

A NEWLY DEVELOPED LABORATORY SLAB ROLLER COMPACTOR (TURAMESIN): AN OVERVIEW

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Abstract Methods of preparing test specimens in laboratories are particularly important. It also holds true in terms of compaction procedure in predicting pavement performance. The currently available laboratory compactor cannot adequately replicate field compaction conditions, especially the Stone Mastic Asphalt (SMA) mixture. The essential element of SMA mixture comprises of stones that are placed next to or on top of each other, and therefore are greatly affected by the compaction procedure. Conclusion of different studies have indicated that rolling wheel compactor, simulates properties that are closer to field compaction. Turamesin was developed as an improved method of laboratory slab roller compactor, to provide a solution for the problem of producing laboratory specimens, which would represent materials laid and compacted in the field. This paper gives an overview of Turamesin and discusses the findings of the units' first phase Pilot Study, conducted in order to provide specific information, to improve procedures for slab preparation and compaction, also determining the criteria for slab compaction and performance of Turamesin. Turamesin is able to compact, a slab area measuring; 600 mm by 500 mm, according to clients' specified thicknesses, with number of passes up to 75, within 15 minutes time period. One compacted slab could produce up to 16 cylindrical core specimens of 100 mm diameter. Turamesin has shown great potential to be adopted as standard laboratory slab compactor, for asphalt mixtures and seems to be capable of simulating field compaction in terms of operational procedures. However, improvement of the Turamesin will need significant amount of research to develop and finalize the optimum procedures.

Keywords Roller Compactor, Slab, Asphalt Mixtures, Laboratory Compaction, Field Simulation

چکیده روشهای تهیه نمونه آزمایشگاهی از اهمیت خاصی برخوردار است. این موضوع در مورد تهیه نمونه ها برای آزمایش تراکم به منظور پیش بینی کارایی در روسازی راه نیز صادق است. متراکم کننده آزمایشگاهی در دسترس (مخصوصاً) شرایط مربوط به تراکم مخلوط سنگ و ماستیک آسفالت) نمی تواند باندازه کافی شرایط واقعی تراکم را نشان دهد. عنصر اصلی این مخلوط از سنگ هائی تشکیل می شود که روی یا کنار همدیگر قرار داده می شوند. بنابراین مخلوط مذکور به شدت تحت تاثیر روش تراکم می باشد. نتیجه مطالعات مختلف نشان می دهد که چرخ غلطان تراکم خصوصیات صحرائی را بهتر شبیه سازی می کند. در این تحقیق، روش تورامسین به عنوان روش اصلاح شده متراکم کننده های غلطان دال ها در آزمایشگاه توسعه داده شد تا بتوان با استفاده از آن نمونه های آزمایشگاهی نماینگر مصالح واقعی متراکم شده در صحرا را تولید کرد. این مقاله یک تصویر کلی روش تورامسین را ارائه داده و دستاوردهای مرحله اول مطالعات را برای بدست آوردن مشخصات نمونه ها و اصلاح کارائی روش تراکم دال ها تشریح می کند. ضوابط متراکم ساختن دال ها در این روش تعیین می شود. روش تورامسین قادر است دالی به مساحت ۶۰۰ میلی متر در ۵۰۰ میلی متر را متراکم سازد در حالی که ضخامت براساس درخواست کارفرما است. تعداد گذرها از روی نمونه می تواند تا ۷۵ دفعه در مدت ۱۵ دقیقه باشد. یک دال متراکم شده می تواند تا ۱۶ نمونه هسته استوانه ای به قطر ۱۰۰ میلی متر تولید کند. این روش پتانسیل خوبی برای استفاده به عنوان یک روش استاندارد تراکم دال های مخلوط های آسفالتی در آزمایشگاه دارد و بنظر می رسد که توانائی شبیه سازی تراکم در صحرا را دارا باشد. به هر حال بهبود روش تورامسین نیاز به تحقیقات قابل توجهی دارد تا روش بهینه توسعه یافته و نهائی شود.

1. INTRODUCTION

Design procedures and specifications for pavement

mixtures, are usually derived from laboratory experiments, conducted on the same types of materials which are to be used in the field, since

laboratory conditions are less time consuming and relatively easy to control [1]. Therefore, laboratory experiments should be able to simulate the conditions, very close to what its like in the field, especially in terms of compaction procedures for asphalt mixtures. Method of compacting asphalt mixtures significantly affects the fundamental properties of the mixtures, such as bulk density and air voids.

