KONFERENCJA - Nowoczesne nawierzchnie drogowe

Recykling w konstrukcjach nawierzchni drogowych

CONFERENCE - Modern Road Pavements

Recycling in road pavement structures

mrp23.ibdim.edu.pl

Warsaw, 18 October 2023

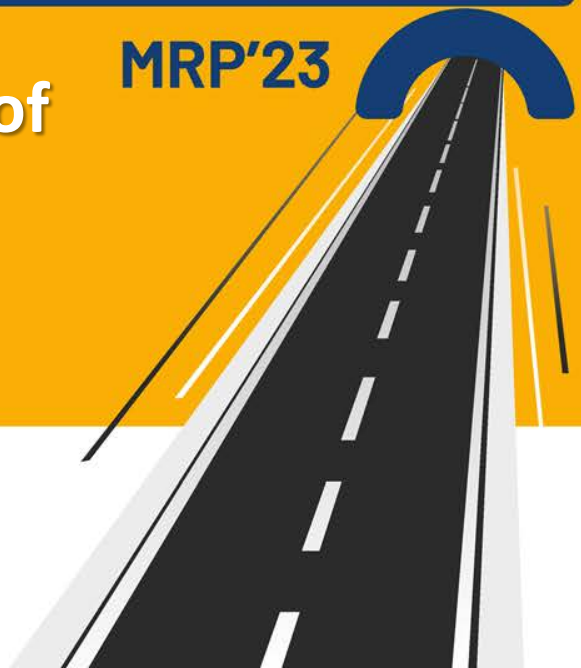
MRP'23

Shear modulus and damping ratio of recycled concrete aggregate from cyclic torsional shear test

Dr Eng. Katarzyna Gabryś

Water Centre

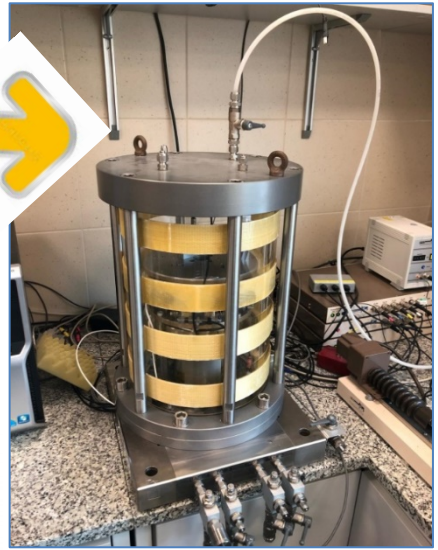
Warsaw University of Life Sciences, Poland



Content

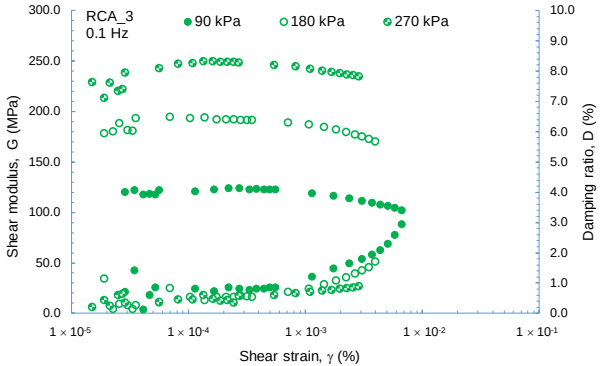
- Introduction
- Materials and Methods
- Selected Results
- Conclusions

