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Sebha University Conference Proceedings

Conference Proceeding homepage: <http://www.sebhau.edu.ly/journal/CAS>



The effect of filler materials on the performance of asphalt road surfaces

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Keywords:

Asphalt
Fillers Materials
Mixes
Marshall Stability and Flow
Wheel Rutting Formation

ABSTRACT

The increasing need for durable and cost-effective road infrastructure has led to a growing interest in the role of mineral fillers in enhancing asphalt mixture performance. This study investigates the influence of different filler content levels—1.5%, 5.3%, and 12% by total mix weight—on the mechanical and durability properties of Hot Mix Asphalt (HMA). The primary objective is to identify the optimal filler proportion that enhances pavement strength, moisture resistance, and rutting performance. To achieve this, laboratory testing was conducted using standardized procedures, including the Marshall Stability and Flow test (ASTM D6927; AASHTO T 245), Hamburg Wheel Tracking test (AASHTO T 324), and Indirect Tensile Strength test (AASHTO T 283). Limestone powder was used as the mineral filler across all mixtures. The results showed that asphalt mixtures containing 5.3% filler provided the best balance of mechanical strength and resistance to moisture-induced damage and deformation. Mixtures with 1.5% filler had excessive air voids and low cohesion, while 12% filler led to stiffness-related cracking and rutting under simulated loading. These findings emphasize the importance of optimizing filler content for improved pavement performance and service life. The results can guide transportation engineers and policymakers in developing more durable, sustainable, and economically efficient roadways. Future research may explore eco-friendly alternative fillers and long-term field validation.

تأثير المواد المالئة على أداء أسطح الطرق الأسفلتية

حسن عويدات سالم

قسم الهندسة المدنية، كلية الهندسة، جامعة وادي الشاطئ، براك، ليبيا

الكلمات المفتاحية

الأسفلت
المواد المالئة
الخلطات
استقرار مارشال والتدفق
تشكل التخدّد بالعجلات

المخلص

تنتج الخلطات البيتومينية الساخنة (الأسفلت) بخلط الركام، والمواد الناعمة (الحشو)، والرابط البيتوميني عند درجة حرارة عالية ومناسبة. تؤثر خصائص الركام، الذي يُشكّل الجزء الأكبر من الخليط، على متانة هذه الخلطات ومتانتها. كما ترتبط مقاومة شقوق الكتل وعمق التخدّد في الخليط بنوع الركام، وبالتالي خصائص كسره، وتحديدًا شكله وحببياته، وخشونة سطحه. تحت تأثير أحمال المرور، يحدث إجهاد في الطبقة السطحية. تُعد المادة المستخدمة في الرصف، وتقنية التنفيذ، وحجم الأحمال من أهم العوامل الرئيسية التي تؤثر على أداء طبقة الرصف. هناك العديد من العوامل الأخرى التي تؤثر على أداء الخليط الأسفلتي، مثل نوع وكمية المادة الرابطة، ونوع وكمية الركام الناعم والخشن. إضافةً إلى ذلك، تؤثر درجة حرارة الخلط، ووقت الخلط، والعناية أثناء الخلط على متانة وأداء الخليط. في حال تجاهل أيٍّ من هذه العوامل أثناء الخلط، ستكون جودة المنتج المطلوب منخفضة. يمكن دراسة تأثير أيٍّ من هذه العوامل على أداء وامتانة الخليط البيتوميني. في هذه الدراسة، استُخدمت مادة الحشو، وهي مسحوق مادة الحجر الجيري المستخدمة في التصميم. ودرست المشاكل التي قد تحدث عند استخدام نسبة حشو في الخليط، ضمن حدود المواصفات، ضمن حدود المواصفات المسموح بها وخارجها. ويمكن زيادة عمر خدمة الأسفلت من خلال تحسين الخليط، ما يعني إطالة فترات الصيانة. تشير النتائج إلى أن معدل الحشو المنخفض يؤدي إلى تكوين الشقوق، في حين يؤدي