Turamesin is a laboratory slab roller compactor which was developed in order to, enable laboratory compaction of a field simulation conditions, and thus provide a solution, to the problem of producing laboratory specimens, which would represent the materials laid and compacted in the field. Turamesin was designed as an improved method for compacting specimens that would match field compaction in terms of operational procedure. Therefore, Turamesin is expected, to simulate field compaction better than the existing laboratory compaction devices, such as Gyratory Shear Compactor and Marshall Impact Compactor [2].

The presently available laboratory compaction methods have intrinsic limitations, due to different modes in mechanical manipulation of the mixtures, and different energy levels of compaction, compared with the actual field compaction [1,3,4]. Several studies have concluded that Marshall Impact Compactor, California Kneading Compactor and Gyratory Shear Compactor have not been able to produce laboratory specimens, that can truly represent the mixtures, as it exists in the field, especially for Stone Mastic Asphalt (SMA) mixtures [5-9]. Thus, the presently available laboratory compaction methods will provide less accurate and unrealistic data to be used in pavement design and therefore, may lead to poor performance of pavement construction especially for SMA mixtures.

SMA mixtures is now, in regular use for surface courses in the United States, the United Kingdom, Germany, Austria, Belgium, Holland, the Scandinavian countries and Australia [10,11]. SMA is a type of asphalt mixtures, which is highly dependent on the method of its compaction, compared to conventional Hot Mix Asphalt (HMA) mixtures. As the future trends in asphalt pavement industry all over the world is gradually changing over to SMA due to its excellent

performance characteristics, hence a suitable laboratory compaction method, that can closely simulate field compaction is evidently needed. Conclusions of different studies have indicated that rolling wheel compactor simulates properties closer to field compaction than others [6,12,13]. However the available rolling wheel compactor is not widely used, as standard compaction device for mix design analysis, due to the difficulties in controlling air voids in the finished specimens. Tedious procedures for preparing and compacting specimens are expensive, bulky in size and not easily portable [3]. Therefore, Turamesin was developed as an improved laboratory compaction method, in order to provide a solution to the problem of laboratory compaction for field simulation conditions.

This paper gives an overview of the Turamesin and discusses the first phase findings of its' Pilot Study, conducted by researchers from University of Putra Malaysia (UPM). The purpose of the first phase Pilot Study, was to provide specific information, to improve the procedures for slab preparation, compaction, determining the criteria for slab compaction and also the performance of Turamesin and the compacted slabs. Nevertheless improvement of the Turamesin will take significant amount of research, to develop and finalize the optimum procedures.

Although Turamesin is designed to match field compaction, in terms of operational procedures, which includes rolling and vibrating the roller compactor, yet during the first phase of the Turamesins' Pilot Study the vibratory function was not included, as one of the determined parameters. The main objective in the first phase was to establish, the validity of the procedures, basic criteria for slab compaction, analyze the performance and uniform distribution of various properties in the compacted slabs. The major problem with any laboratory compaction method is that, the force imparted to the surface of the specimens and thus the properties of the compacted specimens, are not evenly distributed [14]. Therefore, the inclusion of the vibratory function as one of the determined parameters, will results in more complex analysis which is scheduled to be analyzed in the next phase of Turamesins' Pilot Study, after achieving the uniformity of the various properties in the

compacted slabs. Currently, a research for the second phase of the Turamesin Pilot Study is on the way, aiming to establish the vibratory function of the roller compactor, in terms of the optimum frequency and amplitude.

2. BACKGROUND OF TURAMESIN

Turamesin is used to compact asphalt mixtures using a steel wheel roller, just like the heavy duty steel wheel roller on-site. The compactor also provides variable slopes from 0° to 20° from horizontal plane for the purpose of skid resistance analysis and hydroplaning studies. Different levels of pressure can be applied up to approximately 785 kPa (114 psi) developed by a pneumatic system, supplied through air compressor. Turamesin has the overall length of 930 mm, width of 870 mm and height of 474 mm, measured from the frame base to the top of pneumatic tube, and weighted approximately 18 kg without the compacted slab. Figure 1 and 2 show the Turamesin and the schematic drawing in plan view. Turamesin consists of a rigid-steel frame at the bottom which supports the entire assembly and ensures a minimum deflection of slab mixtures, during compaction. Details of the specifications and also the functions of the main components of Turamesin are listed in Table 1.

