RUNWAY SAFE

# greenEMAS

## Engineered Material Arresting System

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## greenEMAS - the locally-assembled foam glass system

**greenEMAS (Engineered Material Arresting System) is a sustainably-designed passive safety system that decelerates an aircraft, bringing it to a safe stop in case of an overrun. It is often referred to as "the locally-assembled foam glass system", since its main arresting component is foam glass – also known as silica foam – for which Runway Safe uses 100% recycled glass.**

**The patented greenEMAS is built on-site and is designed to give optimized performance, tailor-made to fit a runway and to accommodate an airport's specific aircraft fleet mix. greenEMAS is a superior safety solution that is sustainable over a long period of time, as well as being an environmentally friendly alternative.**

### greenEMAS: accepted since 2014

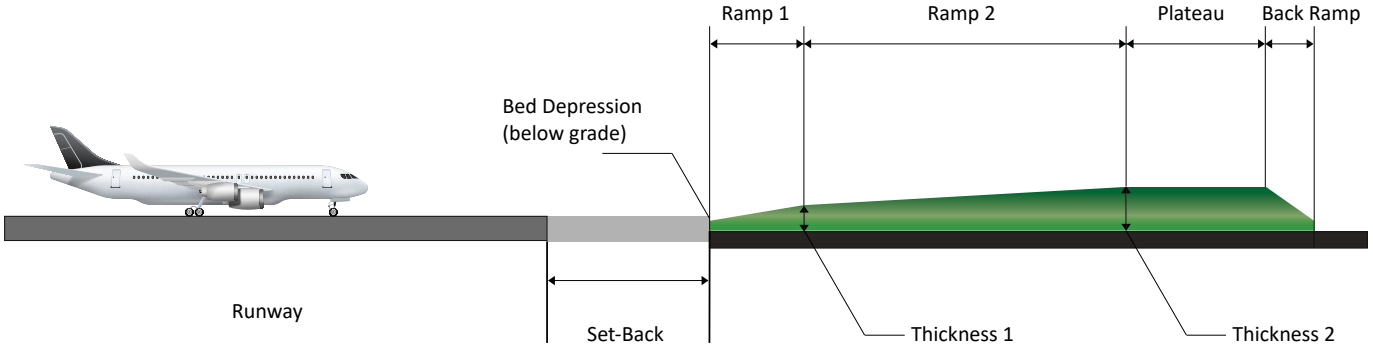
The greenEMAS bed is assembled on-site using local workforce and local materials, apart from the foam glass which is shipped to the location. It has been installed at airports all over the world with the purpose of saving human lives, as well as assets and infrastructure, in the event of an overrun. greenEMAS meets the demands set by several aviation authorities including those in the US-FAA, Swiss-FOCA, Japanese-MLIT, French-DGAC, UK-CAA, UK-MAA and Brazil-ANAC.

