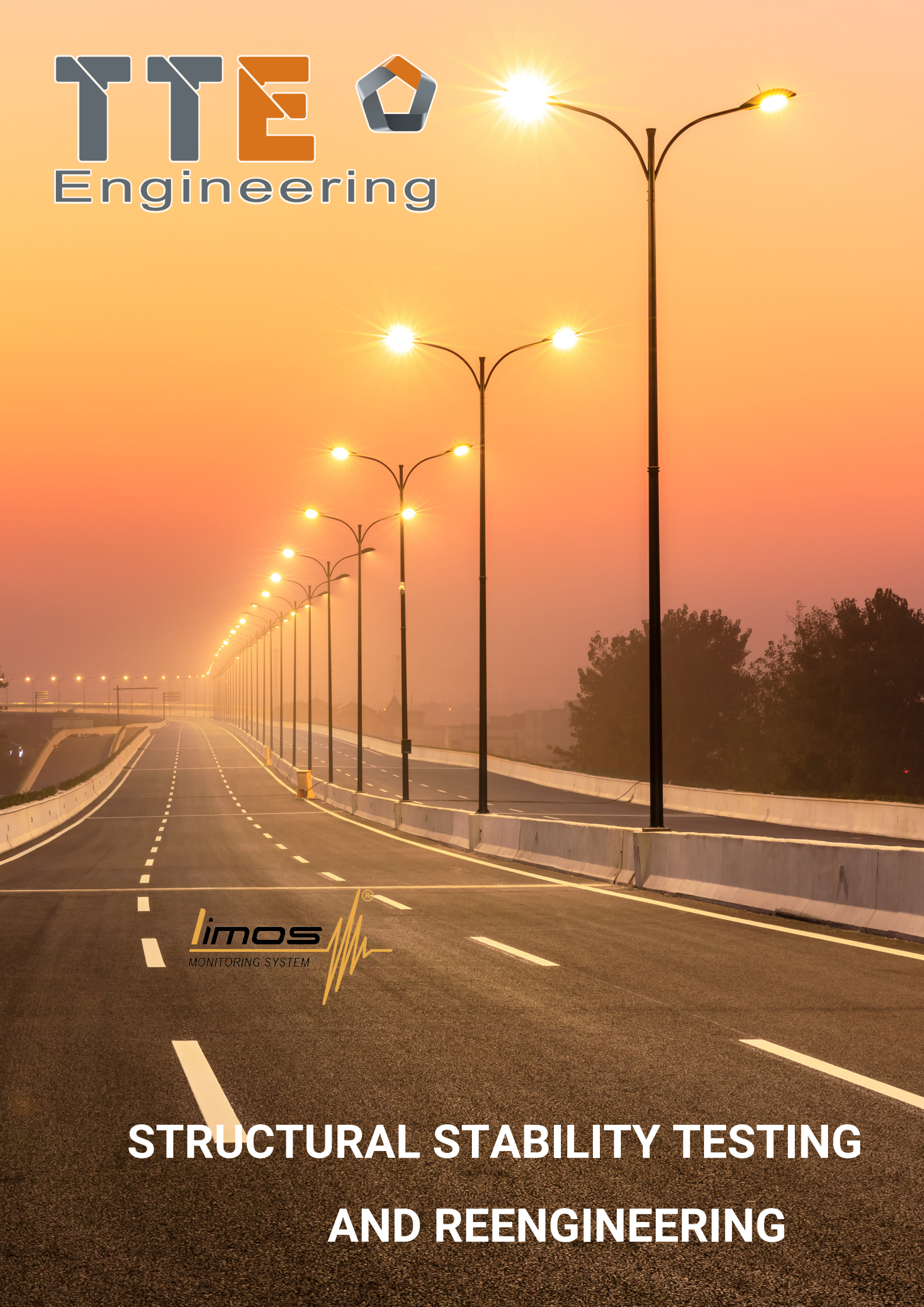
TTE Engineering



STRUCTURAL STABILITY TESTING AND REENGINEERING



Guyed poles



Lighting columns



Traffic signal systems

Damage analysis by determining system frequencies

TTEngineering uses the Limos system to measure the position and structural stability of

- Street lighting columns
- Traffic signal systems
- Guyed poles
- Infrastructure structures

By measuring load-bearing capacity and foundation stability, the Limos system meets the applicable legal requirements.

