# EARTHQUAKE ENGINEERING WITH
# NON-INTERACTING INFILLS

**Safe and simple -
REGUPOL INODIS
innovative decoupling system**

REGUPOL

# REGUPOL INODIS

## A SIMPLE AND SAFE SOLUTION

04 **Preventing the collapse**
of masonry infills in reinforced concrete structures

05 **Concept and general benefits**
of non-interacting infills

09 **Cost benefits and sustainability**
Exemplary calculation of a 6-story building with different design requirements

12 **Design process**
The simplicity of the design and calculation of non-interacting infills

13 **Installation**
Three simple steps to accomplish the non-interacting infill

14 **About REGUPOL**
A family-owned company with tradition and innovation since 1954

# PREVENTING THE COLLAPSE

Reinforced concrete (RC) structures with masonry infill walls constitute a significant portion of the building stock in many countries around the world. Reinforced concrete frames are usually closed with masonry infills due to their simplicity and outstanding characteristics in terms of energy efficiency, fire resistance and sound isolation.

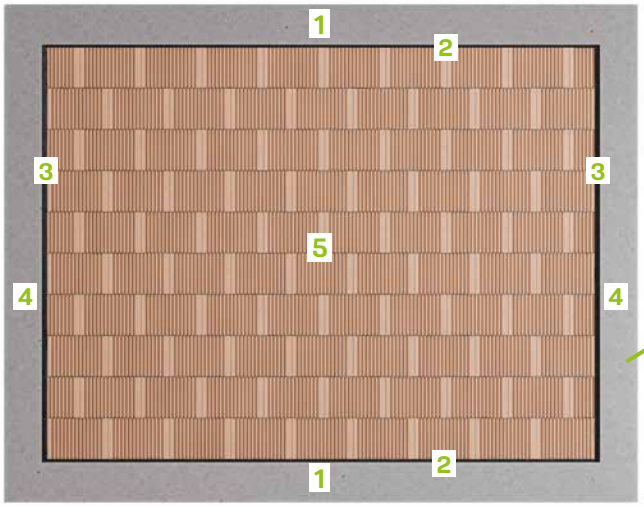
Recent earthquakes have impressively demonstrated the high vulnerability to damage of traditional masonry infills as they interact strongly with the structural system during seismic actions. The structural damage leads to major economical damage due to the repair or reconstruction of infills and equipment, rental and relocation costs along with general income losses or even loss of life.

Despite this, masonry infill has largely been considered as a non-structural element and is therefore typically neglected in the design process. For this reason, the new generation of European codes introduces new design rules for innovative non-interacting masonry infills to allow a safe use of such in reinforced concrete structures.

Consequently, innovative and well proofed installation systems are urgently needed to meet the more advanced code requirements.

# HOW DO WE IMPROVE THE SAFETY OF **CIVIL CONSTRUCTION?** TOGETHER

**REGUPOL INODIS** system



**1** = RC Slab
**2** = **REGUPOL INODIS horizontal**
**3** = **REGUPOL INODIS vertical**
**4** = RC Frame
**5** = Masonry infill

**REGUPOL INODIS** EU-patented system makes masonry infills in RC structures seismically resistant. **REGUPOL INODIS** decouples infill walls from the surrounding frame through a circumferential arrangement of elastomers placed between the infill panel and the frame columns and beams. This allows relative displacements between the frame and infill while preventing out-of-plane failure of the infill walls.