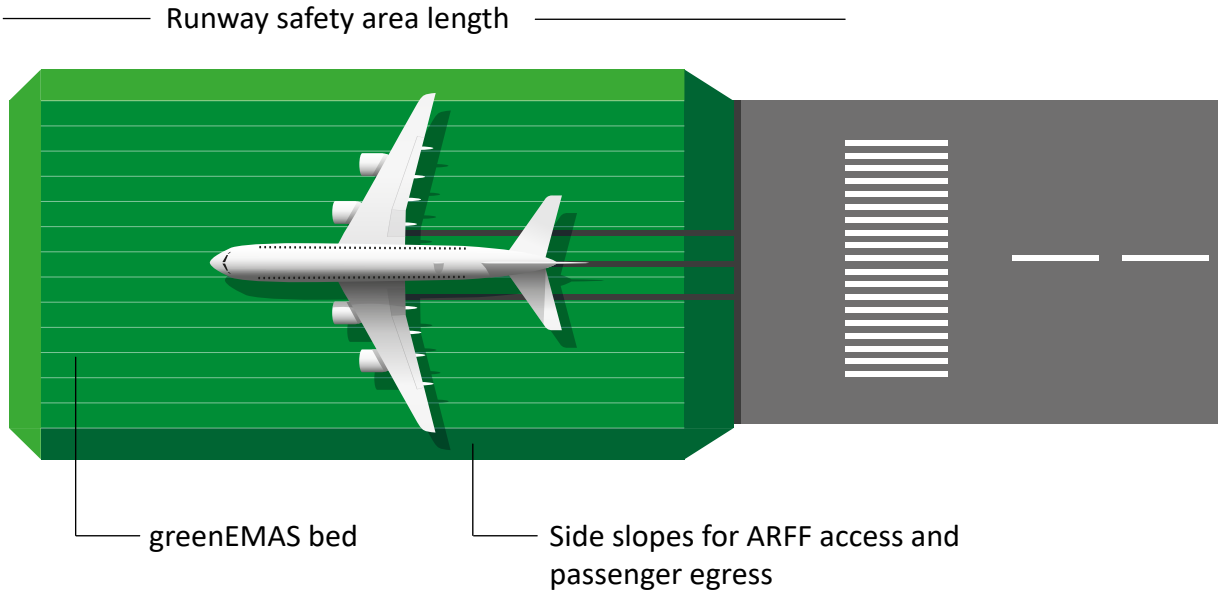
Supported by many years of extensive research and development and field experience, each installation is uniquely suited to its location. Thanks to numerous overrun tests and using various aircraft configurations, we have the data to design the very best airport-specific solutions, based on conditions such as aircraft fleet mix, airfield topography and the amount of runway safety area (RESA/RSA) that is available.

### Tailor-made for each runway

greenEMAS uses a bed of crushable and movable material with reliable and predictable deformation characteristics, placed at the end of a runway. The main component that causes aircraft arrestment is a silica foam aggregate. When an aircraft goes onto the bed, part of the silica foam is crushed and moved under the weight of the aircraft.

The crushing and moving of the silica foam aggregate is an irreversible process and the amount of energy that is dissipated is proportional to the arresting performance of the system. The amount of crushing and moving, or ride depth of the aircraft tire, will affect the breaking performance of the system: i.e. a larger ride depth will lead to a larger drag load. This fact is also crucial during the design phase of a greenEMAS deeper system, especially when considering optimization for multiple aircraft.





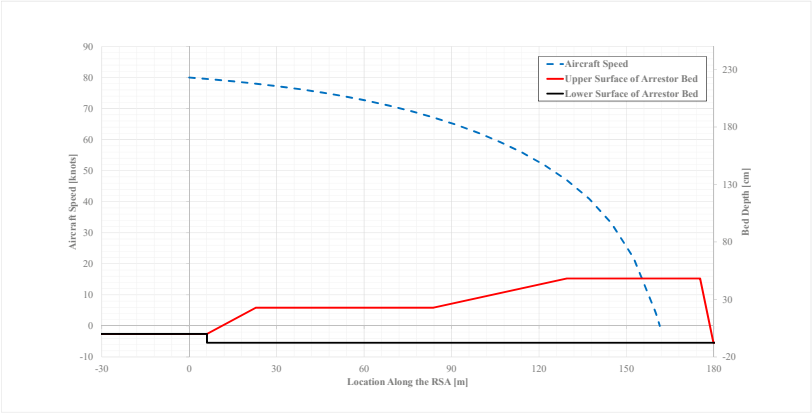

## Installing greenEMAS

greenEMAS is installed at the end of the runway, normally with one or two ramps, followed by a plateau. On both sides of the greenEMAS, side slopes are built to allow for easy egress for passengers and easy access for Aircraft Rescue and Fire-fighting (ARFF) vehicles, letting them drive up onto the bed in case of emergency.

## Product Performance Assessment & Modeling Process

Runway Safe utilizes an FAA-validated design method to predict the performance of the EMAS. The basis of our design method is our FAA-accepted computer simulation program. It carries out complex analysis of over 100 variables for each operating aircraft.