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1. INTRODUCTION

It consists of asphalt material, mineral aggregate, filler, bitumen and air. It is a phased complex material. A certain amount of aggregate in asphalt-aggregate mixtures Filler is essential to provide desired mixing properties and performance [1]. Filler is considered as one of the main components of asphalt mixtures to increase the fine aggregate ratio, reduce the amount of voids and increase the strength of asphalt concrete. The properties of the mineral filler material were used to determine its potential to improve the performance of asphalt concrete, particularly by increasing the stability and durability of the hot mix and reducing problems with drag and rutting. Clifford Richardson, who first defined and realized the importance of elephants, used the terms elephants and dust and emphasized the importance of "true dust" [2]. The use of certain mineral filler materials provides a positive value increase on rutting depth, stiffness and stress increase in asphalt concrete [3,4]. It also has a positive effect against permanent deformation, fatigue cracking and moisture damage [5-6].pdf 12P

There are many studies on the improvement of bituminous binder. The use of different fillers is also being tried to improve the properties of Asphalt. Studies on the effect of elephants can be listed as Portland cement slaked lime (Acar and Tapkın, 1998), marble dust (Karaşahin and Terzi, 2007), ground fuel ash (PFA) (Zoorob, 1995). Sand to improve asphalt strength and properties (Knight et al., 1979), the use of different rock powders has also been extensively studied. [7].pdf 4

In this study, the mixture made with limestone (limestone) powder produced at the Mahroga Crusher plant as a filler for hot bituminous mixtures was investigated. For this, bituminous binder with 60-70 penetration was used.

The continuous expansion of road networks and increasing vehicular loads have placed significant demands on the durability and performance of asphalt pavements. In response to the need for long-lasting and cost-efficient roads, researchers and engineers have been exploring ways to enhance the structural and functional properties of Hot

Mix Asphalt (HMA). Among the various components of asphalt mixtures, mineral fillers—fine materials that pass through a 0.075 mm sieve—play a crucial yet often underestimated role in influencing mixture behavior.

Fillers affect several performance-related properties of asphalt, including stiffness, void content, resistance to moisture damage, and permanent deformation under traffic loads. Their interaction with bitumen alters the mastic properties, thereby influencing the overall cohesion and durability of the asphalt mixture. Studies have shown that optimizing filler content is essential for improving resistance to rutting, fatigue cracking, and moisture susceptibility, especially in regions with harsh climatic conditions or heavy traffic loads (Xiao et al., 2020; Salem & Al-Omari, 2023).

Traditionally, limestone powder has been widely used as a mineral filler due to its availability and compatibility with asphalt binders. However, the proportion of filler in the mix must be carefully controlled. Insufficient filler content can lead to excessive air voids and reduced strength, while an excessive amount can make the mix too stiff, increasing the risk of cracking and early failure. Several standards and design methods, such as the Marshall mix design method (ASTM D6927; AASHTO T 245), incorporate filler evaluation in determining optimal mix compositions.

Despite the extensive use of fillers in asphalt technology, there remains a lack of consensus on the ideal filler content for maximizing mechanical performance without compromising workability. In this context, the present study aims to investigate the effect of varying filler content (1.5%, 5.3%, and 12% by total mix weight) on the structural integrity and moisture resistance of asphalt mixtures. The work involves experimental testing based on standard procedures, including the Hamburg Wheel Tracking test (AASHTO T 324) and Indirect Tensile Strength (AASHTO T 283), to evaluate rutting and moisture damage potential.

The outcomes of this study are expected to contribute to the optimization of asphalt mix designs by providing practical insights into the selection of filler content, with potential implications for improved pavement lifespan and reduced maintenance costs.

2. EXPERIMENTAL METHOD

2.1. Materials

Sr No. Criteria(%)	Aggregate Concensus Properties	Test Results (%)	
1	Course Aggregate	99.7	90/95 min.
	Angularity		
2	Sand Equivalent	76.8	45 min.
3	Flat and Elongated	9.1	10 max.
4	Los Angeles Abrasion	16.8	≤40
5	Aggregate Impact	8.72	≤25
6	Clay Lumps	0.18	≤1.0
7	Crushing Aggregate	100	95 min.



