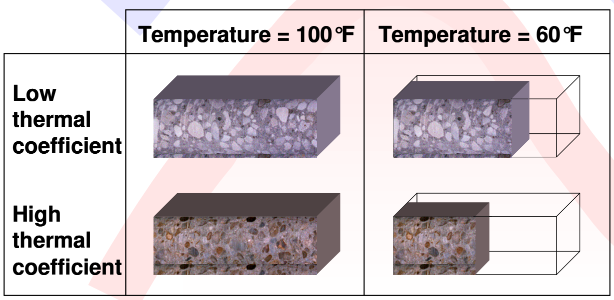
Case Study Topic: ***How would a change in aggregate type affect the probability of cracking under a specific set of climatic conditions?***

BACKGROUND

The aggregate property that has the most significant effect on early-age (and long term) pavement performance is its coefficient of thermal expansion (CTE). The aggregate contributes between 60-80% of the concrete by volume and, therefore, the concrete's CTE is predominantly affected by the CTE of the aggregate. The CTE provides an indication of how the volume of material will expand or contract when exposed to a change in temperature. The following figure provides an indication of the relative volume changes that concretes with different CTE's will experience while being exposed to a temperature drop.



The CTE is especially important for pavements placed in the summer season when temperature extremes are high, and when the peak ambient temperature may coincide with the peak heat of hydration (as in morning placements). Under such conditions, concrete pavements with a high CTE tend to have an increased probability of early-age cracking compared to a pavement constructed from coarse aggregate with a lower thermal coefficient.

The following table provides an indication of typical CTE values for selected aggregates.

Aggregate Type	CTE Range (με/°F)
Sandstone	4.4 - 7.2
Siliceous Gravel	3.9 - 6.7
Granite / Gneiss	3.3 - 5.6
Basalt	2.8 - 5.0
Limestone / Dolomite	2.2 - 4.4

The following scenario was selected for this case study. A contractor is experiencing an aggregate shortage. He can only get enough aggregate to complete the project by using aggregates from two different pits. The project will take about one year to complete. What would be the best time to use the aggregates form each pit? The aggregates from the two sources have the following properties:

→ Pit A, CTE = 4 microstrain/°F

→ Pit B, CTE = 8 microstrain/°F

A 9 inch thick jointed concrete pavement is to be constructed in an area where the summer air temperatures will vary between 65 and 95°F, and winter air temperatures between 45 and 75°F. Although unlikely, assume for the purpose of this case study that none of the other concrete mix properties or strengths, are affected by changing the aggregate type. The HIPERPAV default values may be assumed for all other inputs that are not affected by the change in air temperature or change in aggregate type.

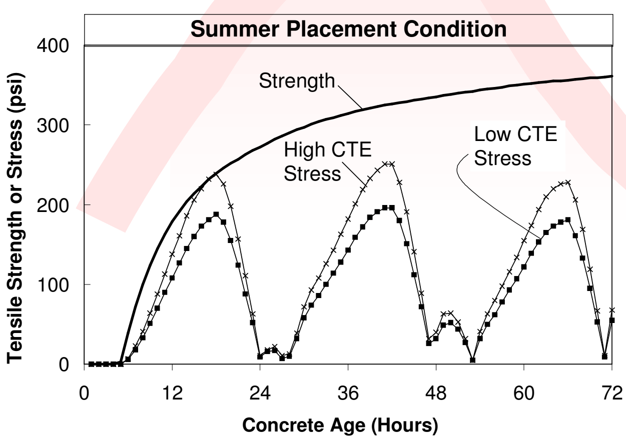
ANALYSIS STRATEGY

HIPERPAV can, with ease, be used to determine what impact a change in aggregate type will have on the probability that early-age cracking could occur. For each of the aggregate types, HIPERPAV analyses can be done under summer and winter conditions. The results of these analyses can then be compared to determine which aggregate type is best suited for each season. The concrete mix temperature and the subbase temperature are expected to change from summer to winter conditions.

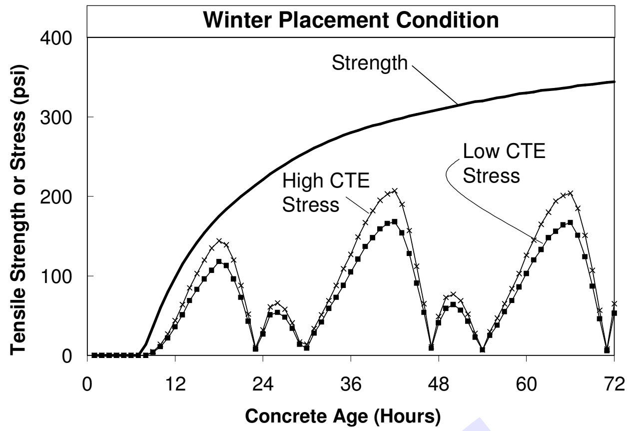
It is expected that use of the lower CTE aggregate will reduce the probability of early-age cracking under most conditions.

SOLUTION

HIPERPAV analyses were performed for each of the two aggregate pits; first under summer placement conditions. A mix temperature of 85ºF and a subbase temperature of 75°F were assumed. The results of this analysis can be seen in the following figure. The impact of a change in aggregate type can clearly be seen. Under the conditions analyzed the concrete with a high CTE aggregate (Pit B) is close to cracking, while the concrete with a low CTE aggregate (Pit A) still has some reserve strength.



The analyses performed above were now repeated, but for the winter placement conditions. A mix temperature of 65ºF and a subbase temperature of 55°F were assumed. The results of this analysis can be seen in the following figure. Winter placement conditions seem to be more favorable than summer conditions, because cracking is not expected to occur at a reliability of 90%. The stresses that develop in the pavement with a high CTE aggregate (Pit B) are higher than those expected to develop in the pavement constructed with a low CTE aggregate (Pit A).



From the results of these HIPERPAV analyses, it may be concluded that the probability of early-age cracking under high temperature conditions (summer) can be minimized by using low CTE aggregates (Pit A). Aggregates with a high CTE (Pit B) could be used during winter months with minimal risk.

The analysis performed in this section could be repeated for the conditions expected to occur in each month to obtain a better understanding of when to switch to the other pit. Under conditions where the daily temperature differential is the highest (cold front), the use of aggregates with a low CTE can be beneficial. In some parts of the country, autumn is often the season where large fluctuations in air temperatures occur. The use of aggregates from Pit A may be preferred during these periods.

The section paved with a low CTE aggregate should provide better long term performance, as lower tensile stresses due to thermal effects should develop. Therefore, if more aggregates of Pit A are available at no extra cost, they should be used all year round to improve the overall pavement performance.