An Overview on Portable Roads and Airfields

Using of matting systems as temporary and semi-permanent roads and airfields

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Foreword

This report is not intended to be an extensive review of the literature or an all-inclusive state-of-the-art report on all types of available portable roads and airfields. Rather, the overall aim of this report is fourfold. Firstly, it is intended to provide a deeper understanding of some available types of portable roads and their applications; secondly, it is allocated to discuss the benefit and usage of matting systems used as portable airfield while the third part focuses on the results of some research carried out on matting systems. The next step to be taken to develop further the commercial portable roads and airfields mats is discussed in the fourth part of the report.

Although this report covers a wide range of matting systems used as roadways and airfields, there is still a need for studies on other types and new methods.

In addition, new research studies should be performed to develop further these products and make them lighter in weight, easier and faster in installation and can be used as semi-permanent roads and airfields. More knowledge about the sustainability and recyclability of the materials used in manufacturing the portable roads and airfields will enhance the spread of their use and hence ensure better transport fluidity and mobility.

Linköping, 2017

Dina Kuttah
Projectleader
Quality review

Internal peer review was performed April 2018 by Björn Kalman. Dina Kuttah has made alterations to the final manuscript of the report. The research director Björn Kalman examined and approved the report for publication 6 September 2019. The conclusions and recommendations expressed are the author’s and do not necessarily reflect VTI’s opinion as an authority.

Kvalitetsgranskning

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Summary

An Overview on Portable Roads and Airfields. Using of matting systems as temporary and semi-permanent roads and airfields

by Dina Kuttah (VTI)

Matting systems used as roadways and airfields are new innovative techniques used to solve mobility problems and make it easier to get around and transport goods under different climate and traffic conditions. The portable roads are extremely versatile and can be used for servicing areas with poor ground conditions, heavy load requirements and high traffic density. They could be used to facilitate vehicular access into areas that contain saturated soils, wetlands or soft/poor subgrade conditions and make secluded areas accessible (remote regions in general.).

Moreover, portable roads can be used as temporary roads for emergency situations to enable aid deliveries to disaster areas, or during maintenance of existing roads or as temporary roads during a traffic jam.

Regarding the portable airfields, some portable runways have been developed to support the heavy rolling loads, including heavy unmanned aircrafts and heavy maintenance equipment. Most of the available portable airfields are used in remote areas where existing runway or airport infrastructure is limited or non-existent. The use of mats to construct an airfield depends on many factors, such as ground conditions, the type and weight of aircraft being deployed, the expected usage levels, and the time available to construct the airfield.

The objective of this report is to provide a practical perspective on construction and performance characteristics of some available portable roads and airfields systems that can be used to solve temporary and semi-permanent transport problems. Literature results are presented to educate the readers on available systems’ types and the best uses of each system in different applications.

This technique is relatively new and requires more investigation and evaluation by testing the bearing capacity of different types of portable roads subjected to long-term heavy traffic and their long-term performance under different weather conditions to test their suitability as semi-permanent roads. It is important to determine to which extend the mates could withstand the weight of heavy equipment under intensive usage, if they are a dust-free alternative to unpaved roads and if they are capable to reduce the driving noise and the tire wear and if they could be used as alternatives for asphalt roads in rural areas.

Further research is required to develop design standards and user manuals for portable roads and airfields to provide the contractors with the design requirement, bearing capacities, long-term durability and usage suitability for the different types. With respect to the portable airfields, it is still required to minimize the weights and increase the deplorability of airfields mats so that they could be more easily transported by smaller aircrafts to remote areas.

Evaluating the validity of using mats as a cost-effective transport alternative and examine the ability of matting systems to withstand climate changes have become essential for a better understanding of their functionality and use.
Sammanfattning

En översikt om portabla vägar och flygfält. Användning av mattor som tillfälliga och semipermanenta vägar och flygfält

av Dina Kuttah (VTI)

Portabla vägar och flygfält är nya och innovativa tekniker för att hålla transportvägar öppna under svåra klimat- och trafikförhållanden. De portabla vägarna är extremt mångsidiga och kan användas till serviceområden med dåliga grundförhållanden, höga lastkrav och stor trafikintensitet. De underlättar fordonstrafik till områden med vattenmättade jordar, våtmarker eller andra områden med mjuka/dåliga undergrundsförhållanden och gör avskilda områden tillgängliga (ofta i avlägsna trakter).