Construction Aggregates



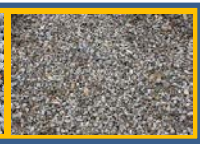
Dynamic Mixture Properties

Similar to natural aggregates



Introduction 1 - RCA

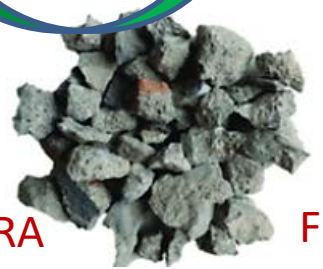




Natural aggregates

Sustainable development

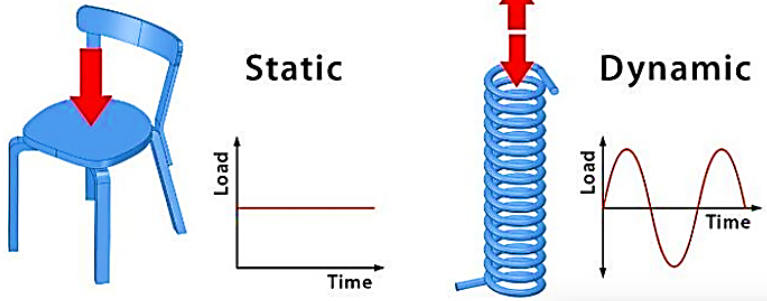
Recycled aggregates


CRA


FRA

RCA: i) aggregates obtained by recycling clean concrete waste where the content of other building waste must be very low – below a few %; ii) widely applied in existing engineering, due to the excellent economy and environmental protection; iii) partially or entirely can replace conventional natural aggregate, etc.

Introduction 2 – Dynamic Soil Properties



Mechanical properties associated with dynamic loading:

- shear modulus (G)
- shear wave velocity (V_s)
- damping ratio (D)
- Poisson's ratio (ν)

