# Open-Graded Emulsion Mixes (OGEM)

### *Introduction*

OGEMS are prepared from medium-setting emulsions containing sufficient solvent to give deferred-set characteristics. Applications include base and surface courses on low volume roadways, patching, reinstatement, re-profiling and repair of shoulders. Depending on the choice of solvent in the medium-setting emulsions, the mixes may be laid immediately in mix-paving operations, laid a few hours after production or be stockpiled for weeks or months.

### *Design of Roads based on OGEM*

Experience in Scandinavia and North Western USA shows that OGEMs are flexible materials with slightly lower stiffness than an equivalent thickness of hot mix but which tolerate greater deflections and which give good resistance to cracking due to fatigue, reflection or thermal stresses. The conclusion is that a structural layer equivalency 0.85-1.0 times that for hot-laid asphalt concrete can be assumed in design calculations. Layer coefficients (a1) values 0.4-0.6 have been back-calculated from condition surveys, compared to 0.35-0.44 for dense-graded hot mix.

### *Aggregate Gradation and Asphalt Content*

A wide variety of gradations has been successfully used with open-graded emulsion mixes, with top sizes up to 75 mm *(3")*. Fines less than 75 micron are usually limited to 2% maximum and the sand equivalency (measure of clay content) should be preferably above 65. Air voids after compaction range from 15% for thin surfacings to 20-30% for base materials and thicker surface layers. Semi-dense mixes can be used with similar emulsion recipes and laying techniques provided the aggregate does not contain reactive fines. Semi-dense mixes are easier to seal than open-graded.

Typically mixtures of washed crusher dust and chippings or other washed materials (including sand) can be used. Crushed aggregates give the best interlock. AEMA recommends that the coarse aggregate should show Los Angeles abrasion values of <50% for base courses and <40% for surface courses, and also that 75% of the aggregate should have two or more fractured faces and >90% one or more.

The asphalt contents in the table are for guidance only. The main object in the mix design is to include as much asphalt as possible without run-off.

### *Design of Open-Graded Mixes*

Laboratory structural tests such as Marshall stability generally underestimate the performance of OGEMs. The design process is directed at finding the maximum film thickness of asphalt that can be achieved without run-off and ensuring good coating and water resistance.

***Typical Recipes For Open-Graded Emulsion Mixes***

| Sieve Size mm | Base | 20 mm Wearing Course | 10 mm Wearing Course | Semi-Dense Wearing Course |
|---|---|---|---|---|
| 38.1 | 100 | | | |
| 25.4 | 95-100 | 100 | | |
| 19.0 | -- | 90 - 100 | | 90-100 |
| 12.7 | 25-60 | -- | 100 | 75-95 |
| 9.5 | -- | 20 - 55 | 85-100 | 60-80 |
| 4.75 | 0-10 | 0 -10 | -- | 40-60 |
| 2.36 | 0-5 | 0 - 5 | 0-10 | 25-45 |
| 1.18 | -- | -- | 0-5 | 14-30 |
| 0.60 | -- | -- | -- | 8-18 |
| 0.30 | -- | -- | -- | 5-10 |
| 0.15 | -- | -- | -- | 3-8 |
| 0.075 | 0-2 | 0-2 | 0-2 | 2-5 |
| Binder | 2.7-4.0 | 3.8-4.8 | 3.6-4.8 | 3.8-4.6 |

The Centrifuge Kerosene Equivalent with SAE 10 oil (Kc) or a calculation based on aggregate grading can be used if necessary to give a starting point for the asphalt content.

Emulsion level = (Kc ( 1.5) + 3.5

Hand-mix tests using different asphalt emulsion formulas and different pre-wet water contents allow a recipe which gives good coating (close to 100% preferred for OGEMs) to be identified, and any unduly stiff mixes to be eliminated. To avoid excess drainage of emulsion, the water content should not exceed saturated-surface-dry (SSD).

The level of asphalt is increased until the drainage of emulsion from the uncompacted mix (e.g. as measured by the Chevron test) exceeds 0.5%. A higher drainage may be acceptable in mix-paving operations since the drained asphalt will help seal the underlying layer.

