Design of SMA - 13 asphalt mixture ratio on Z3 and Z18 of the capital airport

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Abstract. According to the demand of T2 terminal airlines to operate A380 models, to meet the smooth running of the A380 airliner at the west end of the Capital Airport, So Z3 and Z18 taxiway area of the transformation is imperative. According to the design, the upper layer of this project adopts SMA - 13 modified asphalt mastic macadam mixture. We design the SMA-13 modified asphalt mixture on Z3 and Z18 of the capital airport from any respects, including coarse and fine aggregate, filler, asphalt, fiber and anti-rutting agent, and we hope we can find the best SMA-13 modified asphalt mixture.

1. Introduction
According to the demand of T2 terminal airlines to operate A380 models, to meet the smooth running of the A380 airliner at the west end of the Capital Airport, So Z3 and Z18 taxiway area of the transformation is imperative. According to the design, we need design the SMA-13 modified asphalt mixture.

2. Raw materials

2.1. Asphalt
We use shell high modulus asphalt. We test its performance indicators, we put the results on the below table.

| Test items                        | Technical requirements | Test results |
|-----------------------------------|------------------------|--------------|
| Softening point(℃)               | ≥80                    | 93.1         |
| Penetration(25℃,100g,5s)(0.1mm)  | ≤50                    | 43.4         |
| Ductility(5cm/min,10℃)(cm)       | ≥40                    | 57.4         |
| Filmy heating operational test163℃/5h  | Mass loss(%)          | <1           | -0.04        |
|                                   | Penetration ratio(%)   | ≥60          | 75.6         |
|                                   | Ductility(10℃)(cm)    | ≥30          | 40.8         |
|                                   | Flash point(COC)(℃)   | ≥250         | 277          |
|                                   | Elastic recovery(15℃)  | ≥80          | 92.3         |
From the results, it appears that all the performance indicators meet the technical requirements, we can use this asphalt.

2.2. Coarse aggregate and fine aggregate

(1) Coarse aggregate

There are basalt coarse aggregates (10~15mm, 5~10mm) and limestone (3~5mm) aggregates. We tested the aggregate indexes in accordance with the relevant regulations, the test results are shown on the table below.

**Table 2** The Coarse aggregate technical indicators

| Aggregate size | Test results | Test items          |
|----------------|--------------|---------------------|
| 10~15mm        | 2.813        | Bulk specific gravity |
| 5~10mm         | 2.770        |                      |
| 3~5mm          | 2.715        |                      |
| 10~15mm        | 2.935        | Apparent specific gravity |
| 5~10mm         | 2.918        |                      |
| 3~5mm          | 2.805        |                      |

From The Results, It Appears The Bulk Specific Gravity And The Apparent Specific Gravity All Meet The Technical Requirements, We Can Use Them In The Project.

**Table 3** The Coarse aggregate Particle gradation

| mesh (mm) | \( P(\%) \) | 10~15mm | 5~10mm | 3~5mm |
|-----------|------------|---------|---------|-------|
|           | Technical requirements | Test results | Technical requirements | Test results | Technical requirements | Test results |
| 16        | —          | 100     | —       | —     |
| 13.2      | 95~100    | 80.4    | 100     | 100   | —     |
| 9.5       | 0~15      | 35.5    | 95~100  | 94.6  | 100   | 100 |
| 4.75      | 0~5       | 0.8     | 0~10    | 12.0  | 85~100| 99.7|
| 2.36      | —         | 0       | 0~5     | 0.8   | 0~25  | 30.5|
| 1.18      | —         | 0       | —       | 0.6   | —     | 4.2 |
| 0.6       | —         | 0       | —       | 0~5   | 2.2   |     |
| 0.3       | —         | 0       | —       | 1.6   | 2.0   |     |
| 0.15      | —         | 0       | —       | 1.4   | 2.0   |     |
| 0.075     | —         | 0       | —       | 0     | —     | 2.0 |

From the results, it appears that the 13.2mm and 9.5mm passing rate of 10~15mm, the 9.5mm and 4.75mm passing rate of 5~10mm and the 4.75mm and 2.36mm passing rate of 3~5mm can not meet the technical requirements. So we suggest that We should screen 10~15mm, 5~10mm and 3~5mm until the passing rate meet technical requirements.

