.

Significance of the cooling Towers:

It is very likely that cooling towers 6 and 7 at Blackburn Meadows, constructed in late 1930's, are the oldest surviving reinforced concrete hyperboloidal cooling towers in the UK. The first examples of this form of cooling towers were designed by Mouchel in the mid-1920's but were very much smaller than those at Blackburn Meadows. In the years leading up to WW2 there were a number built, but those at Blackburn Meadows, at circa 75m in height, were when built probably the largest of their kind. They incorporate a number of features that while typical of the earlier generation of concrete cooling towers would not be found in similar designs undertaken subsequent to WW2. Some of these features are undoubtedly the reason why these towers have survived relatively intact for the near 70 years of their life so far. Some of these features also give these towers a distinctive aesthetic that make them stand out from the rather less visually distinctive towers that typify more recent designs. But they are undoubtedly of considerable historical interest and significance in setting the pattern that would come to characterise cooling tower design throughout the world.

Structural Qualities of the Towers:

Design drawings show the Blackburn Meadows towers having a shell thickness over most of their height as 4.5 inch (115 mm). While this may at first sight appear thin in relation to more recent construction it has to be remembered that the thickness should be assessed relative to the overall dimensions. Extrapolation of the 4.5 inch of these 75 m high towers to a standard tower (such as those at Ferrybridge and many other UK power stations) having overall height 110 m would result in an equivalent thickness of 6.6 inch. This is well in excess of the 6 inch thickness that was adopted for the 110 m towers following the collapse that occurred at Ferrybridge in 1965. It certainly indicates a tower having an overall rigidity considerably greater than the 5 inch thickness of the pre-collapse Ferrybridge towers.

While the thickness to height ratio is crucial in terms of controlling potential failures relying upon shell stiffness, it is the levels of reinforcing steel that are crucial in controlling the shell strength. It is noticeable that the levels of steel adopted in the Blackburn Meadows towers are well in excess of those that have been adopted subsequently. To ensure equivalent strengths of towers having different heights it is necessary to increase the quantities of steel in direct proportion to the height. This is often achieved by ensuring the steel cross-sectional areas, passing through a unit cross-section of the concrete shell, have a fixed ratio, or percentage. Different percentages are required for horizontal and vertical steel. But for all steel in the Blackburn Meadows towers the percentages are very much higher than those that would today be considered acceptable. For example, in the Blackburn Meadows towers the minimum percentage of horizontal steel is around 0.22% at the level of the throat (the term used to describe the region of minimum diameter) while that found in the class of 110 m tower is often as low as 0.12%. Even without the help of the additional ring beam that has been incorporated into the Blackburn Meadows towers the resistance to the forms of failure that depend upon horizontal steel is almost twice as great as the equivalent modern tower. Percentages in the vertical direction are no less than 0.76% in the Blackburn Meadows towers compared with levels as low as 0.15% in more recent towers. It should be noted that current codes require a minimum of 0.25% steel. So that for all the failure conditions dependent upon the strength of the vertical steel the Blackburn Meadows towers are in excess of 3 times stronger than those designed to current standards. Added to this is the consideration that in

the Blackburn Meadows towers the reinforcement is placed on both the inner and the outer faces which is not the practice with more recent UK towers; this also increases the resistance to failure.

An interesting feature of the reinforcement is that it is placed so that it follows the straight line generators that can be used to develop the surface of the hyperboloidal shell. This means that on both faces there are 2 layers of reinforcement (4 layers in all) placed at small \pm angles to the vertical. This adds even more strength to the horizontal steel.

Current Condition of the Towers:

Details of ground based condition surveys undertaken in 2000 and 2002 were supplied. I am not aware of any prior surveys. For tower 7, errors in surface position of up to a maximum of 350 mm were recorded. Although there was an apparent change in this maximum from 300 to 350 mm between 2000 and 2002 this could easily be accounted for by survey errors. While a surface distortion of this magnitude is noticeable from certain ground based lines of sight it is considered that it does not present an immediate threat to the integrity of the tower. Indeed, it is more than possible that this pattern of geometric errors represent the levels of accuracy achieved in the setting-out of the shuttering during construction. There is some correlation between the geometric distortions and the crack patterns on tower 7 but not at levels that would indicate a growth of distortion related to yield of reinforcement at the cracks. A feature of the distortions that provides some reassurance is that the errors occur over long horizontal wavelengths. In tower 7 the maximum distortion occurs over a wavelength subtending around 110° of arc. In more recent towers where strengthening has been found to be required the distortions are considerably higher and occur over much shorter wavelengths – typically 15 to 25° . These shorter wavelength imperfections are considerably more dangerous than the long wavelengths evident in tower 7.

Tower 6 was in the late 60's provided with an external gunite coating. I am not aware of what additional reinforcement was added during this process. It is noticeable that the geometric distortions and the levels of cracking, at least below the throat, are rather less than in tower 7.

Both towers exhibit areas in which concrete spalling has occurred (a process where surface concrete has broken away, often from reinforcement). The extent to which this has been accompanied by corrosion of the reinforcement is not clear. The owners seem to have plans to carry out a steeplejack based survey to assess the degree of corrosion. From ground level there were no obvious visual signs of extensive corrosion.

There are a few areas where trial blasts have been used to assess the charge strengths required to locally destroy either the shell or its support columns.

Summary of Structural Condition:

For towers of nearly 70 years of age the Blackburn Meadows towers are in remarkably good shape. This is no doubt a reflection of the somewhat conservative (at least in relation to current practice) initial design and the quality of construction that would have been needed to produce towers to the close tolerances demanded by the design. With appropriate repairs to prevent any acceleration of corrosion in area where cracking has occurred and to re-establish appropriate cover where spalling has exposed reinforcement, there would appear to be no reason why these towers could not have their safe working lives extended for a further 10 to 20 years or even longer. There are many cases of shells having much more serious

deterioration being repaired to extend their working lives for similar periods. Clearly, if rehabilitation back to required levels of strength is to be achieved the areas of damage where trial blasts have been applied would also need to be repaired.

Costs of Rehabilitation:

This is not an area where I feel qualified to make definitive estimates, these should be sought from appropriate specialist companies. However, on the basis of figures suggested during the site meeting repairs to the class of 110 m towers deemed to be at risk were suggested to be around £0.5M per tower. On the assumption that the costs are to a large extent proportional to the surface areas of the shells the costs of repairs to 75 m high shells should be less than 50% those of a 110 m high shell. Making allowance for the possibility that the Blackburn Meadows towers are in relatively sound condition compared with some of the more recent shells requiring repairs, but also factoring-in the compensatory factor that additional safety would be required if the Blackburn Meadows towers are to be incorporated into a project allowing public access, it might be fair to estimate that the costs of structural rehabilitation for the 2 Blackburn Meadows towers would also be roughly £0.5M. This would not include any additional work that might be required to remove any remaining pipework, and other now redundant structural support features.

Cautionary Note:

The above remarks are based upon very limited data; this would need to be greatly extended to allow detailed structural assessments to be made. Such detailed structural checks would most definitely be required should a decision be taken to adopt these towers as part of a publicly accessible “big art” project.

James G A Croll, FREng, FICE, FIStructE, FIMA, CEng, CMath
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