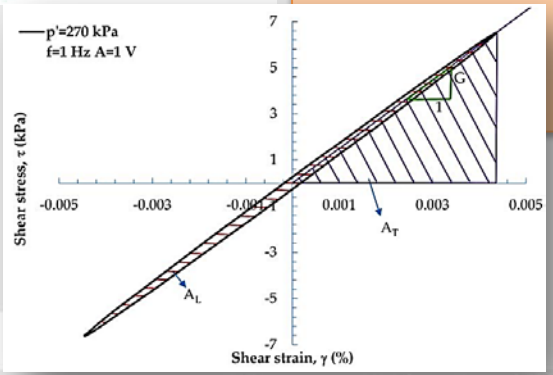
WAVE PROPAGATION

MACHINE VIBRATIONS

SEISMIC LOADING

LIQUEFACTION

CYCLIC TRANSIENT LOADING

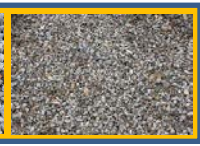


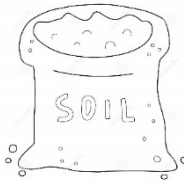
$$G = \frac{d\tau}{d\gamma}$$

$$D_{CTS} = \frac{1}{4\pi} \cdot \frac{A_L}{A_T}$$

Materials and Methods 1








RCA_1

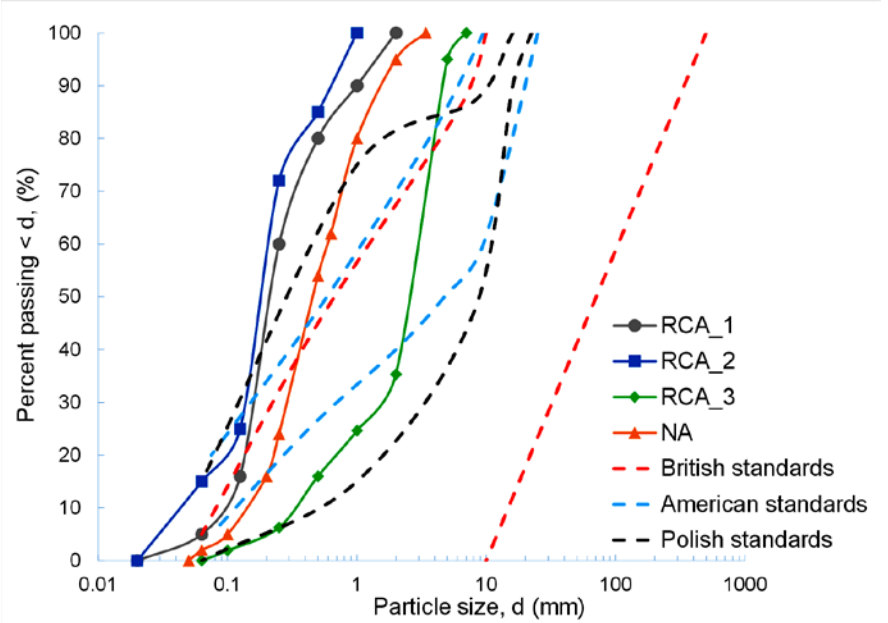

RCA_2


RCA_3


NA

Compositions

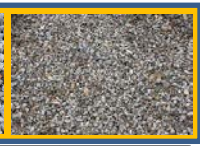
Specimen Code	Composition
RCA_1	95% fRCA (≤ 2 mm) + 5% FF (≤ 0.063 mm)
RCA_2	85% fRCA (≤ 2 mm) +15% FF (≤ 0.063 mm)
RCA_3	100% RCA (≤7 mm)
NA	MSa

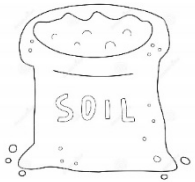


Distributions curves

Materials and Methods 2







Physical Properties

Specimen	G_S [a]	d_{50} [b] (mm)	C_u [c] (-)	C_c [d] (-)	ρ [e] (g/cm^3)	$\rho_{d,max}$ [f] (g/cm^3)	$\rho_{d,min}$ [g] (g/cm^3)	e [h] (-)	OMC [i] (%)
RCA_1	2.61	0.21	2.36	1.01	1.70	1.556	1.338	0.744	13.5
RCA_2	2.61	0.18	4.88	2.49	1.75	1.515	1.285	0.723	16.0
RCA_3	2.60	2.50	9.09	2.59	1.80	1.710	1.390	0.600	9.5
NA	2.65	0.46	3.93	0.86	1.86	2.014	1.677	0.424	12.0

[a] Specific gravity
[b] Average particle size
[c] Uniformity coefficient $C_u=d_{60}/d_{10}$
[d] Curvature coefficient $C_c=d_{30}^2/(d_{60} \times d_{10})$
[e] Bulk density
[f] Minimum bulk density of soil skeleton
[g] Maximum bulk density of soil skeleton
[h] Void ratio
[i] Optimum moisture content

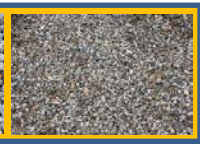
Leachate concentration from RCA mixtures

Specimen	Co (mg/L)	Ni (mg/L)	Cu (mg/L)	Zn (mg/L)	Cd (mg/L)	Pb (mg/L)	Cr (mg/L)	Sulphates (mg/L)	Chlorides (mg/L)	Specific Conductivity (µS/cm)	pH
RCA_1	0.018	<0.015	0.067	0.541	<0.008	0.015	<0.03	55.0	15.0	456.0	9.7
RCA_2	0.013	<0.015	0.045	0.52	<0.008	<0.015	<0.03	155.0	7.0	444.0	10.2
RCA_3	0.1180	<0.015	0.013	no data	<0.008	no data	no data	112.3	21.6	511.7	8.17
Acceptance criteria *	1	0.5	0.5	2	0.05	0.5	0.500	500	1000		

* Official Gazette of the Republic of Poland, Regulation of the Minister of the Environment of 18 November 2014 on the conditions to be met for the introduction of sewage into waters and to land and on substances particularly harmful to the aquatic environment.