Some specifications demand early resistance to rain. In this case a wash-off test is required as soon as 15 minutes after compaction or after 24 hours curing. Less than 0.5% asphalt should wash off when 200 ml water is poured through a compacted specimen in a 4" mold.

A boiling-stripping test is used for a test of compatibility between emulsion and aggregate. 100 g of uncompacted mix is fully cured in an oven at 60°C (140°F) overnight, then placed in 400 ml vigorously-boiling water for 3 minutes, before re-estimating coverage. It should be >85%. An antistripping agent may be incorporated in the emulsion to help adhesion.

### *Emulsion Recipes*

Typical emulsions meet specifications for cationic medium-set emulsions. Slower-setting emulsions based on Redicote E-250 are suitable for semi-dense mixes and allow some reduction in solvent content, when a long stockpile life is not required.

| | | | |
|---|---|---|---|
| *Asphalt* | 65 minimum | 65 minimum | 65 minimum |
| *Solvent* | 10-15 | 5-15 | 5-15 |
| *Redicote E-4819* | 0.35-0.8 | 0.3-0.5 | -- |
| *Redicote E-5* | -- | 0.3-0.5 | -- |
| *Redicote E-250* | -- | -- | 0.6-1.2 |
| *HCl (33%)* | 0.25-0.4 | 0.25-0.35 | 0.02 |
| *$CaCl_2$* | 0.1 | -- | -- |
| *Water phase pH* | 2.0-4.0 | 2.5-4.0 | 5-7 |
| *Water* | To 100 | To 100 | To 100 |

The viscosity grade of the base asphalt should be chosen to suit the local climate. Typically 70/90 or 80/100 penetration grades (AC-20 or AC-5) are used, but the binder will remain softer until all the solvent has evaporated, which may take years. Studies in Northwest U.S.A. have shown that residual binders on the roadway softer than AC-20 give more durable surfaces.

The solvent in the emulsion provides extended workability and the ability to stockpile. It can be added to the binder or water phase or to the hot emulsion as it exits the colloid mill. More volatile solvents give shorter stockpile life but faster cure. The choice of solvent depends on the local climatic conditions and the required stockpile life. A heavy flux may be used in cold regions to provide a permanently soft binder (approximately 5000-10,000 cSt at 60°C) which gives a flexible road resistant to frost heave damage.

### *Manufacturing the Mix*

Simple mixers like concrete mixers or pug mills are suitable. It is even possible to hand-mix small quantities or to use a front-end loader on small stockpiles. Central mix plants equipped with two or more bins for different size fractions are preferred for consistent quality. Mobile mix pavers are also suitable.

Very dry aggregate should be pre-wetted to approximately 1% moisture before adding emulsion but excess water should be avoided because it is the primary cause of emulsion run-off. The mix should leave the mixer still dark-brown but virtually fully-coated, although a few uncoated larger particles are acceptable.

Water will run off the stockpile as the emulsion breaks. Some emulsion run-off is acceptable but it should be light-brown. The mix should be stockpiled for a few hours or days (depending on the cutter) before use. For extended storage life the stockpile should be covered.

***Laying the Mixtures***

The mixtures can be laid by hand, with a paver or with a grader depending on application. Underlying bituminous surfaces should normally be tack-coated; unbound materials should be prime-coated.

Compaction can be by plate compactor or any type of roller used for hot mixes but steel rollers stick less. The roller needs to be wetted to prevent sticking. Vibration is not usually advised. Some wash-off of emulsion may occur in heavy rain but usually this is not severe. The surface of each layer of the mixture is preferably spread evenly with coarse sand or "hokestone") at 3-6 kg/m$^2$ and compacted (trafficking may be sufficient). This especially helps to tighten the surface if a seal coat is planned.

The finished job can be sealed if necessary after about 6 months when most of the solvent has evaporated, but OGEMs can give good performance as wearing courses without sealing. If the surface is not to be sealed then the underlying surface below the OGEM must be sealed by a tack coat or prime coat.

*References*


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