Dessutom kan portabla vägar användas som tillfällig vägar i akutsituationer för att möjliggöra nödleveranser till utsatta samhällen, vid underhåll av befintliga vägar eller som tillfälliga vägar vid trafikstockning inne i städer.

Beträffande flygfält har en del portabla start- och landningsbanor utvecklats för att klara tunga rullande laster inklusive obemannade flygplan och tunga underhållsutrustningar. De flesta av de portabla flygfälten används i avlägsna områden där ”flyginfrastrukturen” är begränsad eller saknas helt. Hur underlaget (mattorna) till flygfältkonstruktioner görs, beror på många faktorer, t.ex. grundförhållanden, flygplanstyper och dess laster, förväntad användning samt tillgänglig konstruktionstid av flygfälten.

Målet med den här rapporten är att ge en inblick på konstruktion och prestanda hos de portabla väg- och flygfältssystem som finns för att lösa tillfälliga och semipermanenta transportproblem. Resultatet av litteraturstudien visar på de tillgängliga typer av system som finns och hur de bäst ska användas (i olika applikationer).

Området är relativt nytt och det krävs mer undersökningar och utvärderingar av till exempel bärighetsförmågan för olika typer av portabla vägar för att säkerställa att de klarar den tunga trafiken i olika väderförhållanden och över tid, särskilt om de ska användas som ”halvpermanenta” lösningar. Det är viktigt att fastslå hur dessa underlag (mattor) motstår intensiv användning av tunga fordon och om de är danningsfria alternativ till obelagda vägar. Andra aspekter är hur de samverkar med däck vad gäller buller och slitage och om de kan användas i stället för asfalterade vägar i landsbygdsområden.

Fortsatt forskning är nödvändig för att utveckla designstandarder och användarhandböcker för portabla vägar och flygfält. De behövs för att ge entreprenörerna designkrav, bärighetsförmåga, hållbarhet (över tid) och lämpliga användningsområden för de olika typerna. Dessutom för att lättare kunna transportera och anlägga de portabla flygfälten i avlägsna trakter behöver de minska i vikt samt att möjligheten till att snabba upp och förenkla montering ökar.

Kostnadseffektiviteten för dessa system som alternativ till ”normala” konstruktioner samt deras användbarhet som permanent öppna rutter borde studeras vidare bl.a. med tanke på kommande klimatförändringar.
1. Introduction

It is well known that the European transport network is highly developed, but some links are still missing while other links have under-capacity compared with traffic evolution.

These new portable roads and airfields mats which are also known as matting systems, can be used to keep routes open under different man made or extreme natural conditions. Some types can be used for servicing areas with poor ground conditions, heavy load requirements and high traffic density.

Portable roads can be used as temporary roads for emergency situations to enable aid deliveries to disaster areas or during maintenance of existing road or rerouting.

The problems of traffic jams can be solved easily by using temporary portable roads in congestions. These roads can be laid down immediately and provide temporary access (roads) for cars and construction vehicles in order to instantly reduce the traffic congestion. Sometimes it takes only few minutes to deploy a temporary portable road by means of a fast deployment tool.

To better connects the isolated remote regions in many European regions to the local transport network, one could use portable roads as semi-permanent roads. This action will facilitate the mobility between the isolated regions and the local transport network by assisting vehicle mobility across difficult terrain.

In addition, portable airfields can be used in remote areas where existing runway or airport infrastructure is limited by using matting systems as aprons, taxiways and runways in rural areas.

