Influence of curing on cold mix mechanical performance

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ABSTRACT
Cold mixes are evolutive materials, especially in their early life. Their initial cohesion is low and builds up gradually. The materials characteristics have to be evaluated at different states: fresh, mature, aged. An evaluation method is already available for fresh cold mixes. Ageing issues have been addressed elsewhere and are not dealt with here. Different curing procedures have been assessed and compared. Their goals are: laboratory curing must be related to field curing, the binder film must not be brought to an artificial state, no binder ageing must be caused by curing. Diverse curing sequences have been applied to grave-emulsion and dense wearing course mix. The effects of temperature, relative humidity and time have been evaluated. During each curing span, the mix moisture content has been monitored. The mechanical behaviour has been characterized by compressive strength and stiffness modulus (measured by indirect tensile testing). At the end of the varied curing periods, the bitumen was extracted and characterized. Special care has been taken in selecting the extraction method, to prevent any alteration of the bitumen. To establish a relationship between laboratory and field, the above results have been compared to those obtained on cores taken from similar mixes laid on roads. Finally, a new curing method has been selected and is proposed to road engineers.

1. INTRODUCTION
It is generally accepted that hot mix asphalt reaches its mature state after a very short period of time. Their characteristics are therefore measured almost immediately after manufacturing. For a number of reasons, the same approach cannot be applied to cold mix asphalt.

2. EVOLUTION OF COLD-MIX. THE CURING ISSUE
Cold mix can be obtained with two sorts of binder: emulsified - or cutback bitumen. Cutbacks are polluting, flammable and, in some instances, potentially explosive.
Emulsions are clearly preferable with regard to health, environment and safety. The following deals with materials in which emulsified bitumen has been incorporated.

2.1 Emulsion cold mixes are evolutive materials

Emulsion cold mixes behave in a peculiar way, especially during their early life. This peculiar behaviour results from the combination of several factors presence of water, aggregate-emulsion reactivity, binder film coalescence and cohesion build-up.

2.2 Need for accelerated curing

In the field, cold mixes reach their mature level of properties only after a period of time. In temperate climate and under medium traffic, at least one complete cycle of seasons is necessary for the mix to attain such stable condition. The curing time may be longer if the climate is cooler or more humid, the traffic lighter - and conversely.

Evaluating cured cold mixes in the laboratory is clearly necessary, but reproducing exactly field curing conditions is too complicated and, above all, time-consuming. An accelerated curing method is necessary. The requirement are:
- The curing procedure(s) should be as short as possible.
- It must produce materials in a state as close as possible to their in-place mature state.
- It must not cause any significant ageing of the bituminous binder.
- The laboratory equipment should not be too sophisticated.

3. THE DIFFERENT CURING SEQUENCES COMPARED

3.1 Temperature

The mix samples were placed in ovens regulated in temperature and humidity. Four temperatures have been tested, i.e.:
- \( \theta = 5^\circ C \) : lowest temperature to which a cold mix can be exposed after being laid.
- \( \theta = 18^\circ C \) : average temperature in many temperate regions, used as France standard temperature for hot and cold mix specimen curing.
- \( \theta = 35^\circ C \) : highest averaged temperature prevailing in pavement in temperate regions.
- \( \theta = 50^\circ C \) : highest temperature prevailing in mixtures in hot regions or hottest summers.

3.2 Humidity

At 5, 18 and 35°C, a comparison was made between dry or humid air draft. In addition, at 18°C, curing was also conducted in an oven regulated at 50% Relative Humidity (RH), so as to comply with the curing procedures of French Standard N° NF P 98-251-4.

At 35 and 50°C, curing experiments were also carried out as dry as possible. With the available equipment, the humidity target was 20% RH at 35°C and 10% RH at 50°C.

4. TYPES OF COLD MIX TESTED

Two main types of cold mix were subjected to curing sequences:
- "Reference GE": 0/14 mm grave-emulsion, made of semi-crushed alluvial aggregate, with 4.0% of 70/100 residual bitumen.
- "Reference cold mix AC": 0/10 mm dense-graded asphalt concrete made of crushed gneiss with 5.0% of 70/100 residual bitumen.

5. OVEN HUMIDITY - SPECIMEN BEHAVIOUR AND MOISTURE CONTENT

5.1 Air humidity in oven

The introduction of emulsion cold mix samples in the oven has always caused a significant increase in air humidity. As a typical example, when the oven was set at 35°C, 20% RH, the humidity rose to 75% immediately after the introduction of grave-emulsion samples having a moisture content of 5%. It then decreased rapidly, reaching 20% after 5 days. Similar observations were made in all cases, the humidity peak and decrease rate depending on the ratio of the fresh cold mix volume introduced over the oven volume. To avoid this humidity rise, one should place only a small quantity of mix in a large oven, which is practically unacceptable.

It has been established that, whatever the magnitude of the initial peak, the relative humidity becomes stable, near the set value, after a few days (3 to 7 for small samples - 7 to 14 days for large samples). Besides, it should be noted that, in the field, mixture moisture content does not drop sharply, but takes months to attain an equilibrium. Procedures implying the rise and fall of air humidity have therefore been accepted.

5.2 Specimen behaviour

The small specimens (i.e. regular and larger Duriez cylinders (ϕ 80 mm, h = 90 mm, weight 1 kg, ϕ 120 mm, h = 135 mm, weight 3.5 kg respectively) did not show any deterioration after any curing procedure. The large specimens (i.e. 1 = 180 mm, L = 500 mm, h = 50 or 100 mm, weight ~ 10 kg or 20 kg respectively) made for wheel-tracking tests or further coring) were affected by cracks when subjected to 50°C - 10% RH curing. (Nota: The set 10% RH could not be obtained with the ovens available containing wheel-tracking slabs; the humidity was near 20% after 5 days). This cracking has been attributed to shrinkage, caused by too fast a water evaporation (see below).

5.3 Moisture content

When the samples are being moulded, part of the water they contain is pushed out. It has been observed that the water loss due to sample compaction ranges, in the reference grave-emulsion, between 2.5 and 2.9% for Standard Duriez and Shear compactor, and between 1 and 1.2% for adapted Duriez and wheel-tracking slabs. For the reference cold-mix AC, the loss has been lower: e.g. 0.8% instead of 1-1.2% for adapted Duriez.