3. CRITERIA FOR SLAB COMPACTION

As a newly developed compaction device, Turamesin does not have any standard procedure for slab preparation yet. In order to develop a standard procedure as a guide or manual in operating Turamesin, literature review on existing specimen preparation and compaction procedures were evaluated and adapted to suit the needs for Turamesin. The referenced documents were studied, in order to prepare some recommended procedures for materials preparation, such as aggregate, mineral filler and asphalt binder, also to develop a set of guidelines for mixing and compacting the asphalt mixtures. The referenced documents are as follows.

- AST 05: 2004 Sample Preparation-Compaction of Asphalt Slabs Suitable for Characterization.
- ASTM D1559-89 Standard Test Method for Resistance to Plastic Flow of Bituminous Mixture Using Marshall Apparatus.

As a result, the standard procedures for slab preparation using Turamesin was developed, and documented as a Method of Specimen Preparation of Asphalt Mix Slab using Turamesin. This document is a description of a method used by the Department of Civil Engineering, the University of Putra Malaysia to compact asphalt mix slab using Turamesin.

Based on the preliminary study, two variables of Turamesin were identified as being significantly important, in affecting the properties and performance of the compacted slab [2]. These variables are, the applied pressure and the number of passes made by the roller compactor. Also, based on the literature reviews and the past studies, the properties and performance of asphalt mixtures appeared to be most closely related to bulk density and air voids [15]. Attaining proper values of bulk density and thus air voids are critical to assure the long-term durability of asphalt pavement. Therefore, a study to find the effects, due to variation of applied pressure and/or number of passes of the roller compactor on bulk density and air voids were conducted in order to develop a correlation which would result in the optimum performance of asphalt mix slab.

A total of nine slabs were prepared in accordance with the Method of Specimen Preparation of Asphalt Mix Slab using Turamesin with different combinations of applied pressure and number of passes the compactor made, are shown in Table 2. Each compacted slab was then cut into nine blocks of equal size (166 mm×150 mm×70 mm) and analysis of bulk density and air voids were performed. Results of the analysis were then, analyzed to develop a correlation between the compactive efforts and properties of the compacted slab, in order to determine the appropriate values of the variables, in achieving the target air voids of 4 %. This target air voids (4%) was selected based on researches and past performances that showed the value is ideal for asphalt mixtures. Experiments have shown, asphalt mixtures must



Figure 1. Actual view of turamesin.