Few temporary runways have been developed to support the heavy aircrafts loads, including unmanned aircrafts and heavy maintenance equipment. Note that some new versions of unmanned aircrafts are relatively heavy. They may reach 4–5 tons in weight and may carry additional 1–1.5 tons. Research is required to make them ideal for long duration projects, performed better over low bearing capacity ground and easy to install and remove.

Using of matting systems as roadways and airfields have faced several problems concerning the lack of design and user manuals and insufficient studies related to LCC and LCA analysis. Studies concerning the long-term performance of different mats are required to standardize their suitability to be used as temporary roads and airfields. Unfortunately, very little attention has been paid to develop the matting systems used as roadways and airfields as compared to the efforts allocated to develop the traditional roads and runways (e.g. asphalt and concrete roads and runways).
2. Portable Roads

In contrast to asphalt and concrete roads, the laying down of portable roads have low environmental impact and they can be removed easily and reused in another place where required. Portable roads could be used as a sustainable and cost-effective alternative for asphalt and concrete roads, see Figures 1 and 2.

![Portable roads used as temporary accesses on grass mate. Photo by RVM Vehicle Mobility.](image)

*Figure 1. Portable roads used as temporary accesses on grass mate. Photo by RVM Vehicle Mobility.*
In the next sections the most common available types of portable roads, the methods of installations and the applications for different types according to their manufacturers’ recommendations, are discussed.

2.1. Types of some available portable roads

The composition of matting systems may include pipes, disposal of rubber tires, wood, aluminum, high-density polyethylene, woven polyester textile, fiberglass and other materials.

Mason and Greenfield (1995) reported that pipe matting system made of PVC pipes and steel wire rope can be used in forest areas and some types are capable of withstanding direct loads up to 826 kPa.

Regarding matting systems made of disposal of rubber tires, Mason and Greenfield (1995) reported that tires are very durable and have long-life attributes, which make them suitable for a portable and reusable crossing of weak soils. The mats are heavy, flexible, but tend to curl under at the ends.

Some modular matting systems are made from high-quality, high-strength hardwoods which can handle the weight of heavy machinery. The prefabricated hardwoods mats can be used to provide easy access to wetlands when erecting transmission lines (Schweitzer and Marinello, 1996). Wood construction platforms (also known as wood mats or wood matting systems) boast numerous uses, including supporting heavy machinery, such as cranes, over soft soils. They have also been used to construct low-volume, temporary roads in which there is no need or desire for permanent access. (Stroble III, 2009 and Stroble III et. al, 2012).

Different types of aluminum road mats are available in the market, for example, rolled mats made of rectangular aluminum tubes connected by a flexible composite material and hexagonal aluminum interlocking panels. Aluminum roadways are relatively heavy but capable of providing heavy-duty access for vehicles (Rushing and Howard, 2011).

Furthermore, several types of matting systems are made of high-density polyethylene and they are available in the form of rolled mats or as rectangular or hexagonal interlocking panels of different
installation methods. Most of the high-density polyethylene mats are considered as medium-duty roadways and are relatively light in weight compared to aluminum mats. The moving and installation of these mats are easy, and the transport costs are relatively low (Rushing and Howard, 2011).

Woven polyester textile and fiberglass have been used also to manufacture flexible portable roadways that can carry a limited number of vehicles passages and able to withstand reasonable ground conditions (Rushing and Howard, 2011). However, according to some manufacturers, some types of woven polyester textile and fiberglass have been developed to carry heavy equipment and able to withstand severe ground conditions.

2.2. System installation methods

It is important to mentioned that most of the matting systems used as portable roads are easy to install. For some types, the installation of mats could be as easy as rolling out a mat over the floor in your house, they can also very easily be removed and transported to another place for reuse.

System installation methods included continuous or segmented rolls of material, and connection of individual panels (panel-type systems). Figure 3 below shows the process of laying individual wood panels to construct a temporary road, while Figure 4 shows deployment method of continuous rolls roadways.