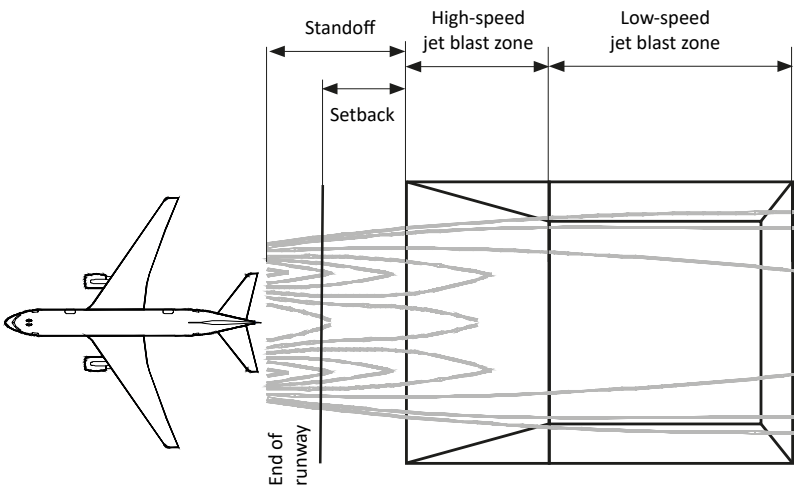
When carrying out its modeling, Runway Safe relies heavily upon the airport client to provide complete, accurate information on the range of aircraft that must be considered, as well as any operational constrains.