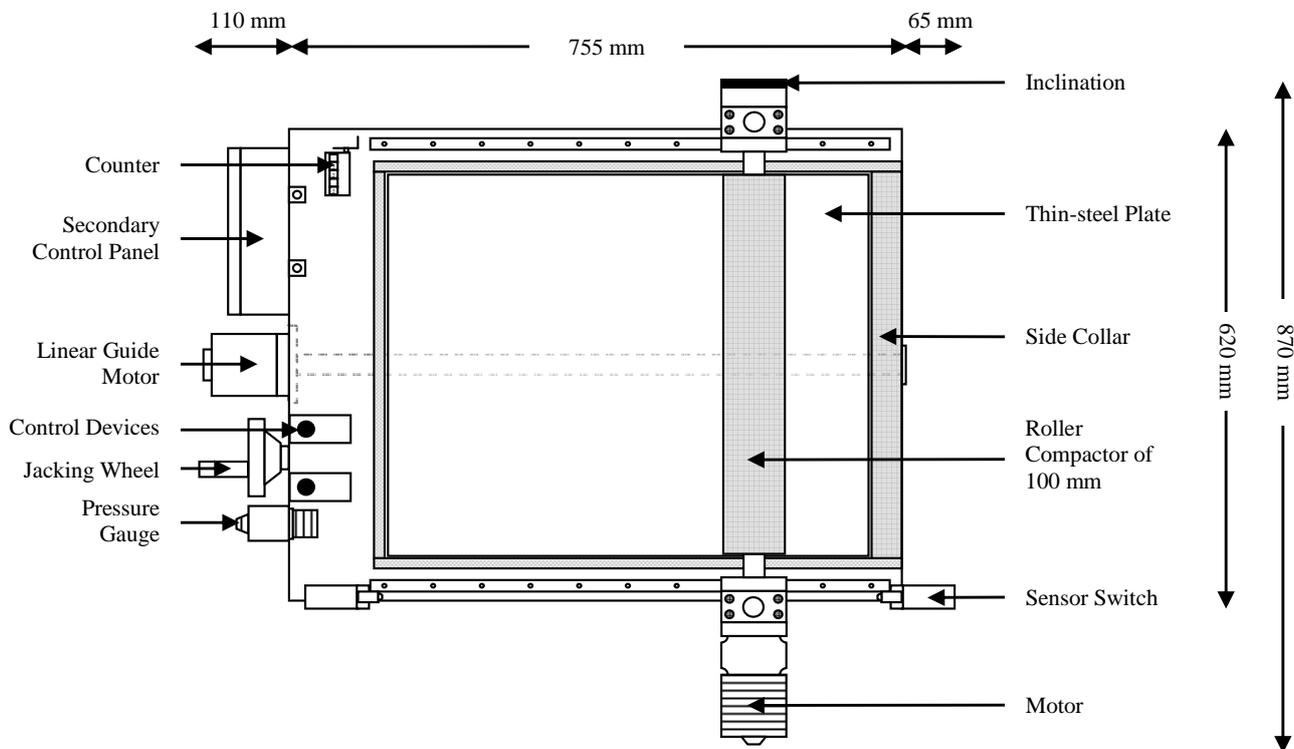


Figure 2. Schematic drawing of turamesin in plan view.

be prepared with an initial air voids of approximately below 8 %, in order to achieve above 3 % air voids content in the final stage after traffic. These values were confirmed by ASTM D2041.

Air voids obtained during mix design or from laboratory compacted specimens, should be an estimate of the final air voids, after traffic. Pavement is believed to reach its final air voids or ultimate density after 2 to 3 years of traffic, with

TABLE 1. Detail of the Specifications and Functions of the Main Components of Turamesin.

Components	Detail Specifications and Functions
<p>1. Pressure Gauge</p> 	<ul style="list-style-type: none"> • Pressure gauge is used to measure the applied pressure channeled to the roller compactor during compaction. • The applied pressure can be adjusted up to a maximum pressure of 785 kPa or 114 psi (8.0 kgf/cm²). • The pressure gauge meter is capable to give reading of applied pressure in unit of kgf/cm² and psi.
<p>2. Control Panel</p>  <p>Main Control Panel</p>  <p>Secondary Control Panel</p>	<ul style="list-style-type: none"> • Turamesin is controlled by a set of switches on main control panel. • The switches on the panel are used to control the main power supplied to Turamesin, required temperature to heat the bottom deck of the rigid-steel frame, and movements of the roller compactor, which consist of forward and reverse movement as well as rolling. • The main control panel is connected to secondary control panel, which is fixed at one end side of Turamesin. • The secondary control panel acts as an electrical circuit board related to motors, control devices, and sensors.
<p>3. Sensors</p> 	<ul style="list-style-type: none"> • A dual-side sensor guide system provides an alternate movement of forward and reverse, as the roller touches the sensors. • The sensors are placed on the side of mould frame at both ends and require a standard 240-volt of alternating current.

TABLE 1. Detail of the Specifications and Functions of the Main Components of Turamesin (Continue).

<p>4. Control Devices (AIRTAC Valve-Model 4H210-08)</p> 	<ul style="list-style-type: none"> • There are two units of control device that are placed side-by-side of each other. • These devices will control the raise and lower movement of roller compactor and wheel tracking roller separately. • Applied pressure that can be channeled through the control device is in a range of 0 kPa to 785 kPa.
<p>5. Roller Compactor</p> 	<ul style="list-style-type: none"> • A 75 mm diameter roller compactor is guided by a two-way motorized gear system that provides forward and reverse movement. • This alternate movement of forward and reverse is reflected by a dual-side sensor guide system. • The rolling speed of the roller compactor is about 10.5 rotations per minutes and is controlled by another motorized system.
<p>6. Wheel Tracking Roller</p> 	<ul style="list-style-type: none"> • A wheel tracking roller consists of two separate steel-wheels of 30 mm wide and a diameter of 75 mm. • Wheel tracking roller is loaded pneumatically by air compressor, and tracked back and forth over a compacted slab to induce rutting. • This device is detachable.

air voids contents of approximately between 3 % to 4 % [16]. Researches and past performances have shown that a final compacted air voids content of 4 % is ideal for asphalt mixtures. Therefore, the amounts of materials for each compacted slab were prepared, based on volume-density calculations with target air voids of 4 %. Results of the analysis were summarized in Figure 3.