![Figure 3. Segment panels portable road. Photo by Autotruk 2013.](image)
Deployment of portable roads rolls can be done manually or by using deployment tools. With the help of deployment tools, a portable road for even heavy equipment can be laid out in minutes. This action gives a big advantage for temporary roads construction as compared to the time required to construct permanent roads (asphalt or concrete) that may not be necessary in rural areas or when instant access roads are required to solve temporary traffic jam problems.

2.3. Uses/applications for matting systems

Rushing and Howard (2011) reported many usages of matting systems during their long-term research in this field. According to Rushing and Howard (2011), matting systems have a wide variety of uses on low-volume roads, including temporary surfaces for construction platforms, sandy or muddy stream crossings, bridging muddy areas caused by flood or high water, protecting natural vegetation in environmentally sensitive areas, temporary- or permanent-haul roads (e.g., forestry and mining), military applications, and disaster recovery.

It is well known that gravel and unpaved roads are viable and important components of the road transportation network throughout the world (Mahgoub, 2011). Unfortunately, unpaved roads suffer different problems, like corrugation, or washboarding and dust generating something which require continual maintenance to control these problems (Alzubaidi, 1999 and Mahgoub, 2011).

In some rural areas, to better connect some isolated regions to the local transport network, decisions have been taken to upgrade and pave gravel roads with asphalt mixes. This action encounters a problem of increasing costs of maintenance of asphalt roads (Jahren et. al., 2005). In such cases, one should think of using portable roads as a good alternative for asphalt roads to upgrade gravel roads. Simply, the portable roads are of faster deployment as compared to asphalt roads. In addition, using of portable roads as semi-permanent roads to upgrade the existing gravel roads will reduce the maintenance work on gravel roads including re-graveling, dust control/stabilization, but on the other hand, portable roads may suffer from other technical problem that require maintenance. It is known that dust thrown up from a passing vehicle on gravel roads reducing visibility and therefore increase the risk of accidents. Moreover, new research shows that prolonged exposure to certain minerals in gravel such as that raised from driving on gravel roads causes a lung cancer (Ryan et.al., 2011 and
Science Daily, July 26, 2011). These disadvantages of gravel roads could be eliminated by using portable roads. Furthermore, using of matting system may reduce the frequent maintenance of gravel roads during the wet period which in turns reduces the maintenance costs and increases the lifetime of the gravel roads. Wheel motion on gravel roads shoves materials to the outside (as well as in-between travelled lanes), leading to rutting (Kuttah 2016 and Kuttah and Arvidsson 2017), reduced water-runoff, and eventual road destruction if unchecked, using of matting system will help to prevent stones from cutting and puncturing tires, or being thrown up by the wheels and they prevent skidding on mud after rain also. In addition, using of matting system may lead to a reduction of noise, rolling resistance and particles diffusion by improving the gravel road surface texture which in turn reduces the vehicle’s vibration, but this assumption needs to be proven by real tests. On the other hand, the portable roads may suffer from inadequate friction problem specially during wet seasons. This issue should be studied in depth for each particular portable road type.

Furthermore, improving the surface texture can reduce sufficiently the tire wear as compared to the gravel road and thus reduce the energy consumption and hence reducing the tire -pavement interaction, but this improvement in the texture should not be at the expense of reducing friction. Here, it is important to mention that driving on gravel roads requires more attention to the variations of the road surface besides the fact that it is easier to lose driving control on gravel roads than on surfaced roads. Since potholes, ruts and loose stony or sandy ridges at the edges or in the middle of the road could be encountered on gravel roads (Skorseth and Selim, 2000 and Huntington and Ksaibati, 2010), this will cause further loss of driving control which in turn affects negatively the driver and the road user safeties. One of the most benefits of matting system is its usage for rapid construction of roadway surfaces in areas where traditional construction practices are too costly and time consuming or environmental concerns prohibit the disturbance of native materials (Rushing and Howard, 2011). The U.S. military uses matting systems extensively as a means of quickly building roads across beaches and mudflats to carry supplies and equipment to forward operating bases. According to Rushing and Howard (2011) the poor terrain conditions may not cause vehicle immobilization due to the capabilities of military equipment, but they may result in reduced logistical throughput and excessive wear on the equipment.

