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TO STUDY THE EFFECT AND THE POSSIBILITY OF USING WASTE PLASTIC AS A SUSTAINABLE COST-EFFECTIVE POLYMER TO MODIFY BITUMEN BINDERS

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ABSTRACT

In the laboratory, penetration-grade bitumen was mixed with two waste plastic products for asphalt binder modification and extension. These waste plastic products were designated as MR 6 and MR 10, respectively. In addition to high temperature Performance Grading, the samples were analysed in terms of the index characteristics detailed in the British modified binder standard. The experiment used 50/70 and 100/150 penetration grade bitumen, each of which included 4-8 percent (by mass) of waste plastic and was conducted at temperatures ranging from 52 to 82°C. *The alteration of waste plastic resulted in a significant improvement in the high temperature performance grading. The more difficult 50/70 penetration grade bitumen produced a more difficult modified binder, and the difference in the amount of waste plastic content between 4% and 6% was significantly greater than the difference between 6% and 8%. The modified binder with the MR 6 was more elastomeric and had a higher resistance to deformation than the binder with the MR 10 modification. It is required to do more study in order to compare the qualities of the manufacturing methods of wet blending and dry mixing.*

Keywords: *recycled plastics; plastomers; asphalt; bitumen; recycling; sustainability.*

INTRODUCTION

The distillation of crude oil is the process that results in the production of bitumen, which is a by-product of the petroleum industry. Asphalt binder is another name for this substance. It is possible to use it as a material in the building of roads due to the fact that it possesses beneficial properties such as a prolonged lifespan, great adhesion, and the ability to withstand the effects of water. Because of these traits, I was given the opportunity to apply for this position. When roads are built, bitumen is used as a binder, and the aggregates are mixed with bitumen to create asphalt. Bitumen is also used to coat the road surface. The performance of the bitumen binder plays a key influence in the determination of the performance characteristics of asphalt mixes as well as the overall durability of the mixtures. These qualities include how well the mixtures work and how long they last. The failure of the asphalt binder is typically directly connected to the failure of the asphalt pavement. This failure can occur as a result of thermal cracking that takes place at low temperatures, rutting that takes place at high temperatures as a result of softening of the bitumen and reduced elasticity of the bitumen, or fatigue cracking that takes place at intermediate temperatures as a result of cyclic loads and ageing of the pavement. All of these factors can contribute to the failure of the pavement.

Due to the fact that bitumen pavement maintenance and repair are unpleasant for a variety of socio-environmental and economic reasons, a significant amount of work is put into the prevention of failures in bitumen pavements. This work can be seen in the amount of effort that is put into preventing failures in bitumen pavements. Numerous research initiatives have been carried out to study the possibilities of changing bitumen in order to manufacture pavements that are of higher quality and may last for a longer period of time. The polymer modification of bitumen is the strategy that is utilised the most commonly. This is due to the fact that it is deemed to be one of the most suitable modification ways out of all the other modification ways that were investigated. Either a chemical reaction, often known as the "wet process," or mechanical mixing can be used to incorporate the polymer into the bitumen in order to produce polymer-modified bitumen. The chemical reaction is more common (referred to as the "dry process"). The bitumen and the polymer are immediately combined with one another during the wet process, which takes place at a high temperature for a certain period of time. This makes it possible for the components to have the adequate amount of time to interact with one another in a chemical and physical sense. The plastic, which may be in the form of flakes, pellets, or powder, is combined with hot bitumen using the wet technique. This method is utilised, for instance, in the process of purifying the polymer from the discarded plastics. Plastics that are utilised for the wet method often have melting temperatures that are lower than those that are authorised for the range. Temperatures between 160 and 170 degrees Celsius are often used for mixing during this operation. In general, polymer modification of bitumen through the wet process makes it possible for improvements to be achieved in the areas of elasticity, adhesion, cohesion, and stiffness. These improvements, in turn, eventually result in higher durability, fatigue life, and resistance to rutting.