All the tabulated data show a positive quadratic curvilinear relationship at which the bulk density

increases at a changing rate of, the number of passes made by the roller compactor, for each specified pressure, but this increase tapers off beyond 80 numbers of passes. Beyond this point, bulk density starts to experience a slow rate of increase and expect to reach a steady-state condition, which can be defined as ultimate density. Continued rolling beyond this point is wasteful and can even be detrimental to the paved finish, in some cases. Based on Figure 3, the

TABLE 2. Experimental Matrix for Different Combination of Compactive Efforts.

Number of Passes	Applied Pressure (kPa)		
	392 kPa (4.0 kgf/cm ²)	588 kPa (6.0 kgf/cm ²)	785 kPa (8.0 kgf/cm ²)
20	Slab 1	Slab 4	Slab 7
40	Slab 2	Slab 5	Slab 8
60	Slab 3	Slab 6	Slab 9

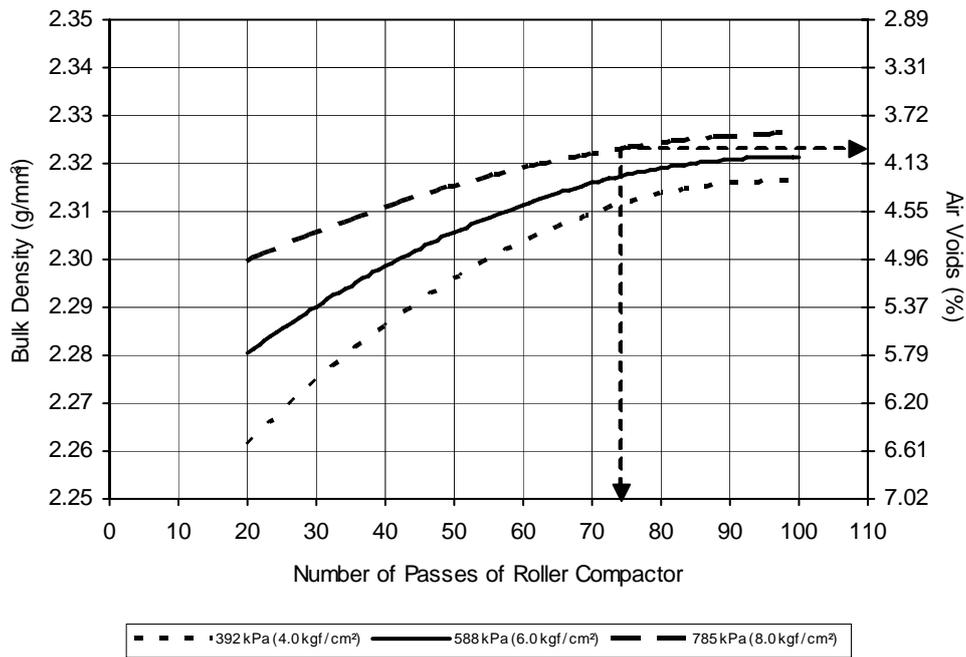


Figure 3. Correlation between compactive efforts (applied pressure and number of passes) and physical properties of the compacted slabs (bulk density and air voids).

desired air voids was achieved after applying 785 kPa pressure, with 70 to 80 numbers of passes made by the roller compactor.

By reducing the applied pressure to 588 kPa, the same value of air voids may still be achieved with higher number of passes by the roller compactor. Increasing the applied pressure above 785 kPa seems to be impossible due to maximum limit of the pressure gauge. Therefore, the optimum value for applied pressure, and the number of passes by the roller compactor, with the closest properties to in-service pavement,

due to 4 % air voids are suggested to be 785 kPa and 75 respectively. These values of compactive efforts were considered as typical parameters for Turamesin to achieve a target air void of 4 % by compaction. The selection of the applied pressure 785 kPa was made, based on the maximum limit of the pressure gauge and reasonable duration for compaction. Reasonable duration for compaction was based on the duration of the asphalt mixtures, to reach the lower temperature limit for effective compaction which is generally around 85°C.