	Fraction Size (mm)			
	Symbo l	Fille r	Fine Aggregate* *	Course Aggregate *
Bulk Specific Gravity (dry)	Gsb		2,574	2,592
Bulk Specific Gravity (ssd)	Gs (ssd)		2,625	2,640
Apperent Specific Gravity	Gsa	2,772	2,712	2,721

Figure .1 - Mahroga Crusher Plant Aggregate

The limestone, which is the highest road construction material and used as mineral aggregate in the study, was obtained from the Mahroga stone enterprise around the city of Brak, Libya.(Figure.1)

Table 1. Properties of mineral limestone aggregate

Aggregate grading (granulometry) is one of the important factors affecting the properties of the mixture.

Fillers :

Mineral fillers are fine-grained materials that pass through a 0.075 mm (No. 200) sieve and are used to increase the compactness and performance of asphalt mixtures by filling the voids between coarse and fine aggregates. In this study, fillers were obtained by sieving limestone aggregate through a No. 200 sieve.

Although mineral fillers constitute a small proportion of the total aggregate, they play a critical role in regulating the properties of the asphalt mixture. It is important to note that not all materials finer than 0.075 mm can be classified as effective fillers. Ideal fillers should be angular in shape, well-graded, and include particles smaller than 0.001 mm to ensure effective void filling and binder interaction. The shape of the particles significantly influences the stability of the mixture.

A high-quality filler should be free from clay, organic matter, or any harmful substances, and should be dry enough to flow freely. It must remain chemically and physically stable at the temperatures used during asphalt production and must exhibit strong adhesion to the bituminous binder.

In asphalt mixtures, fillers serve to increase the fine aggregate fraction, reduce air voids, and improve resistance to deformation under high temperatures. Their space-filling ability contributes to the overall stiffness and stability of the asphalt. In this study, limestone powder was selected due to its availability, chemical compatibility with bitumen, and proven effectiveness in improving bonding strength. Filler contents of 1.5%, 5.3%, and 12% by total

mix weight were chosen to evaluate their influence on mixture performance and to determine the optimal balance between durability and workability.

Table 2 Average values of main elements obtained as a result of chemical analysis

Element	SiO ₂	Al ₂ O ₃	TiO ₂	Fe ₂ O ₃	LiO	CaO	MgO	Na ₂ O	K ₂ O	P ₂ O ₅	CaCO ₃	Others
Limestone	0.83	0.20	0.0	0.05	1.84	90.65	0.25	0.0	0.0	0.0	3.18	3.00

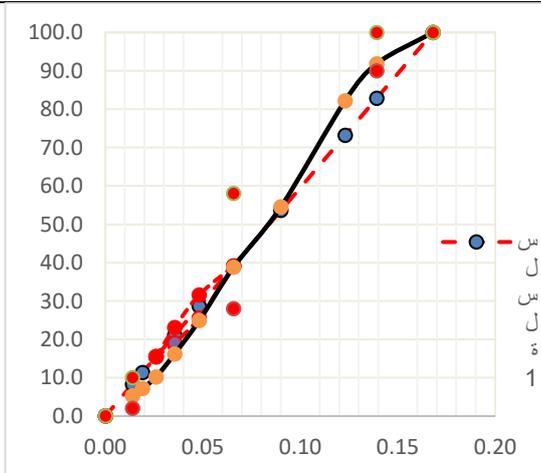
2.2. Bituminous Binder

The penetration value of the bituminous binder used was 61mm at 25°C, its Specific gravity was 1.038 and the Softening Point was 50°C.

2.3. Preparation of the Mixture

Table 3. Superpave Wearing Course Design Aggregate Gradation

Sieve Size (mm)	Trial Blend Superpave (% Passing)
25	100
19	100
12,5	92.0
9,5	82.1
4,75	54.5
2,36	38.8
1,18	24.9
0,600	16.2
0,300	10.2
0,100	7.2
0,075	5.3



In the asphalt mixture, 4 groups of aggregate (Limestone) samples, 0-3mm, 3-8mm, 8-11mm, 11-19 mm, were used. The filler ratio in the mixture was taken as close to the average of the specification values. The rate of fillers in the Wearing Course base is min.2 - max.10. It is set to 5.3 to get the correct rating in the mix.