**FEATURES & BENEFITS**

**Saving lives**

**Prevention of structural damage**

**Cost reduction**

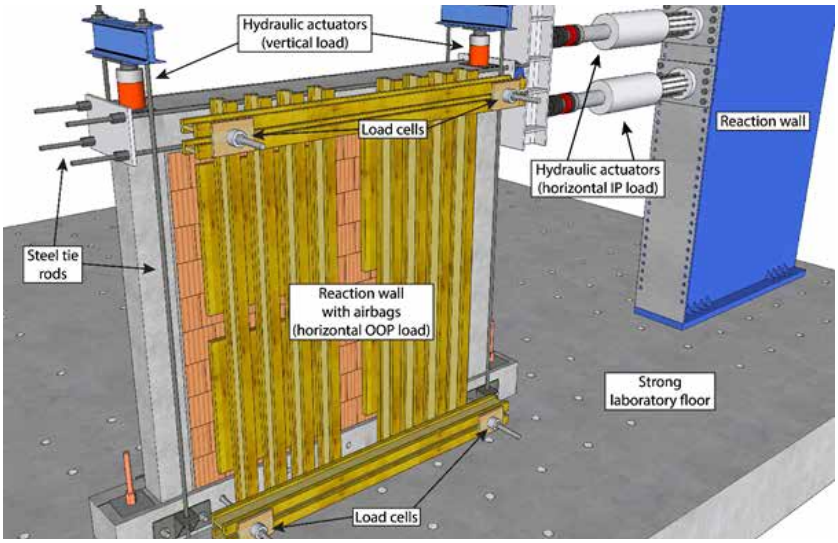
**Simple design**

**Easy installation**

**Recycled materials**

# PROVEN CONCEPT

## REGUPOL INODIS MAKES MASONRY INFILL WALLS SEISMICALLY RESISTANT




The INODIS system has been developed in national and European projects from 2013 to 2024 and its effective earthquake protection has been proven by extensive experimental tests on all typical wall configurations without and with openings (e.g. doors, windows).

- Connection tests at the Institute for Brick and Tile Research in Essen (IZF)
- Static cyclic tests at the University of Ljubljana and the University of Kassel
- Shaking table tests at the Institute of Earthquake Engineering & Engineering Seismology in Skopje

Please contact us for more detailed information.

Traditional interacting masonry infill walls: Significant damage at 0.8 % of interstory drift. (visible damage starts at 0.3 %)

Innovative non-interacting masonry infill walls with **REGUPOL INODIS**: No damage up to 2 % of interstory drift.

## 2023

**EU Project ERIES - FLEJOI**
Shaking table tests: Functionality of the system confirmed under real earthquake simulation 2023 - 2024.

## 2022

**Tests at University of Ljubljana**
Experimental laboratory tests: Systematic quasi-static tests 2020-2022. System confirmed.