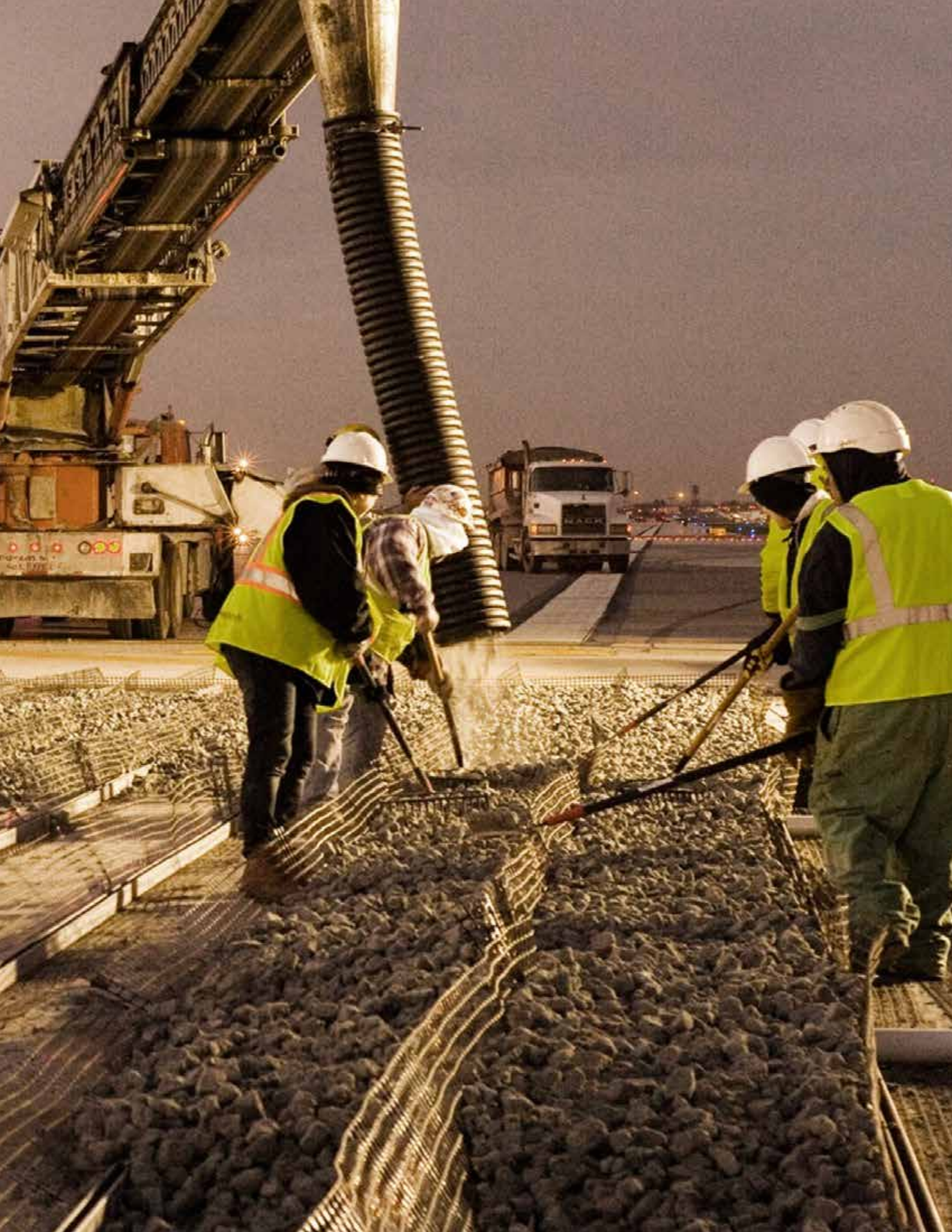


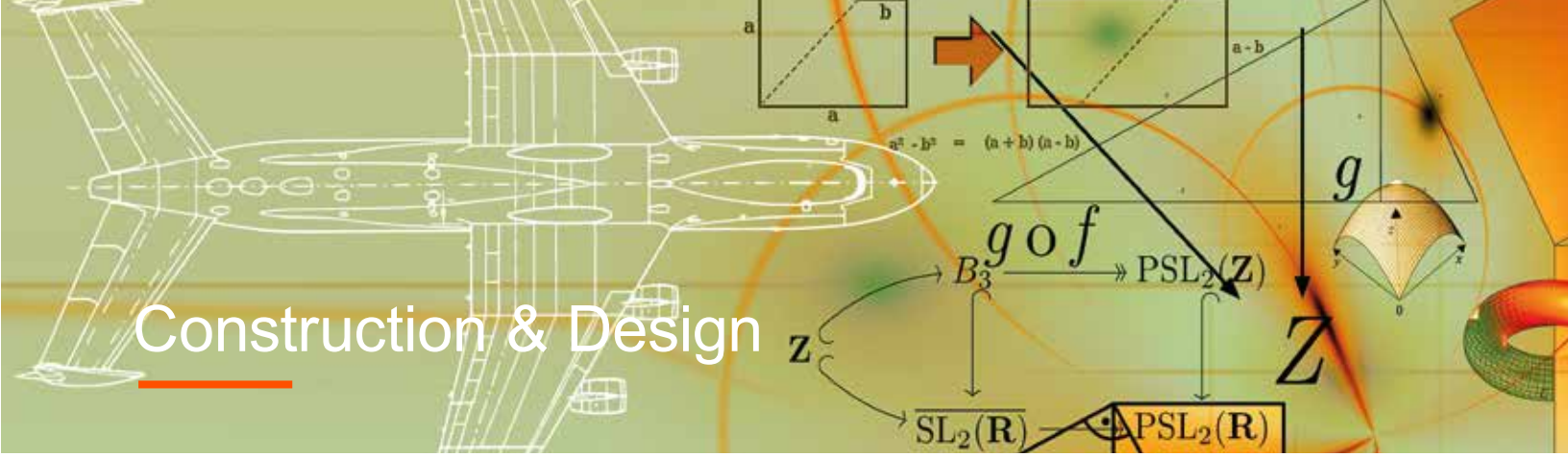

In general, the main objective of the performance modeling is to obtain the maximum EMAS performance achievable within the limits of the landing gear size/strength of each aircraft, as well as the length available for the safety area.

## greenEMAS bed design

The finished greenEMAS arrestor bed typically spans the full width of the runway and is located at the runway's end. The system is sized for 70-knot performance, where space allows for this (Runway Strip + RESA). In highly constrained areas, like locations with short RESA/RSA, we will design the greenEMAS to utilize the space that is available for maximum stopping capability, making the most of what is available.







# Construction & Design

## How is greenEMAS constructed?

**In the event of an overrun, the aircraft's landing gear will immediately engage the greenEMAS bed and begin deceleration. The crushing and moving of the material used to make the greenEMAS is an irreversible process in which the amount of energy dissipated is proportional to the arresting performance of the system.**

**The main material responsible for this energy dissipation is the silica foam aggregate (foam glass). When this foam glass is crushed, and this is combined with the crushing and displacement of the top slab, a drag load is produced on the landing gears, which in turn reduces the speed of the aircraft and brings it to a safe stop.**