In contrast to the wet procedure, the dry method does not require any preliminary mixing of the bitumen and polymer; rather, the dry method requires the addition of the polymer directly into the aggregates at the start of the mixing process. The wet procedure does involve any preliminary mixing of the bitumen and polymer. However, some studies have employed low-temperature melting point plastics with the dry technique as a pre-coating of the hot aggregate before adding the bitumen. It is possible that the temperature at which recycled plastic melts is higher than the temperature at which bitumen is combined. It is proposed that the melting temperature of recycled plastic should be higher than the temperature at which bitumen is mixed when the dry technique of recycling waste plastics is utilised. This is done so because recycled plastic is put into the bitumen mix as a substitute for the aggregate. The latter strategy is sometimes referred regarded as the "mixed" method in certain communities and contexts. When the mixture is created using the dry method, there are less aggregates that are required for it, which means that a greater proportion of plastics may be mixed into the final product. Utilizing this strategy leads to an improvement in the Marshall stability, fatigue life, and stiffness properties of the road pavement mix, as indicated by the conclusions of a number of studies.

Bitumen

The basic binders were composed of three different kinds of bitumen: Middle Eastern bitumen with a penta equivalent of 200, a Venezuelan bitumen with a penta equivalent of 200, and a Venezuelan bitumen with a penta equivalent of 200. The second component that was responsible for holding everything together was a modified binder that was sold under the brand name Polyflex 75 (P75). Styrene butadiene styrene is the name of the three-component modifier that is utilized in the production of Polyflex (SBS). In the trials with P75, a piece of the SBS was removed and replaced with a waste plastic polymer. This was done so that the experiment could continue.

Waste Polymers that Have Been Used Up A diverse range of polymers was used in this study so that the results would appropriately reflect the many different types of waste plastics that are currently on the market. The following contains descriptions of each polymer in a concise form.

Polyethylene is a member of the category of thermoplastic polymers known as polyolefins. This category also contains other thermoplastic polymers. The sorts of polyethylenes that were utilised for this endeavour were recycled high density (HDPE) and low density (LDPE) polyethylenes. This endeavour recycled high density (HDPE) and low density (LDPE) polyethylenes. This particular piece of content was manufactured using a combination of homopolymer polypropylene (HPP) and copolymer polypropylene throughout its entirety (CPP).

The density of the polyetherpolyurethane (PEPU) that was given was 1.09 grammes per cubic centimetre, and it was delivered in the form of chopped fibres. To produce some of the rubber that was utilised in the production of the TTRB, recycled truck tyres were put to use. The sample was taken from an ambient grind, which is a process in which the tyre is broken apart at room temperature and then processed after it has been ground. Smaller than 0.02 millimetres in size, the particles have a density of between 1.1 and 1.2 grammes per cubic centimetre. Table 2 contains information that was supplied by the supplier; its sole function is to act as an indicator of the content that is included.

Rubber flour was an additional kind of rubber that was looked at by researchers (GRRB). Regarding the composition of this polymer, there is not a single piece of information that can be found. The elastic that was utilised in the manufacturing of diapers and swimsuits was the source of this substance, which was in the form of a powder. Ethyl vinyl acetate, more often referred to as EVA, was used into more than one of the mixes that were shown. The fundamental components of this material are a copolymer that consists of polyethylene and vinyl acetate once they have been mixed. The percentage of vinyl acetate that was included in EVA1, EV A2, and EV A3, respectively, ranged anywhere from 14 percent to 20 percent to 33 percent.

OBJECTIVE

- The following are some of the key goals of this research study:
- To slow the degradation of the natural environment and to save the planet's natural resources.
- To investigate the differences in the adhesion qualities of asphalt mixtures brought about by using a variety of waste plastic modifiers and aggregate minerals
- To assess how well two different approaches to mixing, namely the dry and the wet procedure, work together.
- Determine the differences in the results of all of the laboratory tests in order to rank the aggregate quarries.