Proof of structural stability requires both load-bearing capacity (i.e. suitability for the installed loads) and foundation stability (failure-free foundation), i.e. an assessment and evaluation of the foundation.

Measurements by TTEngineering using the Limos system and the special analysis of the measured frequency spectrum represent the state of the art; this is the most advanced and up-to-date development in damage detection and assessment.

Peter Ebenhofer
Managing Director
TTEngineering e.U.
Hechtgasse 5
+43 670 205 94 93
office@TTEngineering.at
www.TTEngineering.at

official partner

Important notice:

The latest valid version of TTEngineering e.U.'s delivery terms and conditions applies - available at https://ttengineering.at under "Delivery Terms"

In cooperation with VCE Vienna Consulting Engineers ZT GmbH & FNDT GMBH

TTEngineering
Hechtgasse 5
A-3382 Roggendorf
+43 650 99 39 459
office@TTEngineering.at
www.TTEngineering.at

VAT ID No.: ATU68494845
Company Reg. No.: FN463491f
Place of jurisdiction: Melk GISA31945998
Bank details: Sparkasse Niederösterreich
IBAN: AT75 2025 6000 0095 3927
BIC: SPSPAT21XXX

Legal notice:
Responsible for content:
TTEngineering

Design:
Ing. Andreas Huber

Contents

Damage analysis by determining system frequencies 2
Contents 3
TTEngineering with the Limos method 4
Legal basis & parameters 5
Limos evaluation 6
Sample inspection report 7-8
Reengineering 9
Determining system stiffness from the system frequency/frequencies 10

TTEngineering with the Limos method

limos® MONITORING SYSTEM

Technology leader - we support you in the safe and reliable operation of your systems.

Scope of inspection:

A structural stability inspection carried out according to the state of the art consists of a visual and an instrumented inspection with corresponding documentation.

Advantages of a measurement by TTEngineering using the Limos system:

- Legally robust result (duty to ensure traffic safety / road operator liability / structural liability / duty of care)
- Load-bearing capacity and foundation stability test (pole and foundation)
- No traffic restrictions
- Non-destructive testing
- Reproducible
- Walk-by system (anything accessible on foot can be measured)
- Clear Excel evaluation
- Individual inspection reports with photos
- GPS coordinates recorded for every measurement
- Proven more than 1,000 times

Practical applications

Within your area of responsibility (motorways/roads/car parks/municipal areas/industrial facilities/hotel sites...), fulfil your obligation and have the structural stability checked by measurements using the Limos system. Depending on the condition, you receive a guaranteed period of structural stability until the next inspection interval, up to a maximum of 8 years.

You have a pole damaged by corrosion/accident/foundation undermining... and need to determine load-bearing and foundation stability... with the Limos system this can be measured and evaluated immediately on site. Here too, you receive a guaranteed period of structural stability until the next inspection interval.

Reengineering

An existing pole is to be fitted with additional or new loads (signs/advertising boards/cameras/other luminaires etc.). Structural verification is required. While conventional structural analysis assumes standard material properties, the Limos system can use the actual condition of the pole and foundation to provide a guaranteed statement compliant with the relevant standard for these load cases.

Floodlight masts | **Bus & rail systems** | **Special solutions**

Legal basis & parameters

Further legal basis for street lighting

Operation of street lighting is not explicitly regulated by law. Rather, the duty to operate street lighting is derived from various legal provisions and case law.

- **Duty to ensure traffic safety pursuant to Section 1295 ABGB**
  Anyone who opens or maintains traffic for people on their own land or on land under their control must ensure traffic safety.
- **Road operator liability pursuant to Section 1319a ABGB**
  If a person is killed, physically injured or suffers damage to health, or property is damaged due to the defective condition of a road/path, the party responsible as operator for the proper condition of the road/path is liable for compensation, provided that they or their employees caused the defect intentionally or through gross negligence. The road/path operator is the party who bears the costs of construction and maintenance and has authority over the road/path, and must take the required measures.
- **Structural liability pursuant to Section 1319 ABGB**
  An outdoor or street lighting installation is a “constructed work” within the meaning of Section 1319 ABGB. The owner of the structure is liable if parts of a structure fall down or become detached and thereby cause damage.