## 2020

**IZF Essen**
Connection and sliding tests at IZF Essen, Germany, 2020-2024.

## 2017

**Tests at University of Kassel**
Experimental laboratory tests: Quasi-static tests on system prototypes

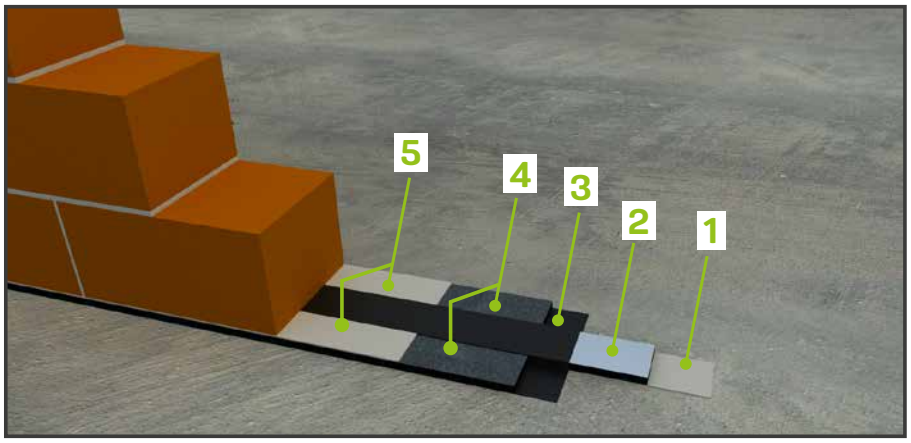
## 2013

**EU Project INSYSME**
First development of system and layout

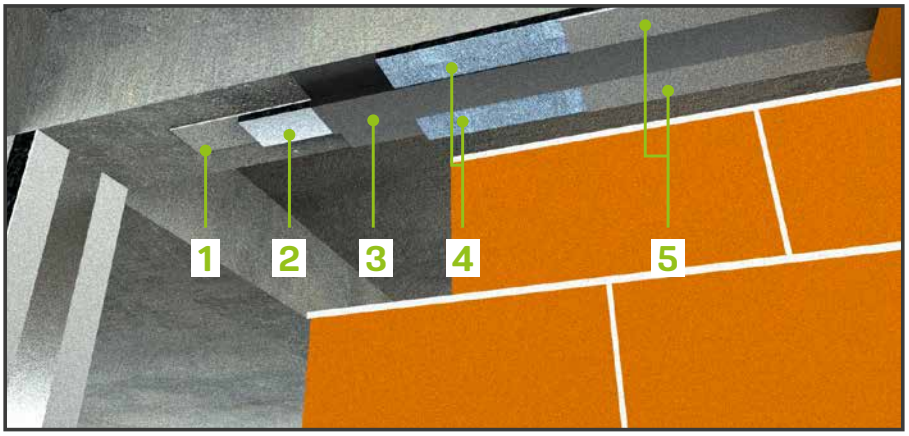
# START

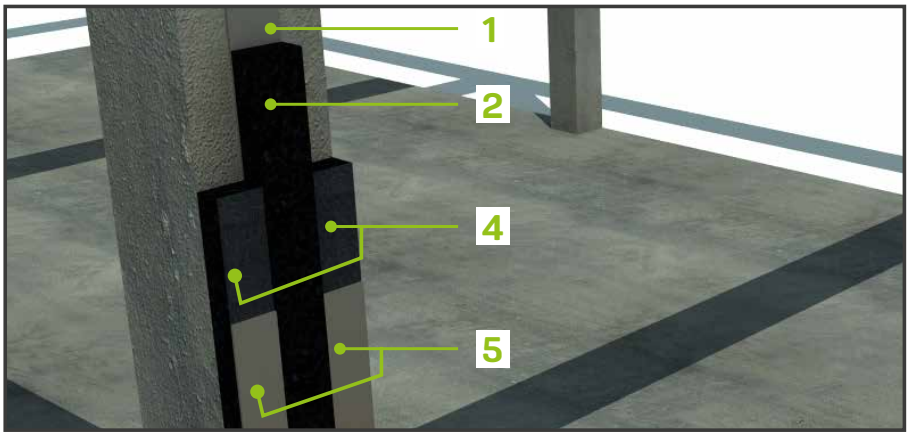
# REGUPOL INODIS
## A SIMPLE CONCEPT

**REGUPOL INODIS** can be applied to all types of bricks and blocks within the standard brick-up process.




**REGUPOL INODIS horizontal**
The combination of outer and middle strips with sliding profiles ensures, that movements in in-plane direction can be accomodated. In addition the out-of-plane failure is prevented.




**REGUPOL INODIS vertical**
guarantees that in-plane movements are absorbed at the columns so that the infills are not being damaged. The vertical elements can be designed according to the requirements.

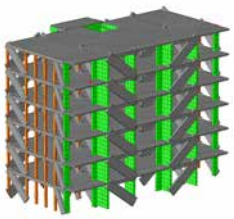
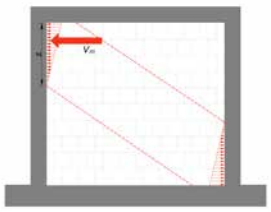
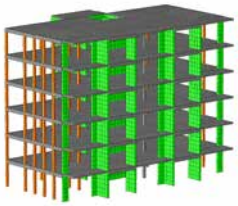
**1** = Thin layer mortar
**2** = **REGUPOL INODIS** middle strip
**3** = Sliding profile
**4** = **REGUPOL INODIS** outer strip
**5** = Thin layer mortar

