Discussion

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Concrete coating for submarine pipelines*

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We would like to commend Dr Palmer for his very informative paper on this topic. It clearly assists those not involved in the pipe-coating industry to understand why the method of application of the concrete onto the pipe and the form of coating give rise to a concrete which exhibits characteristics and modes of behaviour which cannot readily be predicted from studies of conventionally placed concrete.

At several points in his paper, Dr Palmer highlights a lack of information on the characteristics of coatings formed by using the wrapping process. We are currently assessing the structural integrity and the material characteristics of a 12.0 m length of 914 mm outside diameter pipe coated by this technique by Compression Coat Inc. of Texas. The results from the investigation will perhaps answer some, if not all, of the points raised by Dr Palmer.

We would now like to turn to the subject of the quality control of concrete coatings. There are two parts to this problem:

- (1) What is the property, or are the properties, of the material which should be selected as a basis on which to assess its 'quality'?
- (2) When a quality index has been selected, how should it be monitored and interpreted in an accurate manner?

The above aims can be stated more easily than they

can be achieved. Although it may be simple to state the perceived characteristics which are required in the end product, some of these characteristics may be mutually incompatible whilst others do not readily lend themselves to routine quality control testing.

The compromise referred to by Dr Palmer, which has been followed in practice, is to make laboratory cubes which are then used to monitor the intrinsic strength of the concrete and to use cores cut from actual pipes to check the quality of the *in situ* concrete, including the influence of the compacting process. Unfortunately the mix on the pipe may be marginally different from that of the quality control cubes, for reasons involving 'rebound' of some of the constituents during the application process. Furthermore, any cores which are cut from the coated pipes will, because of the thinness of the coatings, be of abnormally small diameter and low ratios of height to diameter. The apparent guidance of BS 1881 : 1971 should be treated with caution, bearing in mind that it is based on and refers to conventional structural concrete, and specifically states that cores should be 100 or 150 mm diameter.

A typical core cut from a coating is shown in Figure I, where it can be seen that there are many potential difficulties to be overcome before a specimen suitable for crushing can be obtained.

A striking feature to emerge from an in-depth study of the distribution of core-crushing strengths along the 12.0 m length of a 914 mm diameter pipe is

* Pages 119 to 129 of MCR 120.

Figure I: A typical core cut from a coating.

shown in Figure II. In many cases, compliance decisions have to be made on the basis of the crushing strength of one such core taken every twelfth (or even less frequent) coated pipe. This will obviously build in unfair risks to the client, who may be forced to accept faulty concrete, and to the producer, who may have good concrete rejected.⁽¹⁾

Three problems have been identified in the work we have undertaken, as follows.

- (1) The most commonly used method of applying the concrete coating, by impingement, can in certain circumstances lead to 'shadowing' in the concrete behind the reinforcement. When this occurs, the concrete outside the reinforcement cage is uniform over the whole area of pipe but the concrete between the plane of the reinforcement and the external anti-corrosion coating consists of rectangles of dense concrete separated by weaker bands of porous concrete behind each reinforcing bar. When cutting the cores, it is necessary to avoid the areas near the reinforcement, otherwise the core strength will be reduced and will have increased scatter if the cores contain some of the more porous 'shadow' concrete.
- (2) When the cores are cut from mid-way between the reinforcement in order to avoid the effect of the 'shadow' concrete, this still leaves unresolved the effect that the zones of weakness will obviously have upon the structural performance of the pipe coating. In fact, it may be of no practical significance. What is certain is that the strength of the cores will in no way monitor the presence of such 'shadow' zones or their influence upon the working performance of the pipeline.
- (3) With regard to the performance requirements of the concrete coating, it is clear that what is being sought is a strong tough concrete, not a strong brittle one. Yet, by choosing crushing strength as

STEEL PIPE (914 mm outside diameter) WITH CONCRETE CASING

Figure II: Variations in crushing strengths of small-diameter cores taken from a concrete coating on a section of submarine pipeline.

the sole index of quality (even though impact tests may be performed), it is inevitable that demands for increased strength, in the belief that it must improve quality, will tend to give rise to brittle concrete. It may be fruitful to shift the emphasis of the mix design towards producing a 'tough' concrete, even though this may lead to a somewhat lower nominal crushing strength.

The addition of fibres to coatings for submarine pipelines is a topic which has received some attention

in the past but, with the range of fibres available, now is perhaps the time for a more detailed study to be initiated.

We tend to agree with Dr Palmer where he refers to the possibility of reeling pipe with thick coatings. We have recently completed an experimental study into the feasibility of reeling flowlines with thick coatings (not cementitious based materials) and have certainly been encouraged by the results to date.

Reply by the author

I should like to thank Mr Maclean, Mr Haldane and Mr Jackson for their interesting discussion. Their example clearly indicates the variability of core strength and underlines the need for a careful choice of acceptance/rejection criteria. It strongly suggests that concrete specifications for pipelines need to take more account of statistics and sampling theory.

I entirely agree with the remark that it is more important for this type of concrete to be fracture-resistant ('tough') rather than for it to be merely strong, in the sense of having a high compressive strength.

REFERENCE

1. MACLEAN, T. A., HALDANE, D. and JACKSON, P. The risks associated with the use of cores for the compliance testing of concrete coatings on subsea pipelines. Paper to be presented to the Fifth International Conference on the Internal and External Protection of Pipes, Innsbruck, Austria, October 1983.