4. PERFORMANCE TESTS AND ANALYSIS OF COMPACTED SLABS

Prior to this study, a total of 15 slabs were prepared, consisting of three different types of asphalt binders, namely Grade 60/70, Grade PG76 and Grade 80/100. A total of 162 core specimens were cored out from the compacted slabs and tested for various performance tests such as resilient modulus, Marshall stability and flow, rutting and fatigue cracking. These tests were conducted in order to determine the distribution of the properties in the slabs and thus to verify whether the mixtures are uniformly compacted using Turamesin, and also to evaluate the performance of three different types of asphalt mixtures, in order to determine whether the properties of the compacted slabs, meet the expected requirements by comparing with the obtained data and results, from past studies, binder properties and fields compacted specimens. Full details of the analysis and results of this study are reported in Jakarni [17].

Based on the various conducted performance tests, it was found that, the compacted slabs, using Turamesin, have uniformly distributed properties in terms of bulk density, air voids, resilient

modulus, Marshall stability, flow and also resistance to rutting. Thus, the results indicated that the asphalt mixtures were uniformly compacted and properties were evenly distributed throughout the slab. In terms of performances of the three different types of asphalt mixtures, it can be concluded that, the compacted slabs tend to agree with the expected performance properties and comparable to the ranges of performances, taken from field compacted specimens [17].

5. PERFORMANCE OF TURAMESIN

One of the most important observations that was made with regards to Turamesin is the compaction time. Based on an area of 600 mm by 500 mm, Turamesin seemed to be capable of fabricating the slab within, 15 minutes time, and for 75 numbers of passes. One compacted slab using Turamesin can produce up to 16 cylindrical core specimens of 100 mm diameter. When comparing the performances, in terms of number of specimens produced over time, Turamesin seemed to be well ahead of the other types of compactor as shown in Table 3.

TABLE 3. Comparison of Different Types of Compactor.

Type of Compactor	Compaction Time (minutes)	Number of Specimen Compacted per Compaction*	Rate of Compaction (Specimens Per Minute)
Turamesin	15	16	1.07
Marshall Impact Compactor	5**	1	0.20
Superpave Gyrotory Compactor	Depend on Traffic Level and Average Design High Air Temperature	1	-
French Plate Compactor	20-25	10-24	0.5-0.96
European Standard Roller Compactor	-	12	-

Note:

* Based on 100 mm diameter cylindrical specimen.

** Based on approximate time of 2-seconds per blow for 75 blows per side.

The procedures for preparing slab using Turamesin was simplified by the application of the rotary drum mixer as mixing apparatus. A total amount of aggregate-asphalt mixtures that are required to be prepared in order to produce one slab is approximately 50 kg which seems to be reasonable, in providing a total of 16 cylindrical core specimens of 100 mm diameter, within 15 minutes duration. The amount of materials required for slab compaction is calculated, using the volume-density calculations, with the predefined value of the target air voids. Therefore, air voids in the finished specimens, are expected to lie within the range of the predefined values of the target air voids and less likely to fall outside the range.

Turamesin provides a variable slope from 0° to 20° from horizontal plane for the purpose of skid resistance analysis and hydroplaning studies which can be conducted directly on the compacted slab. Turamesin also, provides a direct testing for the loaded wheel tracking analysis, through the detachable wheel tracking roller which consists of two separate steel-wheels of 30 mm wide and 75 mm diameter. In the next phase of the Turamesin Pilot Study, pressure sensors and strain gauge will be installed to monitor the distribution of the applied pressure from the roller compactor throughout the compacted slab and also to determine various performance behaviors of the compacted asphalt mixtures.

6. CONCLUSIONS

Based on the studies conducted, Turamesin has shown a great potential to be adopted as a standard laboratory slab compactor for asphalt mixtures and seemed to be capable in simulating field compaction in terms of operational procedures [2]. The dimension of 930 mm by 870 mm by 474 mm shows that Turamesin has a small size compared to other existing compacting devices. The advantages in terms of physical size, measured weight of approximately 18 kg and also the ease to assemble or disassemble, will make Turamesin the most suitable and portable device used in the field, for quality control operations. Although Turamesin is designed to match field compaction in terms of

operational procedures which includes rolling and vibrating the roller, nevertheless in the first phase of the Turamesin Pilot Study the vibratory function was not included as one of the determined parameters. As mentioned Turamesin is at its initial stages of development and would need significant amount of research to finalize the optimum procedures.

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