With regard to street lighting, the owner - unless operation is outsourced to specialist companies - is also responsible for electrical safety, in particular the function of protective measures.

Legal basis for download: click here!

Parameters for determining dynamic properties

The CBR database contains various pole types and vibration characteristics for comparison purposes.

Weight and wind-exposed areas of additional masses:

Luminaire
Signs
Other attachments

Vibrating mass of the pole, material properties:

Pole diameter
Pole height above ground level
Taper
Material
Temperature for correction of material properties
Density
Pole age

Pole foundation (rotational spring):

Soil stiffness (soil conditions)
Damage (e.g. rust formation in the soil or at the ground transition zone)
- Installation defects



Limos evaluation

Documentation

Each measurement is documented in an individual inspection report in PDF format and includes, among other things:

- Images of the measurement object and any damage.
- GPS location
- Inspection interval / inspection date
- Classification into stability classes
- Comments and, if applicable, instructions for action

Several measurements are clearly summarized in an Excel table, which also contains all important information.

The entire documentation (measurement values / inspection reports / evaluations) is stored in a document-proof manner by the licensor of the evaluation software for at least 15 years.

Visual assessment

Inspection of the pole and foundation for obvious damage (cracks, dents, rust, foundation settlement, unintended leaning, etc.)
- Check of surface condition (corrosion on hot-dip galvanized surfaces, condition of any other existing coating - paint, protective coatings, etc.)
- Visual inspection for corrosion, mechanical damage and cross-section reductions.
- Documentation by photos (overall view, luminaire, pole base and, if necessary, photos of signs, guy wires, damage, rust, paint, foundation, brackets, etc.)
- Documentation of measurement conditions such as temperature and weather
- Determination of location coordinates by GPS measurement (longitude, latitude)

Evaluation is performed using Limos software and essentially considers and analyzes:
- Raw spectrum and smoothed spectrum
- ANPSD (Averaged Normalized Power Spectrum Density)
- All relevant natural frequencies
- Mode shapes and fundamental frequencies
- Critical damping of the dominant natural frequency
- Vibration intensity for selected frequencies
- Pattern recognition based on a reference database (CBR)

Frequency drops indicate a reduction in effective system stiffness, which may be caused, for example, by increased friction in cracks, cross-section reduction due to corrosion, or other damage patterns.
The determined damping parameters provide information on how introduced energy is dissipated. Movement in cracks (friction), damaged areas and foundation properties are decisive for damping behavior.
The mode-shape analysis identifies dominant natural frequencies and the associated vibration modes. This allows highly stressed areas to be identified and support conditions to be checked.





Measurement procedure

All measurements are carried out using specially developed Limos recorders. Measurement data, photos, all input parameters, timestamps and GPS coordinates are thus assigned correctly to the measurement object.
The measurement chain consists of:
- Tablet PC with integrated GPS sensor and camera.
- Vibration sensor, 3D acceleration sensor

The vibration sensor is attached to the pole shaft. Excitation is applied manually or with a rubber hammer in two spatial axes at 90 degrees to each other. In each axis, the vibration parameters are recorded by the data logger over a defined period. Manual entries for the test object are made during the measurement process. The measurement can only be completed once all required inputs have been made and all measurement data from the data logger have been saved.

A sample inspection report can be found on the following two pages!