Tolerance ± 2



In case of lower than Filler finishing specification values:

- High voids will form. High void results in high permeability. As the high permeability will cause air and water to pass through the mixture, asphalt ages prematurely and hardens very quickly. This is usually achieved by increasing the proportions of fillers.. As it is seen in the samples taken in high-void asphalt, the gaps formed will affect the quality of the asphalt, as well as it

will deform again under the increasing traffic load and will cause rutting over time.(Fig.2, Fig.3)

In case the fill finish property is higher than the values:

- Optimum bitumen ratio is very important in the designs made. During asphalt production, the mixture gradation is adjusted, and the excess in the filler ratio during the production will bring with it various problems later on. If the filler ratio, which provides the connection between the coarse and fine aggregates, is high, it affects the stability and durability of the asphalt.
- high fillers means a low percentage of voids and causes loss of stability and vomiting due to re-setting of stones and additional compaction after a while after asphalt is opened to traffic. the gap required to be filled by the asphalt to ensure sufficient stability is insufficient. decrease and vomiting may occur. In the asphalt design with optimum bitumen value, if there(Fig.1, Fig.2, Fig.3)



Fig.1 - Fillers ratio is normal, spacing is low

Fig.2 - Low fillers rate, high void



Fig.3 - High filling rate, low void

Considering the reasons mentioned above in the asphalt mixture, the filler ratio and the void ratio it provides are very important. In cases where the void ratio and gradation are sufficient, if there is a problem in the stability values, it means that there is a problem in the aggregate quality and the aggregate quality should be increased.

3 -EXPERIMENT RESULTS

3.1 - Marshall Stability and Flow Test

This test was carried out to measure the stability and resistance to flow of the prepared mixtures, which were prepared with different filler percentages and determined as 5.6% bitumen, with the help of Marshall Stability test device. Samples are kept in 60±1°C water for 30-40 minutes in order to determine the stability and yield values of the samples whose lengths and required weights are taken. The sample removed from the water is placed between two parts of a steel ring and the yield rod is fixed. Loads at a rate of 51mm per minute until maximum load is reached. Marshall stability value

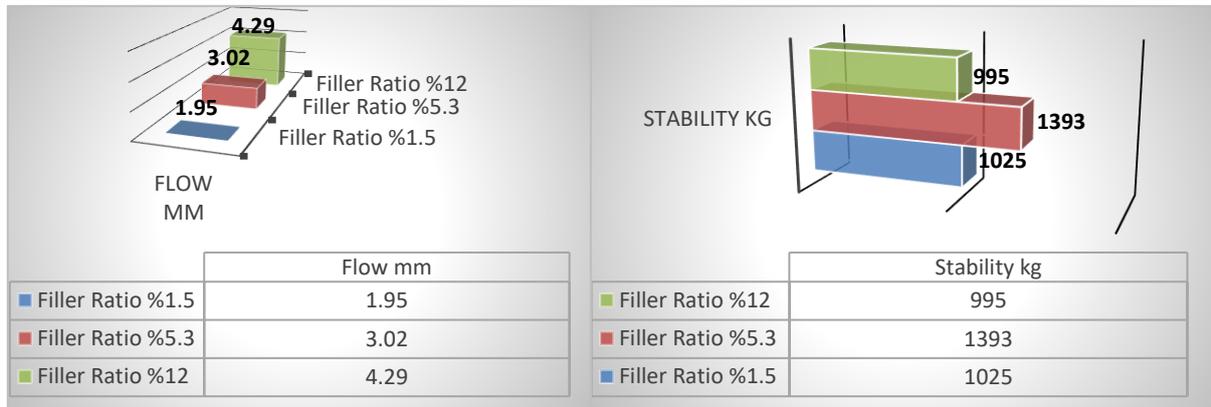


(kN) was taken as maximum force during loading and yield value (mm) was taken as impact at maximum force. In addition, this test determines the unit weight of the mix, the void ratio, and the percentage of binder-filled aggregate inhabitants.

- Mix gradation was done within the specification values specified in Table 3 and 6 marshal briquettes were adjusted. The mixtures prepared by giving AC 60/70 Bitumen at an optimum bitumen rate of 5.6%, were first measured and their densities were found. Then Marshall stability and yield tests were performed.
- On the other hand, 9 Marshall samples with filling ratios of 1.5 and 12 were prepared. Stability and flow tests were performed for comparison..