For this reason, mat-surfaced roads are used to assist vehicle mobility across difficult terrain. Matting system can be used in work areas also, since they are immediately deployable and will efficiently stabilize the work areas in gravel roads to permit vehicular load and provide clean work areas. This in turn will improve the workplace safety and increase the driving safety within the work areas during high rainfall. Obviously, construction sites inside cities may cause serious traffic jams. In this case, the portable roads can be laid down immediately in the areas close to the construction areas and provide temporary access (roads) for cars and construction vehicles to reduce instantly the traffic congestion. The Dutch Ministry of Transport, Public Works and Water Management has formed a project team to find short term solutions to reduce traffic jams. This project team is called "File proof". One of the most promising solutions now is the project called "Verplaatsbaar wegdek" (RVM vehicle mobility, cited in December 2016). This is an instant road to be placed in the soft shoulder to create a diversion around an accident or something else blocking the motorway. This means fewer, faster, more sustainable and better planned interventions to reduce risks associated with traffic jams. When the temporary project is completed, the mats can be easily removed from the current place, transported and used again elsewhere, so the portable roads are reusable.

In addition, portable roads can be used as temporary car parks everywhere, for example on grass as shown in Figure 5. Which type to be use depends on ground conditions, location and access.
Some types of portable roads are particularly suitable for the construction industry as they can take heavy loads over soft ground as shown in Figures 6 and 7.

As shown in Figure 7 below, portable roads can be used as temporary surfacing for existing roads when the road structure has been weakened by heavy rain or snow-thawing effect.
In selecting a mat item for a particular field application, different circumstances must be considered. Rushing et. al (2007) reported that rolled mats may offer advantages in rate of deployment and where uneven terrain is encountered. On the other side, heavy rolled mats may be difficult to unroll up an inclined grade by hand. With respect to the matting system’s ability to provide a radius of curvature in the roadway, Rushing et. al (2007) added that the modular mat systems of smaller panel size results in smoother curves and less unutilized surface area. Maintaining adequate horizontal alignment is very important issue in controlling the driving safety on roads as empathizes by Zilioniene and Vorobjovas, 2011).
3. Portable Airfield and Helipad Matting

Since the European transport network is not fully balanced between regions and countries, some links are still missing, and an effort is needed to complete trans-European connections.

Economic restructuring processes, aging and migration of many young people have led to a significant decrease in population in many rural areas of Europe which consists about 93% of EU territories (Clotteau, 2014). Clotteau (2014) reported that facing this migration problem started by increasing the attractiveness of these regions by encouraging sustainable mobility for all which can be achieved by finding new cheaper transport routes, such as portable airfields. Unfortunately, some of the countries with low economic activity cannot realize their economic potential because there is no efficient supply of materials needed for agricultural or industrial production, or because they cannot move finished goods efficiently to clients. This leads to under-utilization of resources in certain regions and concentration of economic activities in other regions beyond an economically and socially efficient level.

Sometimes it is difficult to provide access to some places due to the temporary nature of their location, therefore, some matting systems have been designed to be installed and removed quickly and to provide a good solution when they can be used as helipads temporary roadway for helicopters, as shown in Figures 8 and 9.

![Figure 8. Temporary Roadway for Helicopter. Photo by Autotrak 2013.](image_url)
Currently, few attempts have been carried out to use matting system as a temporary taxiway to move the airplanes (which require some maintenance) from the runway, see Figure 10.

Using matting systems as aprons, taxiways and runways in rural areas will encourage the mobility for all, therefore, a special attention should be made to develop low cost airfields to fit some aircraft requirements to ensure quick and reliable transport of raw materials and finished goods to rural areas of Europe and European countries of low economic growth. This action can contribute to reduce the migration of many young people from regions with low economic activities.
4. Overview on related research

Different researchers have been studied data for many roadways and airfields matting systems to determine the systems’ suitability for low-volume-road applications or as expedient road surfacing for crossing scenarios when sandy or weak, fine-grained soils are encountered. The results of tests available in the literature have generally showed that control sections strongly indicate that roadway matting systems offer great advantages over an unprotected subgrade; however, some systems provide greater benefits than others under specific conditions as summarized in Table 1.

