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# Laboratory investigation on the use of recycled fillers in improving the performance of Stone Mastic Asphalt (SMA)

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**ABSTRACT:** The present research was conducted with the aim of investigating the effect of the type of filler on the mechanical properties of the stone mastic asphalt (SMA). For this purpose, five types of fillers, including silica filler (SF) as the base filler in the control sample, Portland cement (OPC) and limestone powder (LSP) as common fillers, and recycled glass powder (RGP) and calcium carbide waste (CCR) as recycled fillers, were used in their pure form or combined with each other. In order to investigate the resistance of the samples against rutting, the Marshall test was used to obtain the Marshall strength (MS) and especially the Marshall coefficient (MQ). Also, resistance to cracking and moisture sensitivity was also evaluated by performing the Indirect Tensile Strength (ITS) test in dry and saturated conditions and obtaining the Tensile Strength Ratio (TSR). The results have shown that the samples containing recycled fillers had the best performance in improving the properties of SMA asphalt. such that the use of the combination of recycled fillers, in addition to improving the properties of SMA compared to samples containing silica fillers, The values of MS, MQ, ITS, and TSR have increased by 36, 19, 24, and 31%, respectively, compared to the best results obtained using common fillers (OPC or LSP). Therefore, the use of RGP and CCR compounds as fillers in SMA asphalt, in addition to helping to protect the environment, and natural resources, and economic savings, can also be technically very effective in improving the service life of asphalt mixtures.

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## 1- Introduction

Due to high annual costs in producing asphalt mixtures, pavement maintenance, and rehabilitation, as well as the inability of produced binders to fulfill durability, ductility, resistance to rutting, fatigue cracks and freeze and thaw cycles, moisture and other requirements; pavement engineers aim to improve the engineering properties of asphalt mixtures using various additives. Up to this time besides the common fillers like limestone and siliceous powder as well as lime and cement; the application of recycled fillers such as glass powder [1-3], hydrated lime[4], rice husk ash[2, 5], recycled brick powder [6], carbide lime[1-3], Nanomaterial[7], waste copper mines[2], fly ash[5], have been addressed. Recycled Glass Powder (RGP) and Calcium Carbide Residue (CCR) have positive impacts in improving the mechanical properties of asphalt mixtures. In this research, the Indirect Tensile Strength (ITS) and moisture susceptibility of Stone Mastic Asphalt (SMA) were studied. Various common fillers such as siliceous filler (SF), Limestone powder (LSF), Ordinary Portland Cement (OPC), and recycled fillers including RGP and CCR were investigated.

The aim of this research was to consider the possibility of utilizing these recycled fillers and introducing a new combination to improve the properties of SMA mixtures, besides the economic and environmental aspects. In this regard, Marshall Stability, flow, and ITS tests in dry and saturated conditions were done.

## 2- Test materials and methods

Materials used in this study were: limestone aggregates, 60-70 bitumen from Isfahan, Iran, various fillers including siliceous and Limestone powder, Portland cement, RGP, and CCR.

SMA Marshall Samples were constructed according to ASTM D6926 and they were compacted using 56 blows of Marshall Hammer based on heavy traffic requirements. Table 1 shows filler combinations in different control and modified samples and optimum asphalt content.

## 3- Results and Discussion

The obtained results are summarized in Table 2.

These results were the average of three prepared samples for each filler combination. As it can be seen from Table 2, the highest Marshall stability and Marshall Coefficient (stability divided by flow) belong to samples with recycled fillers. Based on the obtained results in Table 2; the incorporation 40% RGP

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**Table 1. Nomenclature details and contents of samples**

| Tests | Optimum Bitumen Content (%) | Amount of filler (%) | Type and percentage of fillers mixing (%) | | | | | sample code | Sample name |
|---|---|---|---|---|---|---|---|---|---|
| | | | RGP | CCR | OPC | LSP | SF | | |
| MS, $ITS_{uncond}$*, $ITS_{cond}$** | 6% | 9% | 0 | 0 | 0 | 0 | 100 | 1 | control |
| MS, $ITS_{uncond}$, $ITS_{cond}$ | 6% | 9% | 0 | 0 | 0 | 100 | 0 | 1 | main |
| MS, $ITS_{uncond}$, $ITS_{cond}$ | 6% | 9% | 0 | 0 | 100 | 0 | 0 | 2 | main |
| MS, $ITS_{uncond}$, $ITS_{cond}$ | 6% | 9% | 0 | 50 | 50 | 0 | 0 | 111 | main |
| MS, $ITS_{uncond}$, $ITS_{cond}$ | 6% | 9% | 0 | 50 | 0 | 50 | 0 | 112 | main |
| MS, $ITS_{uncond}$, $ITS_{cond}$ | 6% | 9% | 50 | 0 | 50 | 0 | 0 | 113 | main |
| MS, $ITS_{uncond}$, $ITS_{cond}$ | 6% | 9% | 50 | 0 | 0 | 50 | 0 | 114 | main |
| MS, $ITS_{uncond}$, $ITS_{cond}$ | 6% | 9% | 20 | 80 | 0 | 0 | 0 | 115 | main |
| MS, $ITS_{uncond}$, $ITS_{cond}$ | 6% | 9% | 25 | 25 | 50 | 0 | 0 | 116 | main |
| MS, $ITS_{uncond}$, $ITS_{cond}$ | 6% | 9% | 40 | 60 | 0 | 0 | 0 | 117 | main |
| MS, $ITS_{uncond}$, $ITS_{cond}$ | 6% | 9% | 25 | 25 | 0 | 50 | 0 | 118 | main |
| MS, $ITS_{uncond}$, $ITS_{cond}$ | 6% | 9% | 60 | 40 | 0 | 0 | 0 | 119 | main |
| MS, $ITS_{uncond}$, $ITS_{cond}$ | 6% | 9% | 80 | 20 | 0 | 0 | 0 | 120 | main |
| MS, $ITS_{uncond}$, $ITS_{cond}$ | 6% | 9% | 100 | 0 | 0 | 0 | 0 | 121 | main |
| MS, $ITS_{uncond}$, $ITS_{cond}$ | 6% | 9% | 0 | 100 | 0 | 0 | 0 | 122 | main |