RESEARCH METHODOLOGY

Asphalt mixtures were produced using binders modified with the commercial waste plastic products MR6 and MR10 at a weight percentage of 6 percent of the binder. Additionally, asphalt mixtures were produced using conventional polymer modified binders SBS and EVA at a weight percentage of 2 percent, 4 percent, and 6 percent of the binder. In addition to that, unmodified penetration grade bitumen was utilised in the manufacturing process of the combinations. The mixes, which were otherwise theoretically equivalent, mirrored a typical 10-mm-sized dense graded and Marshall designed mixture for road surface in the United Kingdom. This combination was created by Marshall. This combination was concocted in an effort to fulfil the prerequisites of BS EN 13108-1. (Table 1). In order to meet the requirements of European Standard EN 12591, polymer-modified binders were combined in a laboratory setting with a 100–150 penetration-grade bitumen. After the asphalt mixtures had been artificially aged in an oven in the laboratory, their stiffness modulus was determined both before and after the process of ageing so that the different levels of ageing could be compared. The samples were allowed to age for some time before being put through a battery of penetration and softening point tests so that researchers could examine and contrast the impact of different polymers on the ageing of modified binder samples. The evaluation of the sample binders and the samples of the combination were both performed in triplicate, and the results were then averaged. A bitumen with a penetration grade between 50 and 70 was utilised throughout the manufacturing process of the control asphalt mixture samples. It was required that this bitumen live up to the requirements of EN 12591. The recycled plastic modified samples all included 6 percent of the commercial products MR6 or MR10, which was the same number across all of the different samples. This percentage was calculated based on the mass of the unmodified bitumen. The SBS and EVA modified binders were produced with a polymer content that was two percent, four percent, and six percent by mass of the unmodified bitumen, respectively. This was done during the manufacturing process.

Table 1 Asphalt mixture properties.

Table 1. Asphalt mixture properties.			
Property	**Test Method**	**Limits**	**Target**
Binder content (by mass) (%)	BS EN 12697-1	4.5–5.5	5.2
Voids in the aggregate (%)	BS EN 12697-8	18.0–22.0	20.0
Percentage Passing (%) Standard Sieve Size (mm)			
Sieve Size (mm)	**Test Method**	**Limits**	**Target**
10		90–100	99
6.3		62–68	68
2	BS EN 12697-2	25–33	32
1		17–26	22
0.063		4–8	7

Binder Ageing The Rolling Thin Film Oven test, also known as the RTFO test, was carried out in order to simulate the short-term ageing of the binder that is expected to take place during the mixing, transporting, and paving processes. This test was carried out on samples of modified and unmodified binders respectively. The RTFO test required that 35 grammes of binder be weighed out and placed in glass bottles before being heated in a rotatory oven at a temperature of 163 degrees Celsius for duration of 85 minutes. This was done in order to ensure that the binder would not melt throughout the test (BS EN 12607-1). The RTFO technique of ageing is rather common and offers a relatively sufficient indicator of the short-term impacts of binder ageing in real usage. This form of ageing has gained a lot of popularity. In line with BS EN 1426-1427, the samples of the binder were put through the RTFO test both before and after being placed through a brief period of laboratory ageing to establish their penetration and softening point. This was done in order to get an accurate reading on both of these properties.

RESULTS As a marker of the ageing of the binder, we employed the reduction in penetration, as well as the rise in the point at which it softens. Table 2 provides a concise summary of the results of the binder penetration test, which was carried out three times. Table 3 contains a summary of the findings of the softening point test. This table compares the unaged, after RTFO treatment, and after PAV treatment conditions respectively. When it comes to the asphalt mixes, the rise in stiffness modulus was the indication of ageing that was used. [Case in point:] [Case in point:] [Case in point:] The stiffness modulus of the asphalt mixture is summarised in Table 4, both in its unaged form and after each ageing cycle that it has gone through.

Table 2. Binder penetration results

	Unaged	**Post RTFO**	**Post PAV**
	93	52	17
Control	106	51	17
	103	55	16
	68	41	20
2% SBS	76	41	19
	72	42	16
	51	38	14
4% SBS	64	39	15
	58	38	15
	48	24	10
6% SBS	48	23	10
	48	26	10
	78	43	17
2% EVA	91	43	20
	85	43	16
	57	31	15
4% EVA	57	33	17
	57	32	16
	68	22	12
6% EVA	68	26	15
	68	26	15
	46	30	10
MR6	46	29	14
	46	29	12
	64	33	12
MR10	64	39	11
	64	35	12

Table 3. Binder softening point results

Material	Unaged	Post RTFO	Post PAV
	43	52	68
Control	44	50	67
	44	51	68
	48	57	70
2% SBS	49	56	70
	49	57	70
	57	61	78
4% SBS	54	61	77
	56	61	78
	69	69	87
6% SBS	69	70	87
	68	71	89
	50	57	70
2% EVA	51	57	69
	50	56	69
	64	67	70
4% EVA	64	66	71
	63	67	72
	68	67	79
6% EVA	69	69	78
	66	69	79
	61	64	89
MR6	61	63	90
	60	64	90
	52	62	81
MR10	50	61	81
	50	62	82