Contact us for the **REGUPOL INODIS** Design Guide | acoustics@regupol.eu

# COST BENEFITS AND SUSTAINABILITY

**REGUPOL INODIS offers a strategic cost advantage**
This is shown with the following calculation example on a six-story building. The full design of the building was performed according to the Eurocode 8 (EN 1998). For the purpose of comparison, the RC structure was completely designed with interacting (rigidly attached) and non-interacting (decoupled) infills. The amount of materials (concrete, reinforcement, **REGUPOL INODIS**) were determined to calculate the costs for different levels of ground acceleration ($a_{gr}$=0.1 g; 0.2 g; 0.3 g; 0.4 g). The same trend can be expected for higher levels of acceleration.

Two separate building models were made to represent both infill types. Due to the rigid frame/infill connection of interacting infills, additional shear force acting on the columns has to be taken into account, which results in additional reinforcement and concrete. When **REGUPOL INODIS** is applied (non-interacting infills), less reinforcement and concrete needs to be considered which reduces the costs significantly.

| | Interacting infill | | Non-interacting infill with REGUPOL INODIS |
|---|---|---|---|
| Design model |  |  |  |

**Code requirements**

| | Additional shear force due to infill | Additional reinforcement | Increase of size of concrete elements | Costs | Time of construction |
|---|---|---|---|---|---|
| Interacting infill | yes | yes | yes | | |
| Non-interacting infill with **REGUPOL INODIS** | no | no | no | | |

# COST BENEFITS AND SUSTAINABILITY

## Amount of materials

| | $a_{gr}$ | Steel [kg] | Steel difference [%] | Concrete [m³] | Concrete difference [%] | Total difference [EUR] | REGUPOL INODIS [EUR] | Savings [EUR] |
|---|---|---|---|---|---|---|---|---|
| Interacting infill | 0.1 g | 88,652 | | 727 | | | | |
| | 0.2 g | 96,268 | | 765 | | | | |
| | 0.3 g | 109,650 | | 803 | | | | |
| | 0.4 g | 118,573 | | 834 | | | | |
| Non-interacting infill with **REGUPOL INODIS** | 0.1 g | 69,690 | -21.39 | 594 | -18.26 | 44,952 | 34,636 | **10,315** |
| | 0.2 g | 73,440 | -23.71 | 594 | -22.34 | 55,800 | 34,636 | **21,163** |
| | 0.3 g | 80,889 | -26.23 | 594 | -26.03 | 69,610 | 38,100 | **31,509** |
| | 0.4 g | 84,107 | -29.07 | 594 | -28.83 | 82,686 | 41,564 | **41,122** |

NOTE: For calculating the amounts of materials all RC columns, beams, walls and slabs are taken into account, without building foundation. Costs are calculated based on the following estimated prices:

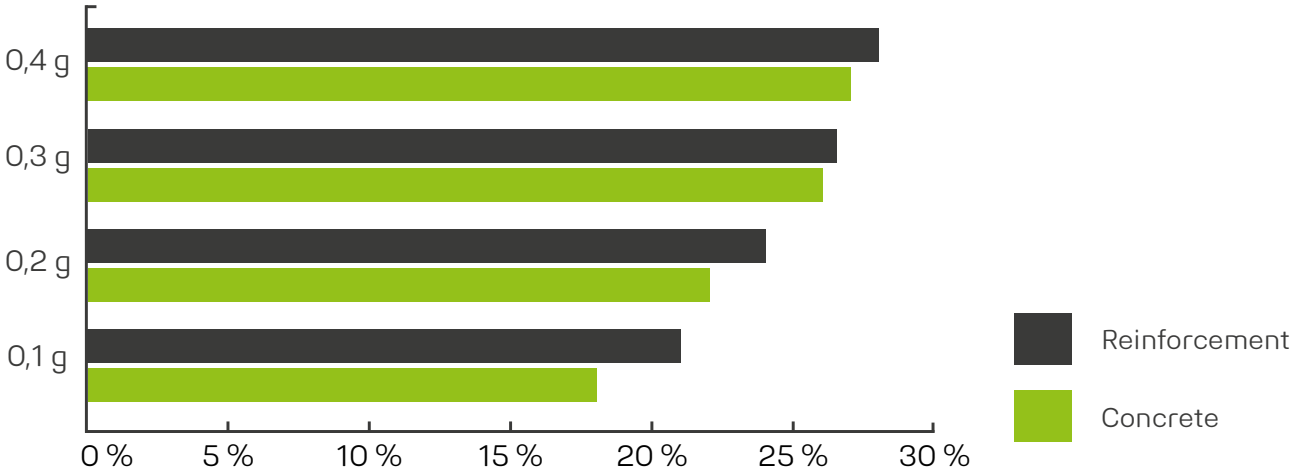
- steel 1.43 EUR/kg for walls, columns, beams and 1.67 EUR/kg for slabs
- concrete 149 EUR/m³ for walls, 209 EUR/m³ for columns and beams, 179 EUR/m³ for slabs