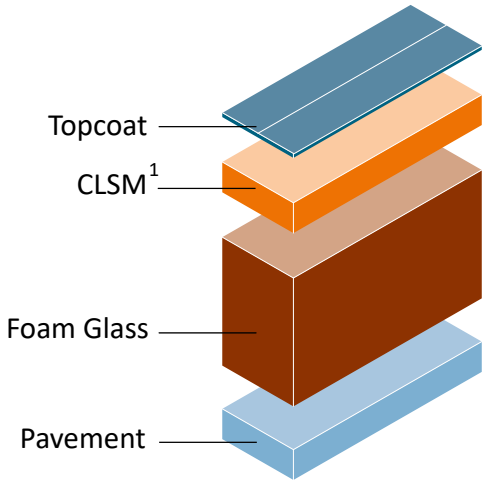
**PAVEMENT** – The safety area is graded to standards for drainage and longitudinal slope, adjusted if necessary, based on aircraft performance. The safety area is then paved (shoulder strength, enough to accommodate occasional aircraft without deformation), from the runway end to just beyond the EMAS. Between the runway end and the arrestor bed the pavement might typically be grooved to facilitate aircraft braking.

**FOAM GLASS** – The silica foam is always sourced from Runway Safe-certified production plants, each of which has passed a number of tests and carried out implementation of Runway Safe's quality routines in order to ensure that the material can provide the required arresting characteristics.

**CONTROLLED-LOW STRENGTH MATERIAL (CLSM)** - The CLSM (cover slab) is anchored to the underlying pavement using pavement anchors: low profile galvanized struts and a geogrid plastic membrane (which is embedded in the cover slab). These ensure high jet blast resistance. Due to the cementitious nature of the CLSM, a specific pattern of expansion joints is necessary to reduce the appearance of cracks over time. The unique cover slab is always blended close to the airport construction site by local batching plants, under the supervision and control of Runway Safe.

**TOPCOAT** – The multi-layer topcoat consists of several layers that protect of the CLSM, extending its life and reducing the scope of any maintenance requirements for the system. The primary layer is a sealer treatment which makes the surface hydrophobic, limiting moisture penetration and optimizing the freeze and thaw characteristics of the bed.

**DRAINAGE PIPES** – The greenEMAS is also equipped with drainpipes for inspection and moisture removal.




[1] *Controlled Low Strength Material*

# Q&A

### When is an EMAS required?

EMAS is an alternative to a fully-dimensioned RESA and is in accordance with, and complies to, aerodrome standards; particularly when there is not enough RESA available or when environmental or topographic features limit runway extension options. However, EMAS does not only replace RESA but will also increase safety in situations with tabletop mountains, water, roads, or buildings and other obstacles that are close to runway ends.

### How does the EMAS work?

The EMAS works by absorbing the energy of the aircraft as its bed components crush and move.

In greenEMAS, the material responsible for this energy absorption is recycled glass - foam glass - that crushes and moves under the gear load, reducing the speed of the aircraft.

### How is EMAS designed?

The performance and design of a greenEMAS is uniquely tailored to each specific airport runway. A detailed performance report is compiled that takes into account the fleet mix and available area for an EMAS on a specific runway. Upon receiving detailed fleet mix data, as well as information about aircraft types, the number of operations, and other relevant information, a greenEMAS is designed to maximize stopping performance for the specific fleet mix.

### Which aircraft can be stopped?

The greenEMAS is designed and optimized for airport-specific fleet mixes. greenEMAS beds have been developed to stop aircraft that weigh more than 12,500 lbs.

### Can you drive on an EMAS?

greenEMAS has been designed with slopes so that vehicles can access them from all sides in emergency situations. However, unless there is an emergency, no vehicles should be driven on the bed unless approved to do so by Runway Safe.

### What is the minimum space required for a EMAS?

Each EMAS is individually designed for individual runway ends, as well as the aircraft fleet mix that uses the runway. As a result, there is no standard reply to this question. Runway Safe offers free consultations as an initial step to discuss specific needs.

### What preparations are necessary before installing a EMAS?

The greenEMAS should be installed after the end of the runway on pavement that can withstand the occasional passage of aircraft without deformation. This is often referred to as shoulder strength pavement. The paved site has to be prepared in accordance with national RESA standards, including drainage and slopes.