(2) Fine aggregate

We use 0-3mm fine aggregate, we test their performance indicators, and put them on the below table
Table 4 The Basalt FINE aggregate Particle gradation

| mesh (mm) | P(%) | Technical requirements | Test results |
|----------|------|------------------------|--------------|
| 4.75     | 100  | 100                    |              |
| 2.36     | 85−100 | 87.6                |              |
| 1.18     |      | 60.4                  |              |
| 0.6      | 20−50 | 42.4                  |              |
| 0.3      |      | 30.2                  |              |
| 0.15     |      | 25.7                  |              |
| 0.075    | 0−15  | 21.2                  |              |

From the results, it appears that the 0.6mm and 0.15mm passing rate of 0−3mm can not meet the technical requirements. So we suggest that We should screen 0−3mm until the passing rate meet technical requirements.

2.3. Filler
We use the limestone powder filler, we test its performance indicators, we put the results on the table 5.

Table 5 The Mineral filler technical indicators

| Test items                      | Technical requirements | Test results |
|---------------------------------|------------------------|--------------|
| Hydrophilic coefficient         | ≤1                     | 0.7          |
| Particle gradation              |                        |              |
| <0.6mm                          | 100                    | 99.6         |
| <0.15mm                         | 90−100                 | 96.5         |
| <0.075mm                        | 75−100                 | 83.9         |
| Apparent specific gravity(g/cm³)| ≥2.50                  | 2.774        |
| Water content(%)                | ≤1                     | 0.14         |

From the results, it appears that all the performance indicators meet the technical requirements, we can use this filler.

2.4. Fiber
We use polyacrylonitrile fiber to test, its main technical indicators are shown in table 6.

Table 6 polyacrylonitrile fiber test results

| Test items              | Technical requirements | Test results |
|-------------------------|------------------------|--------------|
| Diameter(µm)            | 10−25                  | 12.7         |
| Length(mm)              | 6±1.5                  | 6.0          |
| Tensile strength(MPa)   | ≥500                   | 522          |
| Elongation at break(%)  | ≥15                    | 17.5         |

From the chart, we can see all the indicators of polyacrylonitrile fiber meet the specification requirements, and it can be used in the design and engineering.
2.5. Anti-rutting agent
We use haichuan Anti-rutting agent, through results, Adding 0.5% anti-rutting agent of the asphalt mixture we can achieve the best test results. We test its performance indicators, we put the results on the below table.

**Table 7** Anti rutting agent basic indexes test results

| Test items                      | Technical requirements | Test results |
|--------------------------------|------------------------|--------------|
| Density (g/cm³)                | 0.9~1.1                | 0.92         |
| Melt flow rate(190 °C,2.16kg)/(g/10min) | ≥3                     | 7            |
| Water content(%)               | ≤2                     | 0.5          |
| Softening point(°C)            | 110~150°C              | 140          |

From the results, it appears that all the performance indicators meet the technical requirements, we can use haichuan Anti-rutting agent.

3. Mix design of SMA-13 asphalt mixture

3.1. The determination of aggregate gradation ratio
The aggregate gradation ratio of SMA-13 asphalt mixture is formed with five different raw materials. We choose three mix designs. All the mix designs and raw materials are put on the below table.

**Table 8** SMA-13 ratio of mineral aggregate gradation(%)

| Specifications       | 10~15mm | 5~10mm | 3~5mm | 0~3mm | filler |
|----------------------|---------|--------|-------|-------|--------|
| Coarse gradation     | 52      | 26     | 4     | 7     | 11     |
| Middle gradation     | 51      | 25     | 6     | 7     | 11     |
| Fine gradation       | 50      | 24     | 7     | 8     | 11     |

**Table 9** SMA-13 mineral synthesis aggregate gradation

| Mesh size(mm) | coarse | middle | fine | upper | lower |
|---------------|--------|--------|------|-------|-------|
| 26            | 100.0  | 100.0  | 100.0| 100   | 100   |
| 19            | 100.0  | 100.0  | 100.0| 100   | 100   |
| 16            | 100.0  | 100.0  | 100.0| 100   | 100   |
| 13.2          | 89.9   | 90.1   | 90.3 | 100   | 90    |
| 9.5           | 65.1   | 65.8   | 66.5 | 65    | 45    |
| 4.75          | 25.6   | 27.5   | 29.3 | 34    | 22    |
| 2.36          | 18.6   | 19.2   | 20.3 | 27    | 18    |
| 1.18          | 15.6   | 15.6   | 16.3 | 22    | 14    |
| 0.6           | 14.0   | 14.1   | 14.5 | 19    | 12    |
| 0.3           | 13.1   | 13.1   | 13.5 | 16    | 10    |
| 0.15          | 12.5   | 12.6   | 12.8 | 14    | 9     |
| 0.075         | 10.7   | 10.7   | 11.0 | 12    | 8     |
Figure I. SMA-13 grading curve

Content of coarse aggregate P<sub>CA</sub> and Clearance rate VCA<sub>DRC</sub> of more than 4.75mm in three mixtures are tested in table 10.