## Impact on carbon footprint

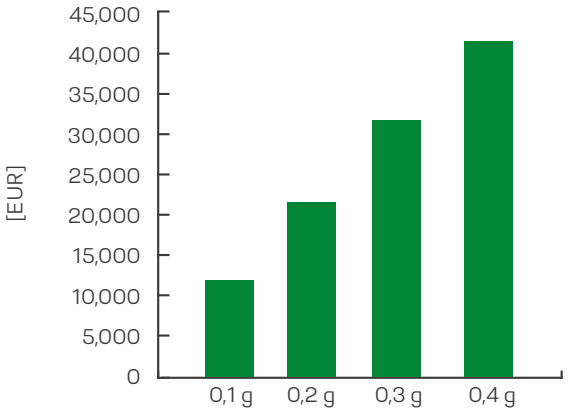
| | 0.1 g | 0.2 g | 0.3 g | 0.4 g |
|---|---|---|---|---|
| Steel savings [kg] | 18,962 | 22,828 | 28,761 | 34,466 |
| $CO_2$ savings from steel [kg $CO_2$ eq.] | 11,669 | 14,048 | 17,700 | 21,210 |
| Concrete savings [m³] | 133 | 171 | 209 | 240 |
| $CO_2$ savings from concrete [kg $CO_2$ eq.] | 34,487 | 44,340 | 54,194 | 62,232 |
| $CO_2$ INODIS [kg $CO_2$ eq.] | 4,046 | 4,046 | 3,734 | 5,295 |
| **$CO_2$ savings total [kg $CO_2$ eq.]** | **42,110** | **54,342** | **68,159** | **78,148** |

Generic data from the oekobaudat database was used to calculate the $CO_2$ savings. Here, 0.6154 kg $CO_2$ equivalent per kg of steel was calculated for the steel. For concrete, 259.3 kg $CO_2$ equivalent per m³ of concrete was assumed. The data for **REGUPOL INODIS** comes from the **REGUPOL** EPD, with additional generic data for the coatings and the sliding profile being added. All data refer to the manufacturing process (A1-A3) and do not include transportation.