### How long does it take to install a greenEMAS?

Delivery and planning of a greenEMAS depends on factors such as location and climate. The standard lead time for planning and installation of a greenEMAS, from order to commissioning, is 9-12 months.

Shorter delivery times may be achieved by reserving capacity in advance of construction. Once a site is prepared, installation of the EMAS is typically a 3-4 week process using night shifts. However, installation can take place in as little as one week if carried out during full runway closure.

### What happens in case of an overrun?

After all passengers are evacuated, the first step is to remove the aircraft. This is usually done by pulling the plane out backwards along its own tracks.

The second step is to remove any loose parts and, if necessary, to put on a temporary top cover. After this, the runway becomes functional again.

The last step is to restore the functionality of the greenEMAS by repairing only the damaged parts. This should usually be done within 45 days.

### How do you repair an EMAS?

In the event of an incursion, the damaged section of the bed can be repaired without affecting other areas. It should be noted that aircraft overrun repairs are typically covered by the aircraft operator's insurer.

### What materials are necessary for repairs?

The same materials and machines that are used to build the bed are also used for repairs. All materials can be supplied by Runway Safe or our local partners.

*"Have respect for the unexpected and have your greenEMAS ready for when the situation arises."*

> *"One should always respect the unexpected."*

# The implementation process

## Is an EMAS the solution for you?

Runway Safe offers consultations for all airport owners. By receiving fleet mix data and information on geographical constraints, our engineers are able to perform a preliminary study of how a greenEMAS can be created for a specific runway. This will give an indication as to whether an EMAS can be considered as a solution for a runway safety area.

A more extensive study is then carried out – a Preliminary Performance Report – where the result leads to an initial greenEMAS design that will be optimized for a particular site and fleet mix, considering dozens of variables including speeds, weights, distances, jet blast etc. The information provided in the Preliminary Performance Report is intended for planning purposes only.

## What happens then?

A Preliminary Performance Report provides the necessary information for the airport to move into the tendering process for a greenEMAS solution. If the Preliminary Performance Report shows that favorable conditions for an EMAS exist, the next step would be a site visit, and a detailed discussion of specific needs, site constraints, construction plans and a draft time plan. Based on the assessment of a pre-study, the Runway Safe team prepares a quotation for a greenEMAS installation that includes the details of the budget process and provides support in the procurement process.

## Design - each greenEMAS is uniquely designed for an individual runway.

Each greenEMAS is unique, and the performance and design of a greenEMAS is tailored to the specific requirements of the runway and the airport. During the design phase, our performance engineers work together with the airport team and airfield consultants to optimize the performance of the EMAS - within local restrictions.

At the end of the design phase, a detailed performance report is compiled, taking into account the fleet mix and available area for a greenEMAS for a specified runway. A bill of materials is compiled, and construction drawings are produced for the planning and mobilization phases.

## Planning & mobilization

As each runway and every situation is unique, thorough preparation is vital in order for the project to be successful. Runway Safe Group cooperates with local construction partners at airports around the world. During the planning and mobilization phase the installation crew is trained to carry out greenEMAS-specific installation tasks.

## Installation & warranty

Depending on runway access conditions, the installation can either be done over several nights or during a complete runway closure. All on-site work starts after Runway Safe and our local construction partner takes over the pavement, which has been designed to support the fleet mix of the specific runway. If this type of pavement is not already in place, it should be planned into the overall project.

As with all infrastructure investments, proper maintenance of an asset is vital in order to ensure performance and reduce lifecycle costs over its 20 year lifetime.

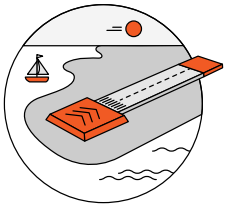
During the warranty period, Runway Safe assumes this responsibility as part of the standard warranty program.

# Reference Projects

### Haneda International Airport (HND) - JAPAN

Haneda Airport – also known as Tokyo International Airport – is one of the two primary airports that serve the greater Tokyo area. It is also the primary base of Japan´s two major domestic airlines, Japan Airlines and All Nippon Airways. It is located south of Tokyo Station. Haneda is the fourth busiest airport in the world, capable of welcoming 90 million passengers every year.