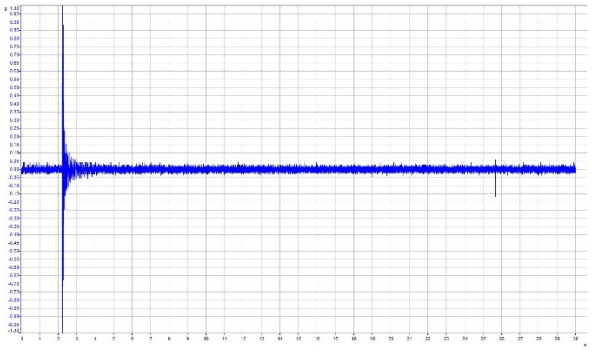
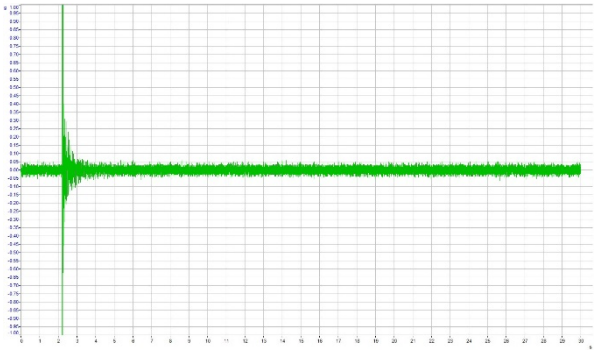
Pole data:

Pole ID	220000
Location	Sample district, Sample Street
GPS coordinates	49,##### N / 16,##### E
Pole material	Steel
Height	7 m
Bracket over 2.5 m	No
Bracket 0.75-2.49 m	Yes: 1
Top-mounted head / luminaire	Yes: 1
Guy wire	No
Guy wire with high load	No
Signage above 3 m	No
Signage area	-
Vegetation	None
Pole category	Cat. 1

Inspection report:

Temperature, weather	24°C, sunny
Coating	weathered
Corrosion	slight
Statically relevant findings	-
Notes and recommended measures	Renew corrosion protection
Result	Class A - The pole is structurally stable
Next recommended inspection	in 6 years

Measurement diagram:

Excitation in Y direction	Excitation in Z direction
	

Photos:





Contractor	Inspector Assessor	Date of inspection	Signature
	Mustermann1 Mustermann2	2026-08-01	

Reengineering

After a structural stability measurement and vibration recording to determine the foundation properties, a stress verification can be performed at the standard-relevant points of the pole for changed load specifications.
The mechanical dimensions required as the basis for the structural analysis are recorded during the stability measurement.
Any flange plates and/or couplings on the pole shaft are not included in the structural analysis as standard.
On request, these verifications can additionally be performed at extra cost.
Design basis for poles up to 20 m LPH is DIN/EN 40-3-3.

Applications:

- New luminaire types
- Conversion of floodlighting systems to LED
- Additional loads such as signs, flower baskets, Christmas lighting, etc.

Result:

- Utilization ratios at the standard-relevant points
- Horizontal deformation
- PDF of the calculation with all parameters

Poles, like all engineering structures, have a limited service life. Steel, aluminium and stainless-steel poles are exposed to a variety of adverse influences:

- Moisture from outside and inside (rain, dog urine, condensation, acidic/aggressive soils, etc.)
- A variety of loads (wind, signs, brackets, guy wires, etc.)

Over time, these factors lead to material fatigue and corrosion. Corrosion in particular can significantly reduce load-bearing capacity as a result of cross-section loss. To ensure structural stability, state-of-the-art stability inspections are essential and required at regular intervals. Every system operator has an obligation to inspect and document structural stability. Systems older than 30 years that have not yet been inspected using methods corresponding to the state of the art must in any case be inspected. (Breach of duty of care (5Ob118/19t))