Table 4 -Marshall Stability and Flow Test Results

ITEM	Description	UNIT	60/70 Bitum	Filler % 1.5	Filler % 1.5	Filler % 1.5	Filler % 5.3	Filler % 5.3	Filler % 5.3	Filler % 12	Filler % 12	Filler % 12
1	Stability	kg	1310	1062	998	1016	1358	1399	1422	938	992	1025
2	Flow	mm	3.05	1,86	1,98	2,02	2.96	3.08	3.02	4.26	4.62	3.99
AVARAGE				Stability : 1025 Flow :1.95			Stability : 1393 Flow :3.02			Stability : 985 Flow :4.29		



3.2 - Evaluation of Wheel Rutting Formation

The test specimens, which were prepared in TS EN 12967-22 test standards, with the compression and air void ratio targeted in the test, 300x300x50 mm in size, in the closed cabinet of the HWT device, at constant temperature, a stuffed wheel made of rubber, which is applied a constant load throughout the test and moves at a constant speed. (dry test) can be dry tested.

In the experiments carried out with the HWT device, 98% of the practical specific gravity (DP) was compressed in the design and 300x300x50mm samples were prepared[11]. The samples are then conditioned for 4 hours at 60°C to be placed in the HWT device after 24 hours. After the first 10 passes of the test wheel, it is measured at 33 points along the axis through which the test wheel passes, without interrupting the test, with an accuracy of 0.01mm.

Table. 5 Technical Data

Standart Test Mode	300x300x50 mm
Wheel Load Contact Pressure	0.7 Mpa
Test Temperature	60°C
Wheel Rotation Speed	42±1dk

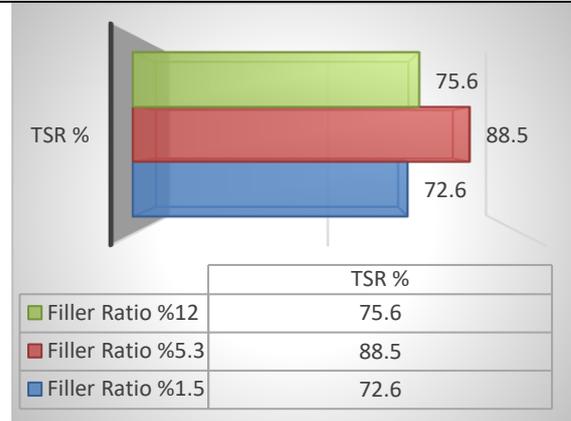
Table 6- Hamburg (HWT) Wheel Rutting Test (mm) Test Results

TEST	Filler %1.5	Filler %5.3	Filler %12	Specification Value
Hamburg (HWT) Wheel Rutting Test (mm)	8.2	3.0	9,9	4.5 ≤

- Whell Rutting tests were carried out on the mixtures prepared by using AC 60/70 Bitumen with the optimum bitumen rate of 5.6% within the specification values specified in Table 3.

- On the other hand, asphalt samples with filler percentages of 1.5 and 12 were also tested.

Photographs of the tests carried out and a sample of asphalt.



4 -CONCLUSIONS AND RECOMMENDATIONS

The principal characteristic of a road superstructure is to guarantee a mixture that should have high strength, to be capable of supporting heavy traffic loads without cracking or rutting. It is possibly highlighted that the duration of the useful life of a road pavement is precisely the resistance that the mixture is able to exert if subjected to strong stresses such as those due to road traffic

Structural strengths of the samples produced in the study were evaluated through Marshall stability, creep, wheel track and Determination Of The Indirect Tensile Strength Marshall stability varies It is assumed that the mechanical resistance to torsion, displacement, rutting and shear stresses of bituminous materials can be depicted. In addition, we performed wheel track and Determination Of The Indirect Tensile Strength.

Stability is achieved mainly from internal friction and cohesion. In this expression, internal friction represents the interlocking and friction resistance of the aggregates. Cohesion refers to the adhesive force of the bitumen used as a binder. It is clear that the Marshall stability test is a decisive analysis in the evaluation, since the filler ratio taken in different percentages taken into consideration in the study is theoretically expected to have an increasing or decreasing effect on the interlocking between aggregates in gradation. As a result of the analyzes and evaluations made:

3.3 - Determination Of The Indirect Tensile Strength

Samples were prepared and tested in accordance with the AASHTO T 283 standard for the purpose of determining the spread against moisture loss in the mixture of the studies.