Table 10 The Marshall test results of different asphalt aggregate ratio

| items     | loose unit weight(g/cm³) | the passing rate of 4.75 mm(%) | bulk specific gravity of above4.75mm(g/cm³) | P<sub>CA</sub> | VCA<sub>DRC</sub> |
|-----------|--------------------------|--------------------------------|--------------------------------------------|--------------|------------------|
| coarse    | 1.622                    | 25.6                           | 2.818                                      | 0.702        | 42.44            |
| middle    | 1.630                    | 27.5                           | 2.810                                      | 0.684        | 41.99            |
| fine      | 1.636                    | 29.3                           | 2.804                                      | 0.667        | 41.66            |

Based on the experience of previous similar airport engineering, we use ratio of 6.0% as a first try oil-stone ratio in Marshall design method, and then mold specimens in accordance with the specification requirements, measure the physical indexes of the specimens. Specific data are shown in table 11.

Table 11 Performance of the first grading

| Test items            | Coarse gradation | Middle gradation | Fine gradation |
|-----------------------|------------------|------------------|----------------|
| Bulk specific gravity(g/cm³) | 2.446            | 2.452            | 2.470          |
| Theoretical density(g/cm³)  | 2.583            | 2.582            | 2.581          |
| VV(%)                 | 5.31             | 5.03             | 4.31           |
| VMA(%)                | 17.5             | 17.4             | 16.8           |
| VFA(%)                | 69.7             | 71.0             | 74.2           |
| VCA<sub>mix</sub>(%)  | 39.08            | 40.32            | 41.25          |
| VCA<sub>DRC</sub>(%) | 42.44            | 41.99            | 41.66          |
| MS(KN)                | 9.38             | 9.12             | 9.93           |
| FL(0.1mm)             | 32.5             | 24.0             | 28.8           |

According to the relevant specifications, the fine grading is the best grading.
3.2. *The determination of the optimum proportion*
We select 3 asphalt aggregate ratio of Marshall test and calculate their physical indicators in order to determine the optimum proportion, the test results are shown in the table 12.

| Test items                      | oil-stone ratio(%) | Specification requirements |
|--------------------------------|-------------------|---------------------------|
| Bulk specific gravity(g/cm³)   | 2.467             | 2.474                     | 2.481 | —       |
| Theoretical density(g/cm³)     | 2.593             | 2.581                     | 2.570 | —       |
| VV(%)                          | 4.85              | 4.14                      | 3.47  | 3~5     |
| VMA(%)                         | 16.6              | 16.6                      | 16.6  | ≥16.5   |
| VFA(%)                         | 70.9              | 75.1                      | 79.1  | —       |
| VCA(%)                         | 41.15             | 41.14                     | 41.15 | ≤VCA_DRC|
| VCA_DRC(%)                     | 41.66             | 41.66                     | 41.66 | —       |
| MS(KN)                         | 9.67              | 9.04                      | 11.05 | ≥6      |
| FL(0.1mm)                      | 25.9              | 25.6                      | 28.5  | —       |

According to the requirements of the relevant specification, calculated the optimum proportion of 6.0%.

3.3. *The optimum proportion of validation*
In the optimum asphalt aggregate ratio of 6.0%, we make Marshall specimen and the dynamic stability of specimen, then test their Physical and mechanical performance. We put the results on the below table.

| Test items     | Test results |
|----------------|--------------|
| △M(%)          | 0.05         |
| △S(%)          | 1.9          |
| DS(time/mm)    | 10002        |
| MSo(%)         | 92.3         |
| TSR(%)         | 86.1         |
| Cw(mL/min)     | 21           |
| TD(mm)         | 0.84         |

From the results, it appears that all the test results can meet the requirements of related technologies.
4. Conclusion
If we want to design the best SMA-13 modified asphalt mixture, we should achieve these important ways.

First: Starting from the raw material, we should choose the qualified raw materials.
Second: we should choose good aggregate gradation.
Third: In order to obviously improve the dynamic stability of mixture, it is reasonable to adding anti-rutting agent.

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