DISCUSSION

Binder Ageing Utilizing samples of the binder that had been artificially aged allowed for the examination and verification of the procedure's impacts on the physical characteristics of the binder as a result of the ageing process. Because of the short-term ageing that was carried out with the RTFO, every one of the binder samples had a significant rise in softening point in addition to a decline in penetration (Figure 1). (Figure 2). After doing long-term binder ageing with the PAV, it was found that all of the samples saw an extra decrease in penetration (Figure 1), in addition to an additional increase in softening point. This was determined after the PAV was used to perform long-term binder ageing (Figure 2).

The decrease in penetration and the increase in softening point that were observed as a result of short-term binder ageing through the RTFO reflect the hardening of the binder that occurred as a result of an increase in binder viscosity that occurred as a result of oxidation in the short-term ageing phase. This was observed as a result of short-term binder ageing. Previous study [26] found that these results were consistent with their findings, and they indicate that the binder became more rigid. The decrease in penetration is a reflection of an increase in binder stiffness, which is a result of a loss of volatile oils during short-term ageing. This loss occurs when the binder is aged for more than a short period of time. The process of ageing was responsible for the loss of these volatile oils. In addition, the results of the softening point test demonstrate that the binder had grown more stiff, as evidenced by the fact that each sample had a rise in its softening point after being subjected to RTFO (Figure 2). This may be the outcome of the process of volatilization, which takes place when oil-like substances in the mixture are evaporated. As a result, this may be the case. After treatment with RTFO, the results of penetration were decreased by an average of 46%, and after treatment with both RTFO and PAV, the reduction was a total of 78%. During this period, the results of the average softening point test shown an increase of 10 percentage points following RTFO therapy and an increase of 37 percentage points following treatment with both RTFO and PAV. The following is a reading of the data obtained from binder ageing, which can be read as follows: Previous statements that the binder will become more viscous as a result of both short-term and long-term binder ageing have been supported by the data obtained from binder ageing, which can be read as follows:

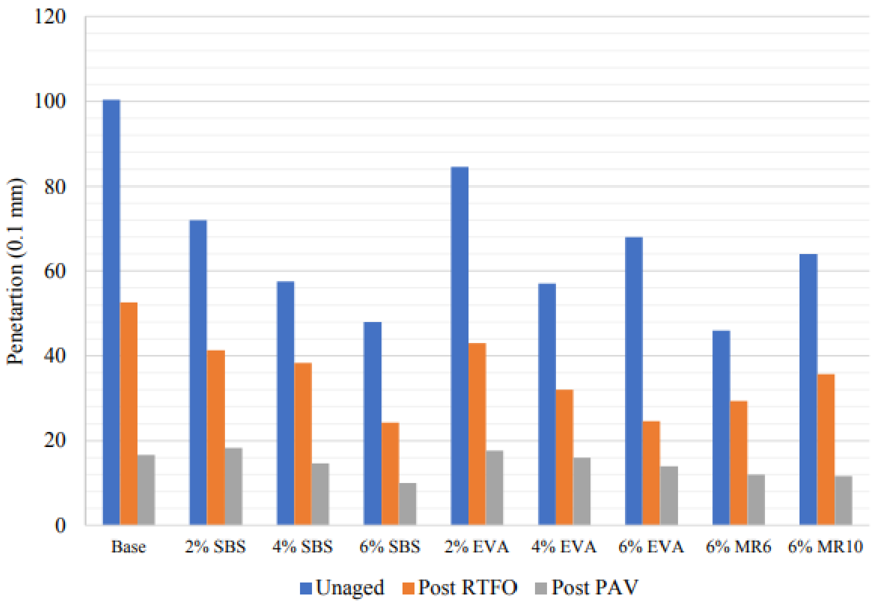

Figure 1. Binder average penetration before and after ageing.