In the method specified in this standard, each For the Asphalt Layers type, at least 6 samples are compressed to have a void ratio of 6-8%. Up to three of these particles were left in a vacuum to fill 50-80% of the space Figure 4.1. These samples are then kept at -18°C for 16 hours and

then kept in water at 60°C for 24 hours Figure 4.2. After this conditioning process, the techniques It is kept in water at a height of 25°C for 1 hour and broken by axial parallel lateral loading. On the other hand, dry pieces break after being kept in water for 1 hour when the time reaches 25°C

without being subjected to the conditioning process. ITS (kPa) of samples by indirect tensile using the maximum load value obtained from the shearing process. It is determined by formula 1 [13].

$$TSR=100x (Pcondition / Pdry)$$

Here, Pcondition conditions represent the mean (kPa) of the ITS values of the detailed samples, and Pdry refers to the mean (kPa) of the ITS values of the unconditioned samples. According to the standard, the fact that the TSR enclosures are over 70% indicates that it is appropriate to take the mixture against the external structure of moisture.

- TSR tests were performed on mixtures prepared using AC 60/70 Bitumen, which has an optimum bitumen ratio of 5.6% within the specification values specified in Table 3.

- On the other hand, an asphalt sample with a filler percentage of 1.5 was also tested.

Table 7- Determination Of The Indirect Tensile Strength Test Results

TEST	Filler %1.5	Filler %5.3	Filler %12	Specification Value
TSR (%)	72,6	88,5	75,6	80 ≥

- In Marshall stability tests, it was observed that the stability and flow values of mixtures made with low filling ratio were low. Although the stability value of mixtures made with high filling ratio is low and the flow values are high, it has been observed that the durability of such mixtures will not be high, especially on heavy tonnage roads. The stability and flow values of mixtures with appropriate mixture gradation and filling ratio close to the average of the specification values are quite positive. Of course, it should not be forgotten that the choice of aggregate for these tests is very important.

- Void ratio is one of the factors that most affects the material's susceptibility to creep. In general, the relationship between void ratio and rutting ratio is parabolic. The void ratio limits where the material is most stable are generally between 3% and 7%. As a result of the tests, the void ratio formed due to the low filling rate in asphalt caused the bitumen to bleed onto the asphalt surface. High filler content causes tire marks. Considering the increasing traffic load, the use of non-standard low fillers at the optimum bitumen rate will cause vomiting in the asphalt. As can be seen from the test, the fillings in the asphalt mixture must be adjusted well. Low and high occupancy rates cause problems under traffic loads.

- Evaluation of TSR strength for each layer of flexible pavement is one of the main tasks that must be carried out to guarantee better performance in terms of stiffness and strength resistance. Pavements are subject to cycling of environmental conditions, but when moisture is present, repeated hydraulic loading occurs with the development of pore pressure in the mixtures. Therefore, the Tsr Test does not consider the effect of pore water pressure, but instead considers the effect of a single load on

environmentally conditioned samples. Dynamic modulus testing of environmentally conditioned and saturated mixtures better simulates the repeated hydraulic loading to which pavements are subjected. As a result of the tests, it was seen that conditioned and normal mixtures made with low and high filler ratios did not meet the Tsr specification limit.

- This study demonstrated that filler content plays a crucial role in determining the performance of asphalt mixtures. Among the tested levels, a filler content of 5.3% by weight of total mix yielded the best balance between structural strength, durability, and moisture resistance. Lower filler content (1.5%) led to higher air voids and reduced cohesion, while excessive filler (12%) caused stiffness and rutting potential.

The findings suggest that optimizing filler proportions is essential for improving the longevity and mechanical stability of flexible pavements. Furthermore, applying standard test protocols such as Marshall Stability (ASTM D6927), Hamburg Wheel Tracking (AASHTO T 324), and Tensile Strength Ratio (AASHTO T 283) ensures consistent quality control in mix design.

For future research, it is recommended to explore the use of alternative sustainable filler materials such as fly ash, slag, or nano-silica to further enhance performance and reduce environmental impact. Long-term field validation studies and modeling tools could also be developed to predict the pavement behavior under varying traffic and climate conditions. Practical applications of this study include guiding civil engineers and transportation authorities in selecting optimal filler content for cost-effective and durable pavement construction.

5 –REFERANCE

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