*Unconditioned Indirect tensile strength (in dry state).
**Conditioned Indirect tensile strength (in saturated state).

**Table 2. The results of th tests**

| Sample name | Code | Filler composition (%) | MS (kgf) | MQ (kgf/mm) | ITS $_{uncond*}$ (KPa) | TSR |
|---|---|---|---|---|---|---|
| Control | 1 | 100SF | 590 | 144 | 1493 | 0.56 |
| Improved | 1 | 100LSP | 708 | 148 | 1789 | 0.64 |
| Improved | 2 | 100OPC | 723 | 150 | 1718 | 0.62 |
| Improved | 111 | 50OPC+50CCR | 761 | 146 | 1886 | 0.7 |
| Improved | 112 | 50LSP+50CCR | 762 | 156 | 1881 | 0.73 |
| Improved | 113 | 50OPC+50RGP | 705 | 144 | 1941 | 0.65 |
| Improved | 114 | 50LSP+50RGP | 706 | 139 | 1846 | 0.76 |
| Improved | 115 | 80CCR+20RGP | 832 | 179 | 1741 | 0.8 |
| Improved | 116 | 50OPC+25CCR+25RGP | 807 | 150 | 1782 | 0.76 |
| Improved | 117 | 60CCR+40RGP | 863 | 204 | 1904 | 0.84 |
| Improved | 118 | 50LSP+25CCR+25RGP | 779 | 164 | 1884 | 0.78 |
| Improved | 119 | 40CCR+60RGP | 737 | 176 | 1920 | 0.77 |
| Improved | 120 | 20CCR+80RGP | 747 | 166 | 2216 | 0.73 |
| Improved | 121 | 100RGP | 742 | 149 | 1928 | 0.69 |
| Improved | 122 | 100CCR | 820 | 146 | 1867 | 0.7 |

*Unconditioned

and 60% CCR (60CCR+40RGP), leads to maximum Marshall Stability and Marshall Coefficient. RGP has angular particles compared to other fillers which produce better internal friction and interlocks [1, 2]. Increased stability in CCR samples is related to both physical and chemical properties. From the physical point of view, CCR has a textured surface which leads to better adhesion to bitumen and increases the consistency of the mastic. From the chemical point of view, due to the high PH of CCR and the relatively acidic property of binder, these materials bind well together and contribute to asphalt mixture stiffness [1-3].

Due to the different properties of these two fillers, the combination of these materials provides both the particle shape and surface texture properties. In addition, the highest dry and saturated ITS values and the resulting TSR belong to recycled fillers. Replacing LSP and OPC by RGP and CCR leads to considerably increased ITS and TSR values. The highest dry and saturated ITS values were seen in 20CCR+80RGP and the highest TSR was seen 60CCR+40RGP. The improved performance of CCR (compared to RGP) in the presence of water, is related to the presence of insoluble minerals such as Pentlandite, Calcite, and dolomite [1, 2].

Furthermore, the textured surface of CCR and better adhesion of the binder results in improved performance against moisture [8]. Therefore, according to the above, some proportions of CCR (60 to 80 percent) and 20 to 40 percent of RGP can be used as the optimum combinations to illustrate the superior performance in terms of MQ, ITS, and TSR characteristics.

## 4- Conclusion

Incorporating recycled fillers increases the Marshall Stability, Marshall Coefficient (MQ), indirect tensile strength (in both dry and saturated conditions) as well as TSR values compared to control samples. Improved TSR values indicated reduced temperature susceptibility which in turn results in increased operational life and durability.

Samples with the combined effect of CCR and RGP (60-80% CCR); exhibit the best performance in terms of Marshall Stability, MQ, ITS, and TSR. Incorporating these recycled fillers helps in improving the mechanical properties of asphalt mixtures as well as reducing environmental damage and protecting non-renewable natural resources.

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