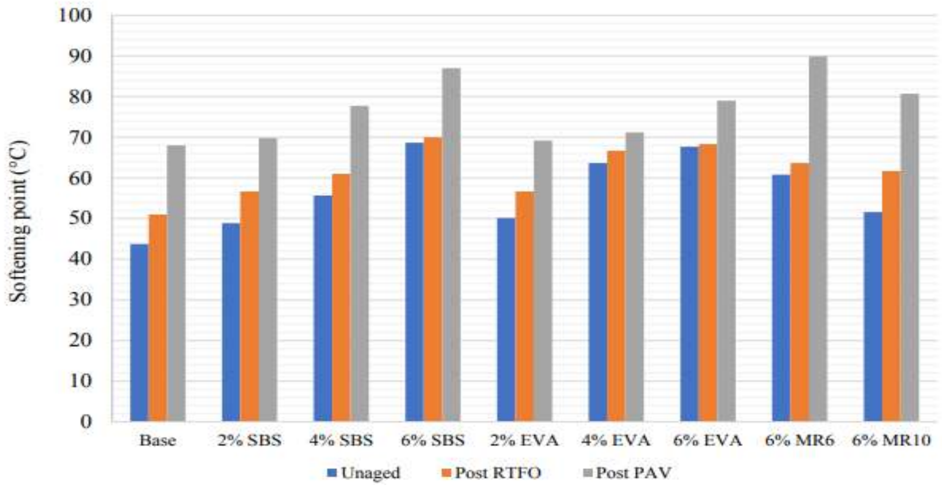

Figure 2. Binder average softening point before and after ageing.

Mixture Ageing

After the first ageing cycle of 72 hours, the stiffness modulus of each combination saw an increase, which was subsequently followed by a further increase after the second ageing cycle and a tiny increase after the third cycle of ageing. (Figure 3). The stiffness modulus typically increased as the mixtures aged and became older, with the exception of the mixture that contained 6 percent EVA, which was associated with a considerable decrease in stiffness modulus after the second ageing cycle. This was because of the association between the two factors (Figure 4). The asphalt mixture stiffness modulus rose by 13 percentage points after one ageing cycle, 19 percentage points after two ageing cycles, and 23 percentage points after three ageing cycles. All of these increases occurred after the mixture was subjected to ageing. That is to say, the artificial ageing cycles caused the asphalt mixture's average modulus to continue to grow, but at a rate that was steadily reducing as the cycles progressed.

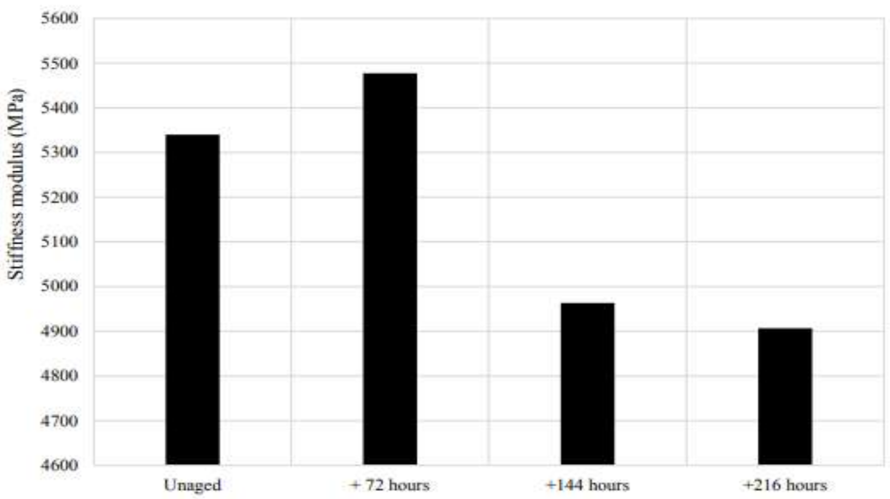

Figure 4. Average 6% EVA asphalt mixture stiffness modulus before and after ageing.

