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Influence of warm mix asphalt technology on asphalt physical and mechanical properties

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HIGHLIGHTS

- WMA technologies allows to lower the HMA mixing and working temperature by 30 °C.
- The physical and mechanical properties of WMA reach the same level as HMA.
- Required amount of additive vary from 0.3 to 2.0 of amount of binder.

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ABSTRACT

With increasing concerns of global warming and increasing exhaustion of greenhouse gases, the asphalt industry is looking for alternatives of hot mix asphalt (HMA). Reasonable solution is a use of warm mix asphalt (WMA) technologies, which allows to reduce asphalt mixing and working temperatures. The advantages of WMA are reduced energy consumption, reduced emissions and improved workability. This article presents the overview of different WMA production technologies, advantages and disadvantages of these technologies. Water bearing, chemical and organic additives were used for WMA production and temperature of produced asphalt varied from 150 °C to 120 °C. Results of experiment for selection of optimal amount of temperature lowering additives and their influence to physical mechanical characteristics of asphalt mix are presented too.

1. Introduction

The technological improvements are being explored in the asphalt industry for the last years. It will allow to reduce high asphalt mix production temperatures. However, it does not change asphalt mix workability and physical mechanical properties [1–3]. The production of warm mix asphalts and half-warm mix asphalts is one of the attempts to reduce pollution and to use another lower temperature asphalt mix benefits [1,4–5].

Asphalt mixtures, according to their mixing temperature and energy consumed for the heating process of materials, are divided into [6]:

- Cold mix asphalt (CMA), asphalt mixture produced at ambient temperature using bitumen emulsion or foam;
- Half warm mix asphalt (HWMA), asphalt mixture produced at a temperature below water vaporization;
- Warm mix asphalt (WMA), asphalt mixture produced at a temperature range from 120 °C to 140 °C;
- Hot mix asphalt (HMA), asphalt mixture produced at a temperature range from 150 °C to 180 °C in relation with the used binder.

WMA is a modified hot mix asphalt mixture that is produced, placed and compacted at a 10–40 °C lower temperature than the conventional hot mix asphalt mixture. WMA is described as the asphalt mixture produced at 20–40 °C lower temperatures than the hot mix asphalt but at a higher temperature than the water boiling temperature [1,7–8].

When asphalt is produced at lower temperatures, there are many potential benefits as: reduced energy consumption (fuel) in

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asphalt plant and reduced noxious gases emissions; increased safety of workers due to reduction of smoke emissions; possibility to place asphalt mix in cooler ambient temperatures and to haul further distances without compromising workability [9].

WMA fundamentally does not differ from HMA. It still comprises of aggregates and asphalt binder that are heated to obtain the proper mixing and workability. However, the difference specifically lies in the temperature used to obtain proper mixing and workability.

There are numerous of WMA technologies around the world. However, the number of tests has been done using various methods. On the basis of the main researches done so far and their findings, it appears secure to state that the quality of WMA is comparable to hot mix asphalt in most of the ways. However, it is only about from five to ten years (depending on method) since the earliest WMA field tests were started. Therefore, this long-term performance is still unproven. A pavement can exist from fifteen to twenty years or longer. Hence, there is still some time before effect of WMA on the pavement's service life will be fully known [10].

2. Warm mix asphalt technologies

WMA has been described as a group of technologies that allows reduction in the temperatures at which asphalt mixtures are produced and placed. There are many different processes and products that could be used to achieve this reduction in temperature, but, generally, WMA technologies are separated into four categories [11]:

1. Water based processes, the non-additive processes based on foaming. Bitumen foam is caused by spraying water into the heated bitumen (175–180 °C) or by adding moist sand (fine mineral particles) into asphalt mixture. The foam ensures sufficient coating of the asphalt binder and aggregate that makes asphalt mix workable. WAM-Foam, Terex WMA System, Double Barrel Green; LEA – Low Energy Asphalt, Ultrafoam GX;
2. Water bearing additives are natural and synthetic zeolites also based on foaming. The foam is caused by adding natural or synthetic zeolite into the asphalt mixture during asphalt production. When zeolite is added to the mix at the same time as the binder, water entrapped in this mineral structure is released. This water release creates foaming of the asphalt binder. Thereby, it temporarily increases workability and enhances aggregate coating at lower temperatures. Aspha Min is synthetic zeolite. Advera WMA Zeolite is synthetic zeolite and natural zeolite;
3. Organic additives are wax additives as Fischer Tropsch, Montan waxes and fatty acid amides. These organic waxes have longer chemical chain lengths, thus, their melting point is at about 100 °C. The longer chains help to keep the wax in solution and they reduce binder viscosity at typical asphalt production and compaction temperatures. The use of organic additives allows asphalt mix production and laying temperatures to be reduced by 20–30 °C. Sasobit®, Ashphaltan B, Licomont BS 100;
4. Chemical additives change asphalt binder structure and reduce viscosity that allow to reduce asphalt mix producing and laying temperatures about 40 °C. Iterlow T, Cecabase.