Table 1. Comparison between different portable roadways and airfields types as given in the literature.

<table>
<thead>
<tr>
<th>Type of the mat (Reference)</th>
<th>Type of the subgrade soil underneath the mat during testing</th>
<th>Suitability/Advantage</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>The ROLLAROAD™ MKIII (Rushing et. al, 2007)</td>
<td>Uniform sand of 15% CBR</td>
<td>Rapid deployment and moderate cost</td>
<td>Performed poorly, and its unit weight and unit volume were average for the sampled mats tested by Rushing et. al. (2007)</td>
</tr>
<tr>
<td>The Rover Deck™ item (Rushing et. al, 2007)</td>
<td>Uniform sand of 15% CBR</td>
<td>Relatively compact, expedient, inexpensive, and may serve well for lightweight vehicular traffic</td>
<td>Ride quality may be poor and incurred heavy damage at high traffic levels</td>
</tr>
<tr>
<td>The Fast Composite Roadway (FCR) (Rushing et. al, 2007)</td>
<td>Uniform sand of 15% CBR</td>
<td>The best performer under traffic of the nine items tested by Rushing et. al (2007)</td>
<td>It presented the greatest logistical burden (considering both unit weight and volume) as well as extremely high cost among the sampled mats tested by Rushing et al. (2007)</td>
</tr>
<tr>
<td>The plastic hexagonal item (Rushing et. al, 2007)</td>
<td>Uniform sand of 15% CBR</td>
<td>The lowest cost of the items tested by Rushing et. al (2007) and second lowest weight</td>
<td>Rutted rapidly under traffic</td>
</tr>
<tr>
<td>The aluminum hexagonal item (Rushing et. al, 2007)</td>
<td>Uniform sand of 15% CBR</td>
<td>Performed very well after moderate initial Rutting</td>
<td>It is the heaviest and most expensive of the items tested by Rushing et. al. (2007) and the slowest to install</td>
</tr>
<tr>
<td>The BRAVO® Mat system (Rushing et. al, 2007)</td>
<td>Uniform sand of 15% CBR</td>
<td>Performed very well under traffic</td>
<td>It was the third heaviest mat and occupied the second most volume per unit area among the mats tested by Rushing et al. (2007). Installation was relatively slow, and its cost was moderate</td>
</tr>
<tr>
<td>Type of the mat</td>
<td>Type of the subgrade soil underneath the mat during testing</td>
<td>Suitability/Advantage</td>
<td>Disadvantage</td>
</tr>
<tr>
<td>--------------------------------------------------</td>
<td>-------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>The ACE-Mat™ test item (Rushing et. al, 2007)</td>
<td>Uniform sand of 15% CBR</td>
<td>- The mat was stiff and largely elastic so that it bridged the underlying ruts in the sand. It performed very well under traffic, incurring no damage. -Mild logistical footprint and of moderate cost</td>
<td>There was some minor damage in the sense that some connectors became loose.</td>
</tr>
<tr>
<td>The DuraDeck item-HDPE panels (Rushing et. al, 2007)</td>
<td>Uniform sand of 15% CBR</td>
<td>- It exhibited moderate performance under traffic with no permanent damage. - Its cost was second lowest among the items examined by Rushing et. al (2007).</td>
<td>Installation was slower than average.</td>
</tr>
<tr>
<td>The Mobi-Mat® A2X item (Rushing et. al, 2007)</td>
<td>Uniform sand of 15% CBR</td>
<td>Exhibited the best logistical footprint, offering the lowest weight, smallest volume, and fastest deployment of all items tested by Rushing et. al (2007)</td>
<td>- Rutted heavily, demonstrating the worst performance under sustained truck traffic. - Its cost was greater than average.</td>
</tr>
<tr>
<td>The Supa-Trac matting system (Rushing et. al, 2009)</td>
<td>Uniform sand of 15% CBR</td>
<td>Rut development was slow. Failure mark had not been achieved after traffic was concluded at 3,500 passes</td>
<td>Few plastic retainer clips were broken.</td>
</tr>
<tr>
<td>The Supa-Trac matting system (Rushing et. al, 2009)</td>
<td>High plasticity clay (CH) of 7% CBR</td>
<td>- With respect to the rut depth, the system performed satisfactorily over a CBR of 7 or greater - After 2,000 passes, no mat damage was noted</td>
<td>-</td>
</tr>
<tr>
<td>The Supa-Trac matting system (Rushing et. al, 2009)</td>
<td>Low -plasticity clayey silt ML-CL with CBR of 1-3%</td>
<td>- Ruts formed rapidly during trafficking. - The Mat breakage exceeded the 20% failure criteria of both Supa-Trac test sections after only one pass</td>
<td>-</td>
</tr>
<tr>
<td>The Mobi-Mat® A2X item (Rushing and Howard, 2011)</td>
<td>Low -plasticity clayey silt ML-CL with CBR of 1-3%</td>
<td>Increase the traction and slip resistance of vehicles in muddy subgrades</td>
<td>- The rut depth reached about 18 cm after one pass - Not recommended to be used in clayey soils</td>
</tr>
<tr>
<td>Type of the mat (Reference)</td>
<td>Type of the subgrade soil underneath the mat during testing</td>
<td>Suitability/Advantage</td>
<td>Disadvantage</td>
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<tr>
<td>The AM2 Single Aluminum⁴, the M19 Aluminum Honeycomb⁴ and the Aluminum Honeycomb Composite (Garcia and Howard, 2016)</td>
<td>High plasticity clay (CH) of 6%±1% CBR</td>
<td>Worked well at distributing the applied load so that a fraction of it was experienced by the subgrade</td>
<td>Mat breakage occurred quickly without advanced warning and created tire hazard that required panel replacement immediately</td>
</tr>
<tr>
<td>Carbon Fiber Composite (Garcia and Howard, 2016)</td>
<td>High plasticity clay (CH) of 6%±1% CBR</td>
<td>With respect to the rut depth, the system performed very well and better than any of the other matting systems tested by Garcia and Howard (2016)</td>
<td>Mat breakage occurred quickly without advanced warning and created tire hazard that required panel replacement immediately</td>
</tr>
<tr>
<td>MLC-70 Trackway (Garcia and Howard, 2016)</td>
<td>High plasticity clay (CH) of 6%±1% CBR</td>
<td>Had no mat breakage</td>
<td>Reached 3 in (7.6 cm) of deformation after only 350 passes.</td>
</tr>
<tr>
<td>Aluminum Truss (Garcia and Howard, 2016)</td>
<td>High plasticity clay (CH) of 6%±1% CBR</td>
<td>The internal support provided by the “truss-like” members appears to be a key contributor to preventing excessive subgrade deformation</td>
<td>Mat breakage occurred quickly without advanced warning and created tire hazard that required panel replacement immediately</td>
</tr>
</tbody>
</table>

For expedient road surfacing for beach crossing scenarios, Rushing et. al (2007) tested a full-scale test section of each mat system. Each mat system was trafficked with a fully loaded 7-ton military truck. Mat deformation and damage were monitored at traffic level intervals up to 2000 truck passes. The failure criteria were defined as (1) the rut depth in the wheel path exceeded 3 in. (7.6 cm) or (2) more than 20% of the mat surface sustained physical damage.

With respect to the mats used for expeditionary roads, as tested by Rushing et. al. (2009), each mat system was trafficked with a fully loaded 7-ton military truck. Mat deformation and damage were monitored at traffic level intervals up to 3500 truck passes. The failure criteria were like the one defined by Rushing et. al (2007).

For low volume roads applications, Rushing and Howard (2011) tested the Mobi-Mat® A2X mat system using loading system and failure criteria similar to those adopted by Rushing et. al (2007).

Regarding the airfields applications for matting systems tested by Garcia and Howard (2016), the loading system consisted of a load cart designed to simulate a fully loaded F15E aircraft. The cart was loaded such that the test wheel was supporting half of the main gear load (i.e., 156 kN) and the data monitored at traffic level up to 1500 passes. The failure criteria adopted by Garcia and Howard (2016) for simulated F15E traffic were either (1) 10% mat breakage or (2) the development of 3.18 cm (1.25 in.) of permanent surface deformation.

Note that researchers have used different tests equipment and tests approaches to achieve the results summarized in Table 1, therefore results of one researcher does not correlate with the other.
5. Conclusions and Recommendations

5.1. For matting systems used as portable roadways

Typically, the portable roads have only thin structural layers, resting on subgrades of variable quality including also soft clays and peatlands. These roads are occasionally exposed to very high axle loads of heavy trucks serving the transportation needs of local industries, farming, forestry, fishing etc.

Unfortunately, this technology has so far limited use in Europe due to the uncertainty that the contractors have with respect to the deformation characteristics and bearing capacity issues of the portable roads as compared to the information available with respect to asphalt, concrete and stone pavements.

In order to improve the applicability of portable roads, a good understanding of the material used with respect to the terrain properties on which it is to be used is required in terms of mats flexibility, fast deployment and recovery, light weight, re-usable, recyclable, durability.

Providing design, construction and maintenance techniques of temporary and expedient road pavements that are sustainable (due to the possibility of very high percentage re-use) will contribute to development and application of effective and efficient materials, technologies and tools used to fulfil the sustainability goals.

It is important to apply a risk and reliability assessment framework to allow those who deploy road pavements to cost-effectively manage and decrease risk of distress during use. So, enhancing the use of matting systems used as roadways will provide innovative approaches for transport.

This will permit highway and transport authorities and their contractors or agents to provide extra, temporary lanes during planned or emergency roadwork to reduce congestion during maintenance and related activity. This in turn will reduce air pollution, and carbon dioxide (CO₂) emission and car noise caused by traffic jams. The development of portable roadways (matting systems) will open the doors for alternative solutions and materials that can be used to reduce traffic disruptions of transport flows from inspection, construction and maintenance activities.

Furthermore, it is important to evaluate the possibility of using portable roads as temporary or semi-permanent surfacing for existing roads when the road structure has been weakened by heavy rain or snow thawing effect. The condition of the gravel road network varies a lot; especially during thaw weakening periods when the maximum axial load should be reduced on some roads. As a result, one should verify the possibility of using matting technology in order to improve the conditions of gravel roads in Europe. This usage of portable roads may extend the life span of ageing transport infrastructure (roads), or at least provide extra time before repairs are done.

5.2. For matting systems used as portable airfields

It is costly to connect the European rural regions by building a complete and well-designed airport in each village but using the developed matting system will help in solving the problem and enable better and economical transport between the European remote regions.

It is well known that the Internet provides companies and consumers around the world, even in the remotest areas, to buy, sell and pay for goods. There's almost no difficulty for a tradesman in Thailand to sell his goods to a customer living in a remote area in Europe, but the problem is getting the goods to Europe in a cheap, reliable and timely way. This can be achieved by developing low cost airfields using matting systems which will extend considerably the air trade system in many remote areas in Europe.

The matting systems used as portable airfields should be easy to build anywhere, with as many standardized components as possible. This applies to run- and taxiways, and terminal aircraft.
guidance. The required investment should be low risk, for example, by making as many components as possible re-usable. The operating cost structure should be so that no high utilization is required to maintain a minimal level of profitability. An added advantage would be if the airport can be set up quickly, possibly with a short provisional runway that can later be expanded if needed.

The portable airfields are considered as a new technical system which leads to increasing infrastructure capacity and optimizing maintenance costs for air transport mode and contribute to low energy construction and maintenance of existing infrastructure in Europe.
References


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