The Influence of Polymer Content on the Aging of Mixtures

In a similar manner, asphalt mixtures that were modified with 2% EVA, 4% SBS, and 6% MR6 and MR10 were evaluated and compared in order to determine the influence that polymers have on the ageing of asphalt mixtures. The purpose of this evaluation and comparison was to determine the influence that polymers have on the ageing of asphalt mixtures. The stiffness modulus of MR10 underwent a change after the first ageing cycle that was equivalent to that of 4 percent SBS, with a relatively moderate shift of 10 to 20 percent. This change occurred after the first cycle of ageing. In contrast to this was the shift that occurred with the combination that contained 2 percent EVA, which had a substantially higher rise (38 percent) than the other three mixes combined (Figure 7). The change in stiffness modulus of MR10 and SBS remained relatively consistent after each ageing cycle, which suggests that the effect of MR10 and SBS, added at a standard dosage, on the ageing process of asphalt mixtures is comparable. This was determined by observing that the change in stiffness modulus of MR10 and SBS remained relatively consistent after each ageing cycle. This was found by noticing that the change in stiffness modulus of MR10 and SBS stayed approximately the same after each cycle of ageing even though they were both subjected to different ageing conditions.

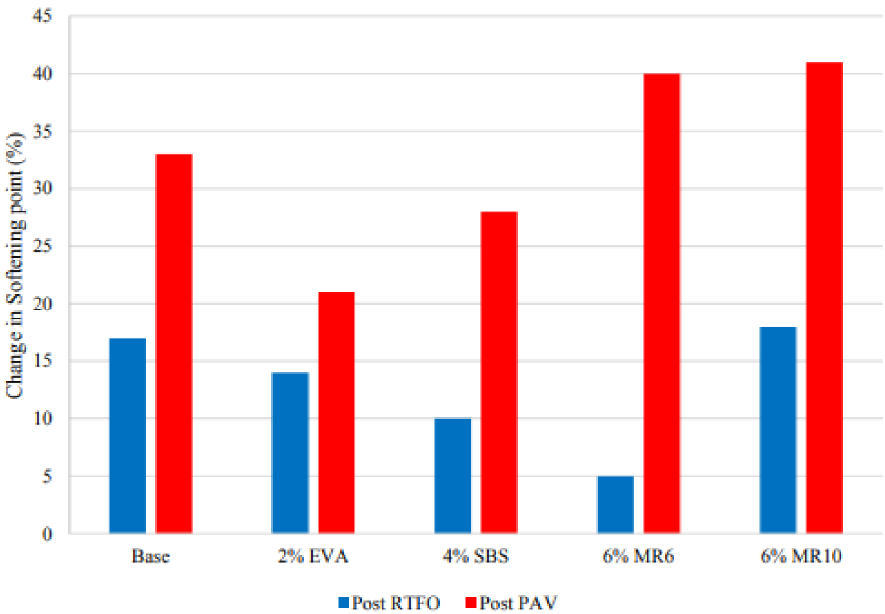

Figure 5. Change in average binder softening point before and after ageing therapies.

CONCLUSIONS

It was usual for there to be two or more PG increases, also known as grade-bumps, as a result of the modification of waste plastic, which was associated to a major improvement in binder qualities. This improvement was linked to the recycling of waste plastic. The binder was enhanced by both types of waste plastic and by all components of waste plastic; nonetheless, it was established that the best dose was 6 percent of the binder's mass, and MR 6 produced a bigger improvement than MR 10. It was discovered that MR 6 and MR

10 modified bitumen had qualities that were analogous to those of popular multi-grade and polymer-modified binders utilised in Australia. However, it was discovered that MR 6 modified bitumen displayed a greater elastic response to load than MR 10, which is contrary to what the producers represented as their objective for the two products. MR 10 modified bitumen was found to exhibit a less elastic response to load. “It is recommended that additional research be carried out in order to gain a better understanding of the tendency for wet blended waste plastic modified to not fully digest or to segregate after mixing. Additionally, it is recommended that further research be carried out in order to determine whether or not more consistent results can be achieved by using waste plastic pellets of varying sizes, shapes, and densities. In addition, it is recommended that further research be carried out in order to compare the properties of waste plastic modified asphalt to the properties of otherwise comparable asphalt produced with polymer modified and multi grade” binders, as well as to compare the properties of asphalt and binders when waste plastic is either wet blended or dry mixed. This is because the properties of waste plastic modified asphalt and the properties of otherwise comparable asphalt produced with polymer modified and multi grade binders are otherwise comparable. Taking this into consideration will assist establish which approach is more successful? Due to the fact that there are several benefits associated with the utilisation of waste plastic as a substitute for asphalt binder, it is necessary to conduct an impartial analysis of the economic and environmental advantages provided by items that offer equivalent performance.

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