Investigating and Preventing Premature Deterioration of Colored Concrete Pavement

What Was the Need?
The use of colored concrete in pavement projects has gained popularity in Minnesota in recent years. Colored concrete may improve safety when used to delineate critical road features and so provide guidance to pedestrians and drivers. It is also used simply to look appealing.

Many colored concrete pavement projects in Minnesota have displayed microcracking near contraction joints. While this type of distress also happens in regular concrete pavements, it appears to be accelerated in colored concrete pavements, with deterioration observed within five years of construction in some instances.

For colored concrete to be practical for continued usage in Minnesota pavements, agencies need to have confidence in its durability. However, there was little published research on the performance of colored concrete that might identify the cause of or remedy for premature deterioration.

What Was Our Goal?
This project sought to determine the causes of premature distress in Minnesota colored concrete pavement projects and identify suitable repair and rehabilitation techniques for projects that have suffered this distress.

What Did We Do?
Researchers first identified 45 projects in Minnesota that included colored concrete pavement, sidewalks or medians, and collected data about each project including its construction date and any distresses observed. They visited several of these projects as well as three current construction sites where they could observe construction practices for colored concrete.

Then 17 core samples were collected from four projects that had experienced significant early distress. Researchers conducted petrographic analysis in accordance with ASTM standard C856 on 11 of the core samples to determine a variety of characteristics for each, including an estimate of the water-to-cementitious materials ratio. The purpose of this analysis was to determine if early deterioration was caused by poor workmanship or the components within colored concrete.

Based on observations and knowledge from pavement experts, researchers recommended construction methods, mix designs, and repair and rehabilitation techniques for colored concrete.

What Did We Learn?
Researchers did not identify a conclusive reason for premature distress in colored concrete. High porosity caused by high water-to-cementitious materials ratio mixes was commonly found and thought to likely have increased the tendency toward reduced freeze-thaw durability of the mixes. The presence of magnesium from deicers in concrete pores may also be a cause, but the sample size was too small to confirm it as a definitive cause.
Researchers made several recommendations for improving the mix and construction of colored concrete. These include a maximum water-to-cementitious materials ratio of 0.43 for colored concrete placed in climates like Minnesota’s. Higher ratios correspond with higher porosity, which allows more moisture and deicing chemicals into the concrete and reduces its freeze-thaw resistance. Core samples from only one of the colored concrete sites tested had average water-to-cementitious materials values below 0.45. Researchers also recommended specifying a total air content in the mix of 7.0 percent before consolidation to create a well-distributed air void system. Laboratory testing suggested that the pigments used to color concrete have little impact on its freeze-thaw durability.

Several core samples showed evidence of chemical attack of the cement paste and fine aggregates, and alkali-silica reaction, which can cause cracking or spalling. Finding ASR was surprising since these mixes used the same aggregates as standard concrete, which does not typically develop ASR in Minnesota pavements.

Since colored concrete is typically used in relatively small areas, it is usually placed and formed without mechanical equipment. While construction techniques were not found to be the primary cause of concrete distress, researchers did make some construction recommendations. These include using mechanical vibration when possible to level and consolidate the concrete, making provisions for the difference in thermal expansion between different colored concrete mixes and devising improved methods for curing. Standard repair and rehabilitation techniques should work for colored concrete pavement. However, when damage is expansive or rapidly developing, full slab replacement is often the only viable option.

What’s Next?
The ready-mix colored concrete industry has recognized the seriousness of poor durability and is working to educate producers and placers about the need for proper mix design, placement techniques and curing procedures. Agencies considering the use of colored concrete should be careful to consider whether it can be produced and placed properly. Concrete stains, pavers or colored high-friction surface treatments may be appropriate alternatives to consider.

These research results were presented at the TERRA Pavement Conference, and a webinar is planned to help publicize this work.

Further research may be warranted to determine whether following best practices provides the expected improvement in colored concrete durability. It may also be worthwhile to investigate the cause of chemical attack that was discovered during this project.