*Haneda International Airport*



One of their runways (runway 34L numbered end) lacked the necessary RESA and, since the airport continues to grow, they had to find a workable solution to make the runway safe, as well as ensuring that capacity could be increased. The solution was the installation of a greenEMAS. By installing a greenEMAS, instead of having to build out into the sea, the available space was utilized and optimized to a tailor-made greenEMAS installation - giving both higher levels of safety, and increased capacity.

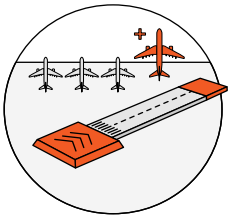
*Island of Mayotte, Photo credit: Google Earth*

### Mayotte (DZA) & Réunion (RUN) - France

Mayotte and Réunion are two French territories with airports that mainly serve destinations throughout Africa as well as cities in mainland France. For several years, the flights operated with an exemption from the regulating authorities of a minimum RESA of 90 meters. In order to maintain their certificates, the airports had to either extend their RESA or risk not being able to use the airports for direct flights from Paris – thereby losing direct flights to Europe.

Both airports had the end of the runways located close to the sea, and Mayotte runway was also situated very close to the city. A possible extension would have been very costly. The current fleet mix required the total runway length so extension of the RESA by shortening the runway was not possible.

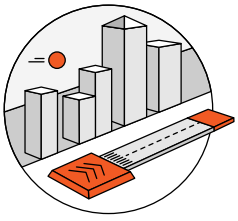
Instead, the solution chosen was the installation of a greenEMAS at one end of the runway at Réunion and two greenEMAS at both ends of the runway at Mayotte. This enabled both airports to renew their certificates and continue operations with wide-body aircraft from mainland France without having to make major investments by extending the runways into the sea or compromise with smaller aircraft by a shorter runway, negatively impacting tourism, trade, and revenue.



### Chicago Midway International Airport (MDW) - USA

In 2012, the City of Chicago's Department of Aviation made the decision to install a total of four greenEMAS systems at Chicago Midway International Airport. With these, Midway was able to greatly improve the safety of their airfield - benefiting both the flying public and Chicago Midway International Airport by maintaining the full runway length. This is exactly why EMAS was invented: to improve safety as much as possible within a given space (when 1000ft RSAs are not practical) and allow airports to keep as much runway open as possible.

*Chicago Midway, Photo credit: Google Earth*



*Safety and long-term commitment will **always** be our first priorities.*


# Partnership

## Service Agreements

Increase the life expectancy of your EMAS bed. Reduce unneccessary costs with a Runway Safe Service Agreement adapted to your specific needs.

Runway Safe provides Service Agreements for both of its EMAS products, greenEMAS and EMASMAX®. These Service Agreements will provide the necessary Inspections, Verification of Fleet Performance (in case the fleet mix changes), and Inspection, Maintenance & Repair Training for airport staff, as well as any other services that might be of interest. Our goal is to ensure that you have EMAS-specific materials and equipment with which you can inspect and maintain your EMAS bed, helping to ensure the long life of your investment.

By having a Runway Safe Service Agreement, you can be confident of getting the right maintenance at the right time – which will keep your EMAS secured for years to come. With decades of experience in maintaining EMAS beds Runway Safe know that every airport is unique. This is why Runway Safe also offers tailor-made Service Agreements that are specific to your airport and EMAS.

As a Runway Safe Service Agreement holder, you are entitled to prioritized support and many other benefits throughout the agreement period. You will get discounts on Runway Safe original spare parts, consultation, and the materials that are necessary to carry out maintenance of your EMAS.

## Runway Safe Partnership

With over 20 years of experience in providing EMAS systems globally, we want you to have a safety system that performs as expected. Runway Safe takes its responsibility as a manufacturer of safety systems seriously – which is why we also continue working on R&D with suppliers and engineers to be able to offer the best EMAS product, anywhere in the world.

We at Runway Safe see the decision to install a Runway Safe EMAS as the start of a long-term partnership between us and your organization. We will be there from the initial planning phases, for the duration of the installation, and throughout the entire lifetime of your EMAS system.

Taking the first step is as simple as getting in touch with us: we’re only a call or an email away.

*”Safety - from start to stop.”*

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