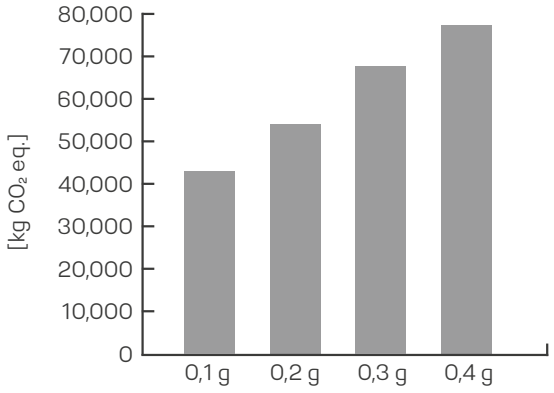
## OVERALL SAVINGS WITH REGUPOL INODIS




## COST SAVINGS




## $CO_2$ SAVINGS



# REGUPOL INODIS

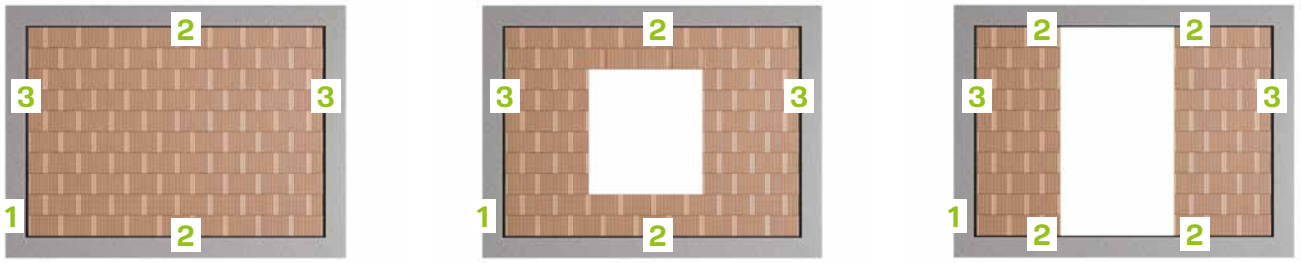
## SIMPLE DESIGN CONCEPT

**Basic idea**
The **REGUPOL INODIS** system decouples masonry infills from the surrounding reinforced concrete frame and turns them into non-interacting elements. This reduces harmful interactions with the structure, allowing infill panels to withstand strong seismic actions safely.

**Requirements Eurocodes**
RC frames with masonry infills decoupled with the system **REGUPOL INODIS** can be classified as non-interacting masonry infills according to the Eurocodes, as they meet the following criteria: minimal effect on the lateral stiffness and resistance of the structure, minimal interaction between the frame and the infill, and adequate safety against out-of-plane loading.

**Performance objectives**
The performance objectives of the Eurocodes, defined as the limit states Significant Damage (SD), Damage Limitation (DL) and Fully Operational (OP), are met by simple design rules with **REGUPOL INODIS**.

**Design**
The in-plane design of the system is simply carried out by calculating the required thickness of **REGUPOL INODIS vertical**, based on the maximum inter-story drift taken from the standard building calculation. The verification for the out-of-plane actions is straightforward, as **REGUPOL INODIS horizontal** provides a stable arching effect. The **REGUPOL INODIS** system is designed and installed in the same way for infill panels with and without openings and the design is carried out for the whole building or individual storys using tabular values for the decisive panels, minimizing the structural engineer's workload.




**1** = RC Frame
**2** = **REGUPOL INODIS horizontal** (thickness = 15 mm)
**3** = **REGUPOL INODIS vertical** (thickness according to the dimensioning)

# EASY AND QUICK
## INSTALLATION

**REGUPOL INODIS** can be applied to all types of bricks and blocks within the standard brick-up process using standard tools and mortars. All parts of **REGUPOL INODIS** can be cut either by a craftsman knife or a metal hacksaw.

Apply the **REGUPOL INODIS vertical** strips with mortar to the centre of the column. Place the two outer strips next to the middle strip.

Attach **REGUPOL INODIS horizontal** strips with mortar to the bottom and separate the strips by a sliding profile. Brick-up the wall in usual way.

Leave a gap of approximately 2 cm between the top row of bricks and the concrete surface to insert the sliding profile. Insert **REGUPOL INODIS horizontal** strips with mortar facing towards the bricks.

Now, in the event of an earthquake, **REGUPOL INODIS** ensures, that masonry infills are not damaged and that human lives can be protected. For more detailed information, please refer to the **REGUPOL INODIS** installation guideline.