Numerous of experimental laboratory researches have been carried out using different warm mix asphalt technologies in recent years. Gaudefroy et al. [12] summarized information about the influence of total organic compounds emissions by using the low-emission asphalt (LEA®) technology for WMA production. WMA with Cecabase temperature lowering technology was compared to traditional HMA by Gonzalez et al. [13]. Energy and reduction of emission, the possibility to use reclaimed asphalt (RAP), increased haul distances and cold weather paving benefits were summarized by him. Nejad et al. [4] determined that rutting properties of the asphalt mixtures replacing up to 60% of the virgin aggregate with RAP could be improved, but too much RAP in asphalt mixtures could increase moisture sensitivity. It was found that the optimal replacement of RAP level is 50%. Zelelew et al. [1] analyzed Sasobit® additive impact on WMA rutting and fatigue cracking parameters. It was found that the asphalt binder containing Sasobit® increase the high-temperature binder grade by 6 °C. Equally, WMA with Sasobit® demonstrate better resistance to rutting and moisture damage comparing to traditional HMA. Wax modified bitumen research has been studied by Metzker and Witsuba [14]. Silva et al. (2009) [15] analyzed Sasobit® and Cecabase usage in WMA mixes. It has been summarized that temperature reductions, used on site, have been overestimated, leaving some concerns about it. In order to obtain the adequate results with WMA mixtures, it is essential to have narrow control of the production temperature in the plant. China experience using WMA with Sasobit® and Rediset has showed relatively best performances in areas, where rutting and stripping are the main failures of asphalt pavements [2]. Soenen et al. [16] studied foamed bitumen in half-warm asphalt mixes. Su et al. [17] determined that WMA mixtures produced with special temperature lowering wax (made by Japanese company) at the temperatures 30 °C lower than traditional HMA are suitable for use in pavement rehabilitation of an airport. However, the identical WMA mixture produced at 50 °C lower temperatures cannot be accepted due to poor tests results. Liu et al. [3] analyzed the performance of WMA with polyphosphoric acid (PPA). It has been found that WMA containing 1.5% PPA achieves good intermediate and high temperature rheological properties. Xiao et al. [18] researched fatigue behavior of rubberized asphalt concrete mixtures containing WMA additives. He indicated that the addition of crumb rubber and WMA additive (Aspha Min and Sasobit®) in asphalt mix reduce mixing and compacting temperatures and it effectively extends the long-term performance of pavement compared to traditional HMA mixture. Midrange temperature rheological properties of WMA binders were investigated by Biro et al. [19].

WMA mixtures have also been investigated in Lithuania recently. Vaitkus et al. [6,20] summarized the use of warm mix asphalt mixes in Lithuania roads. Compaction properties of WMA were investigated by Vaitkus et al. [21] also. It has been determined that the optimal reduction of hot mix asphalt working temperature, when using synthetic additive Iterlow T, is 30 °C. In addition, that warm mix asphalt concrete with Iterlow T compaction level of 97% has been reached after four–five passes of roller with static load. With increasing HMA mixture output in Lithuania the possibility on the use of WMA increases as well. According to Sivilevicius and Sukevicius [22], HMA mixture output in Lithuania has increased twice (from 0.8 million tons in 1998–2001 to 1.7 million tons in 2006–2008). Numerous of temperature asphalt mix benefits can be attained by using WMA instead of HMA. Thus, there is a demand on more warm mix asphalt researches in Lithuania in order to determine the optimal WMA technology or additive that is the most suitable for this region.

3. Advantages and disadvantages of WMA

The major advantages of WMA are related to the lower viscosity of the asphalt mix. Generally, the improved workability could have various effects throughout the production and placement processes. Improved workability has the following advantages [9]: