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Concrete Pavement Slab Replacement – Latest Research

Introductory Comments

It is a fact that road agencies in Australia and US approach patch design and construction from the mindset of conventional new concrete paving. This results in a number of unique properties and requirements of the patch repair being overlooked.

The goals of the highway agencies should be to provide a method of patching that reduces the time required (also interference and traffic safety), allows lower concrete strength for opening to traffic, reduced cost and still results in a patch with a long life.

In the past High Early Strength concrete has been thought to be the answer for early opening. In the last 15 years Caltrans has replaced 70,000 slabs (322 lane kms). Their current criterion for placement under traffic is 13.8 MPa in 6 hours. In the US there is no consensus between the States on what the required minimum compressive strength should be. The variations range from 13.8 to 20.7 MPa (2.0 to 2.8 MPa).

The RTA NSW requires 25 MPa officially, but local ill-informed decisions have raised this to 30 MPa (cylinder strength) on a number of projects. The proof of this illogic is that 41 years ago when the Warringah Expressway was constructed, the specified pavement concrete 28 day strength was 17 MPa. Recent coring shows this now to be 50 – 55 MPa To my knowledge no slabs have needed replacement. (Currently RTA also requires the filling in core holes to be 15 MPa).

The following extracts and summaries are from a paper by Jim Grove (FHWA), Jim Cable (Cable Concrete Consultation) and Peter Taylor (NCPTC); **"Concrete Pavement Patching – Simpler Can Be Better"** that was presented at the (FHWA) National Conference on Preservation, Repair and Rehabilitation of Concrete Pavements held in St Louis , Missouri 22 – 24 April, 2009:

What opening strength is needed?

All the minimum opening strengths are empirically established limits and they are more conservative than necessary for concrete pavement maintenance and repair. This is because they were established during the time when the only way to measure pavement strength was by cylinder strengths. It is an accepted fact that the cylinder strength does not represent that of concrete in the patch. Nowadays, however in-place testing methods, like Maturity Testing, can more closely estimate concrete's in-place strength. This eliminates the safety factors that were built into the application of cylinder strength.

The research by Okamoto et al (1994) and Davis and Darter (1989) determined that the necessary strength needed for opening a concrete pavement to traffic is significantly less than the value commonly used by road authorities.

High Early Strength Concrete?

- The faster concrete gains strength, the sooner it will slow or stop, ie accelerating early strength gain can sacrifice long-term strength.
- Addition of extra cement may not provide extra early strength (Buch et al 2004), but will increase drying shrinkage, heat, cracking risk and cost of the concrete.
- Usually less strength is required to provide service life corresponding to the remaining life of the pavement.

The Latest Research

Okamoto's research for the FHWA found that for a 254 mm pavement, for **compressive strength of 7.18 MPa** and flexural strength of 1.38 MPa the pavement would experience no fatigue damage over 10,000 cycles.

He also stated that: **"Interior loading produced virtually no fatigue damage for 254 mm and 305 mm slabs, even if loaded when the compressive strength was 1.8 MPa".**

Davis and Darter in 1989 found that the thicker the patch, the lower the opening strength needed to be. And that for a 254 mm slab, **1.38 MPA flexural strength** was sufficient.

Cable et al in 2004 in a very detailed research found that:

- Increased patch depth enhanced the concrete strength gain associated with the heat of hydration determined by **Maturity Testing** (see PIN 39).
- Performance measures indicated no difference due to concrete mix (standard mixes or those with calcium chloride), opening times to traffic or concrete patch depths.
- Maturity Testing proved to be an accurate and consistent method of estimating concrete strength gain with regard to determining the strengths for opening to traffic.

Buch et al (2008) reported that high-range water reducers negatively affect the air-entraining system.

Narotam and Vu (1993) reported that:

- Water reducers resulted in lower early strengths.
- The recommended minimum **curing time should be 6 hours.**

ACPA Concrete Paving Technology – Guidelines for Full-Depth Repair recommends a minimum strength requirement of 1.72 MPa for 254 mm patches for opening to traffic opening. This is also referenced in the **FHWA** publication "Concrete Pavement Preservation Workshop" (FHWA 2008).

Conclusions

- These practices are applicable where a minimum of 6 to 8 hours curing is acceptable.
- For strength measurement for opening, the Maturity Method should be used (breaking a cylinder or beam merely determines the sample strength and not the pavement strength).

Recommendations

- Use a conventional concrete mix with no calcium chloride.
- Use age as the only criteria for opening, along with certain curing and temperature requirements.
- Conduct laboratory testing to establish opening to traffic criteria based on time only.
- Test the strength of the mix, using a reduced strength requirement, at temperatures similar to those anticipated for field conditions.
- On the basis of the above research, for a 254 mm patch, a flexural strength of 1.38 MPa (about 7.2 MPa compressive strength) could be used as a minimum strength for determining the time for opening to traffic.

PS I For details of non-destructive Maturity Measurements see PIN 39.
2 If anybody is interested in the references, I can supply these.