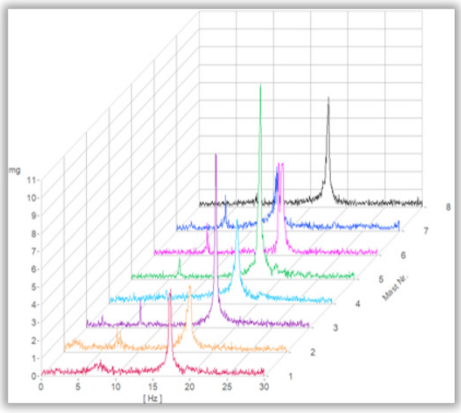




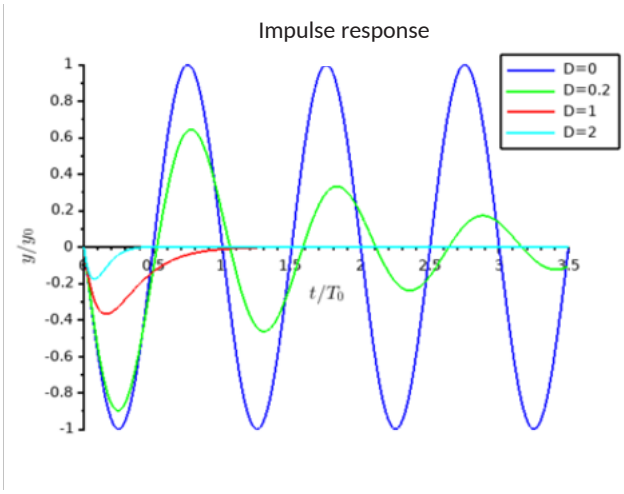
Determining system stiffness from the system frequency/frequencies (fe)

$$f_e = \frac{1}{2\pi} \cdot \sqrt{\frac{Cgen}{Mgen}} = \frac{\omega_e}{2\pi}$$

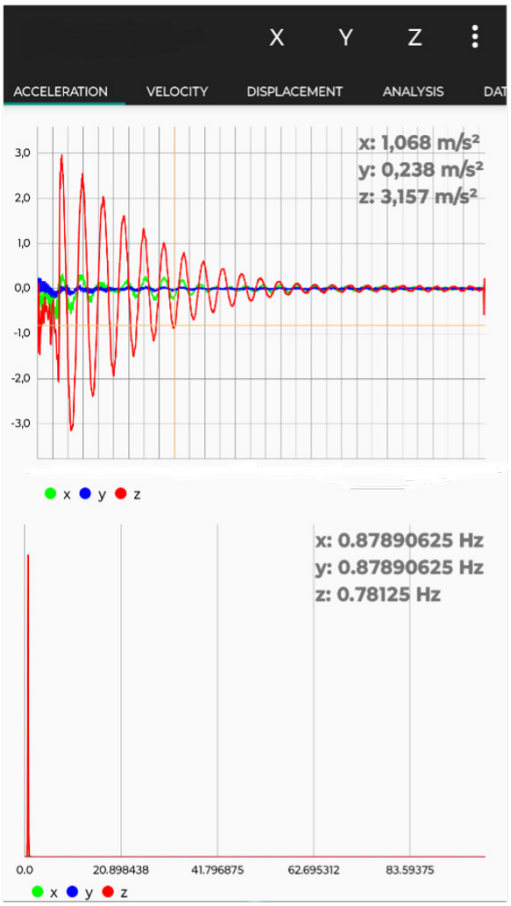
Mgen,	generalized mass
Cgen,	generalized stiffness



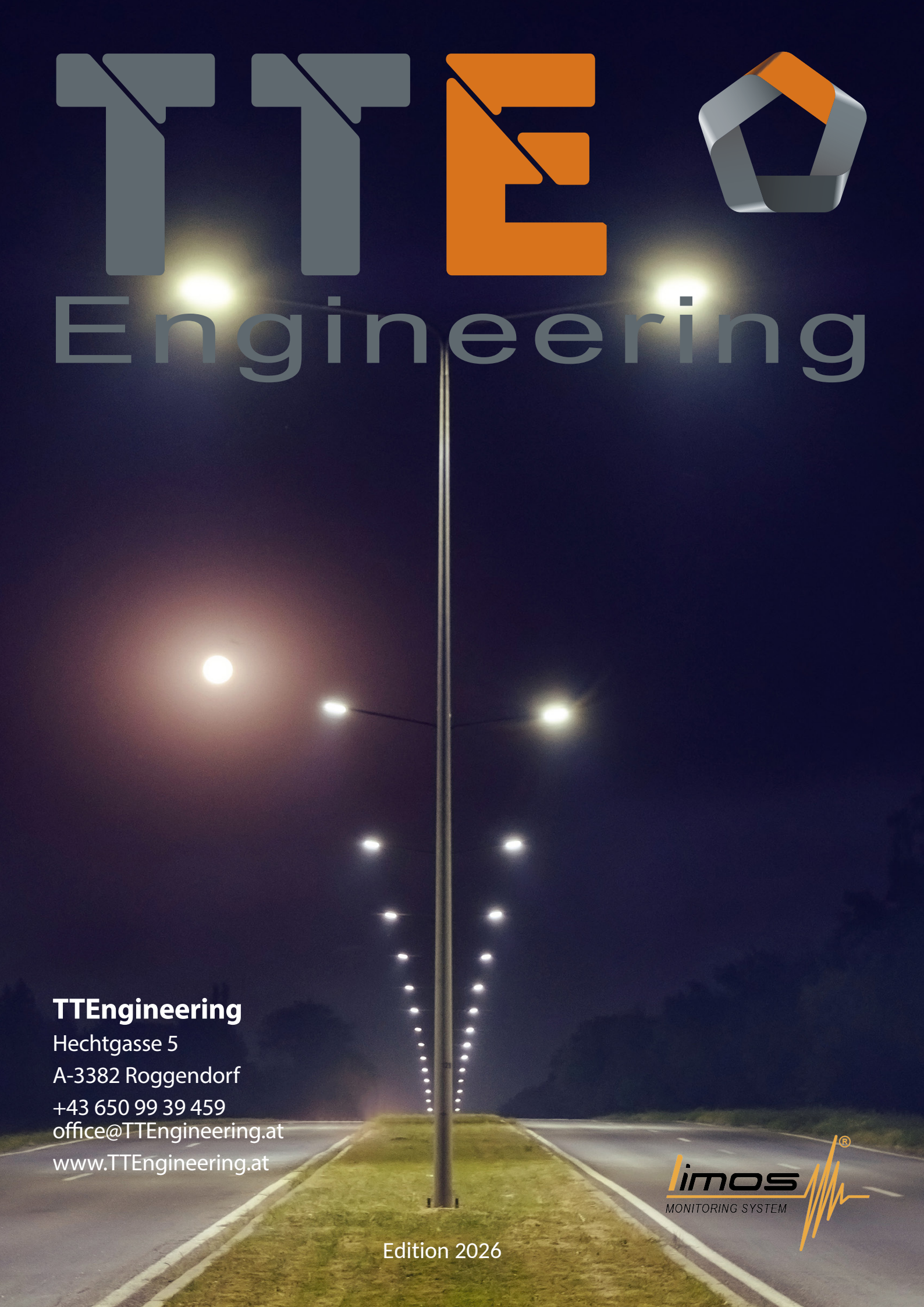
If we have a model of the pole, the system stiffness can be determined and compared via the measured natural frequency. (CBR database: Case-Based Reasoning) Cross-section reduction, e.g. due to corrosion, reduces system stiffness!
If the excitation is a Dirac impulse (impulse hammer), the calculation is performed using an inverse Laplace transform and then solved with the Euler formula. If the excitation is a displacement excitation (manual excitation), the explicit Euler method is sufficient.
In the free-decay test, we determine the damping of the vibration and can thus draw conclusions both about foundation properties and possible damage to the pole (e.g. cracks increase damping because they create additional friction).



$D < 0$	$-\frac{p_\delta}{m\omega_d} e^{-\delta t} \sin(\omega_d t)$	unstable system
$D = 0$	$-\frac{p_\delta}{m\omega_0} \sin(\omega_0 t)$	undamped vibration
$0 < D < 1$	$-\frac{p_\delta}{m\omega_d} e^{-\delta t} \sin(\omega_d t)$	damped vibration
$D = 1$	$-\frac{p_\delta}{m} t\, e^{-\delta t}$	critical aperiodic case
$D > 0$	$\frac{p_\delta}{2m\omega_d} \left(e^{-(\delta+\omega_d)t} - e^{-(\delta-\omega_d)t}\right)$	creep case



TTE Engineering



TTEngineering
Hechtgasse 5
A-3382 Roggendorf
+43 650 99 39 459
office@TTEngineering.at
www.TTEngineering.at

limos® MONITORING SYSTEM

Edition 2026