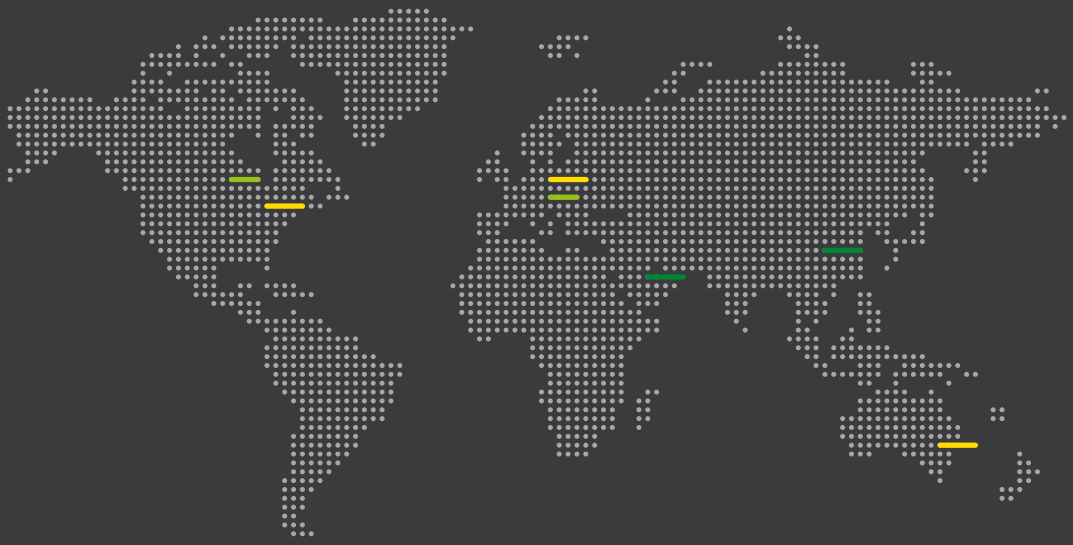
# ABOUT REGUPOL

**Welcome to REGUPOL - tradition and innovation since 1954**
**REGUPOL** is a leading family-owned company specialised in the production of high-quality elastomers since 1954. Originally known for upholstery in seating furniture and elastic floor coverings for sports applications, our company has continued to develop and today, with its **REGUPOL Acoustics** division, has been an expert in the field of vibration and noise protection for more than 30 years.

**Our expertise**
At **REGUPOL**, we understand the complexity of vibrations and noise. Our elastomers are used worldwide in a broad range of applications, including impact sound insulation, vibration isolation for railway and marine applications, machine isolation and vibration protection for buildings. Our experienced team works closely with customers and engineers to develop solutions that meet their specific requirements.

**Our values**
As a family-run company in its fourth generation, we are proud to continue the values of our founders: Quality, partnership and sustainability. We are actively committed to a sustainable economy by using recycled elastomers and implementing environmentally friendly manufacturing processes. With a recycling rate of over 85 % and processing more than 90,000 tons of recycled elastomers per year, we make a significant contribution to the circular economy.

# REGUPOL WORLDWIDE



**11** **LOCATIONS**
including eight subsidiaries

**07** **COUNTRIES**
REGUPOL is at home all over the world

**132** **COUNTRIES OF ORIGIN**
of our customers

**1954** **ESTABLISHMENT**
A family company for 70 years

**800** **EMPLOYEES WORLDWIDE**
Many colleagues around the world

**140** **MILLION**
euros turnover per year

**90** **THOUSAND TONS**
of recycled elastomers per year

**85** **PERCENT RECYCLING**
quote

**60** **PERCENT SALES**
export

REGUPOL

**REGUPOL Germany GmbH & Co. KG**
Am Hilgenacker 24
57319 Bad Berleburg
Tel.: +49 (0)2751 803-0
info@regupol.de

**REGUPOL America LLC**
**REGUPOL Australia Pty. Ltd.**
**REGUPOL Acoustics Middle East FZE**
**REGUPOL Schweiz AG**
**REGUPOL Zebra Athletics LLC**
**BSW Shanghai CO. LTD.**

**www.regupol.com**

REG B AK INO EN 102024
Print Version October 2024