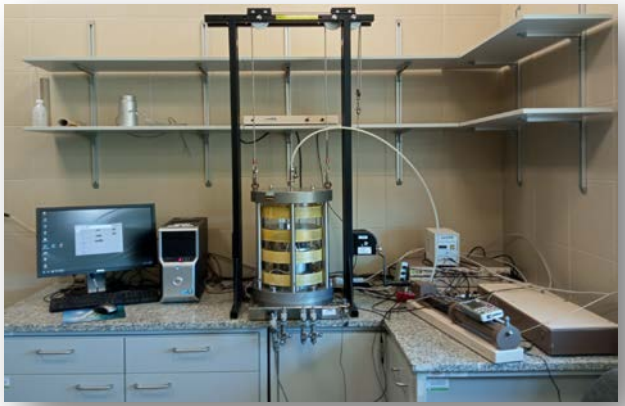
Materials and Methods 3





-LABORATORY-

Resonant column / cyclic torsional shear device

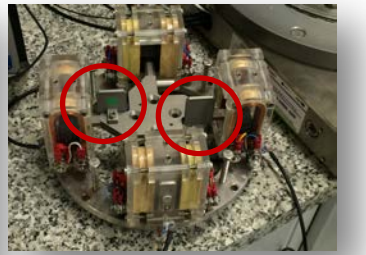


View of the test stand in Water Centre-WULS

Torsional shear upgrade

GDSRCA Control Box v2

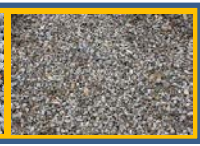
Proximitor sensor



Proximitor targets

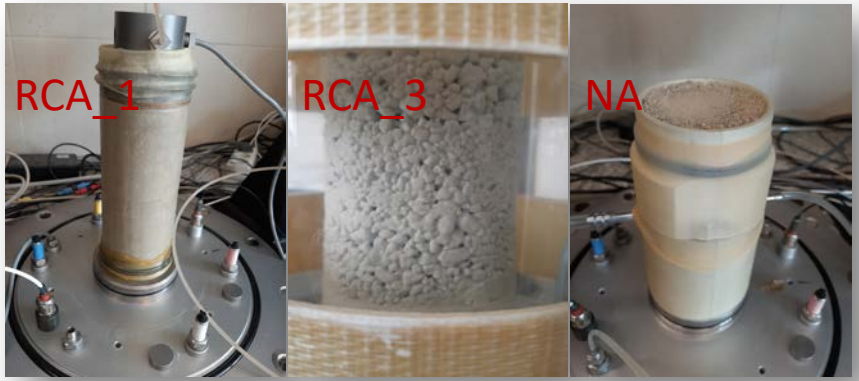
Materials and Methods 4



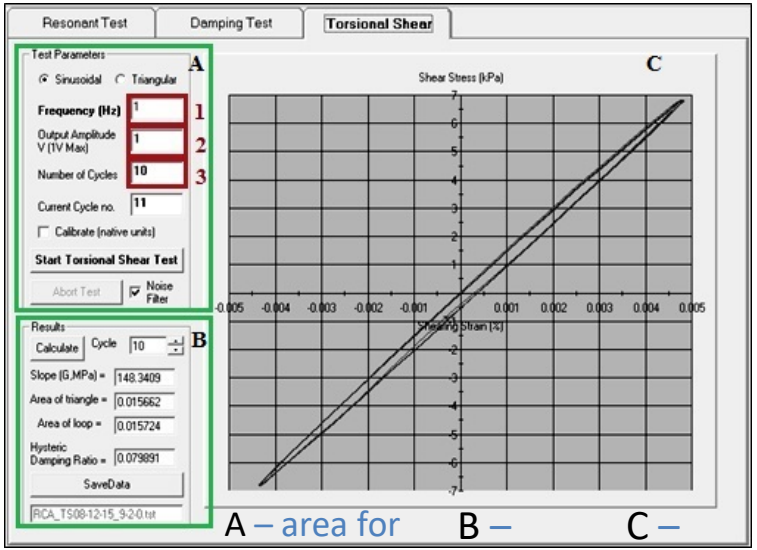


-LABORATORY-

Selected specimens at initial stage



Torsional Shear Test Window



A – area for changing parameters

B – results

C – hysteresis loop

Mixtures preparation:

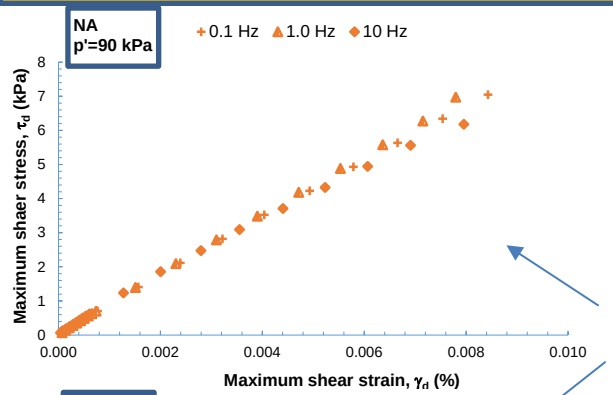
- ✓ wet tamping method,
- ✓ aluminum split mold d=70 mm, h=140 mm,
- ✓ under-compaction technique,
- ✓ initial relative density $D_r \geq 76\%$.

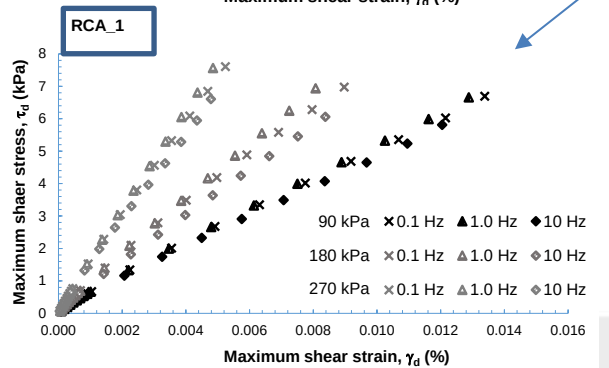
Testing procedure:

- ✓ saturation by back pressure method,
- ✓ degree of saturation $S_r \geq 80\%$,
- ✓ isotropic consolidation at p'=90, 180, 270 kPa,
- ✓ changing loading conditions: f=0.1,1.0, 10 Hz; N=10, 100; A $\in$ <0.01 V, 1.0 V>.

Shear modulus and damping ratio of recycled concrete aggregate from cyclic torsional shear test

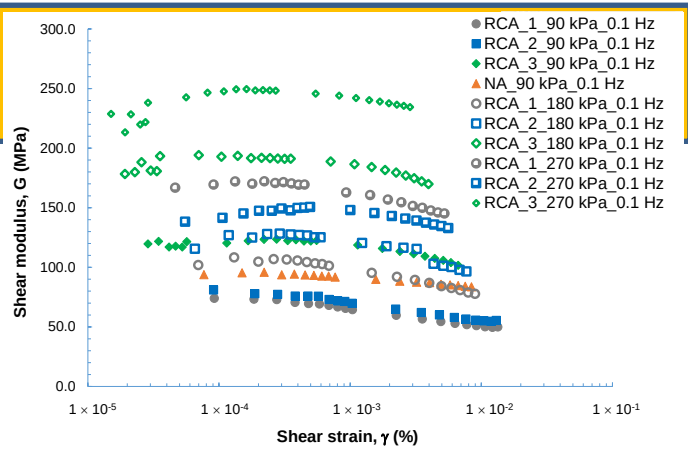
Selected Results 1



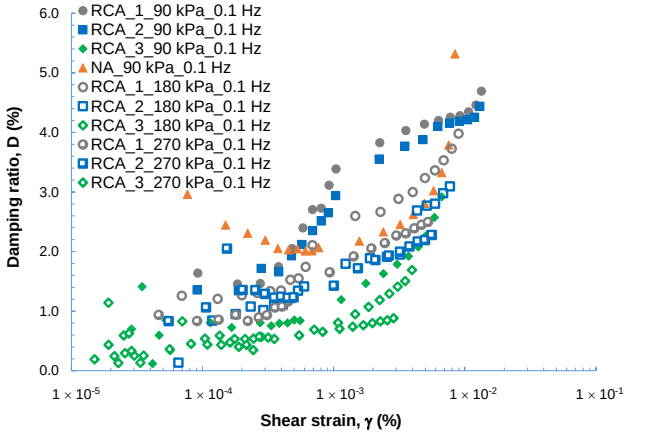


1. Dynamic diaphysis curves

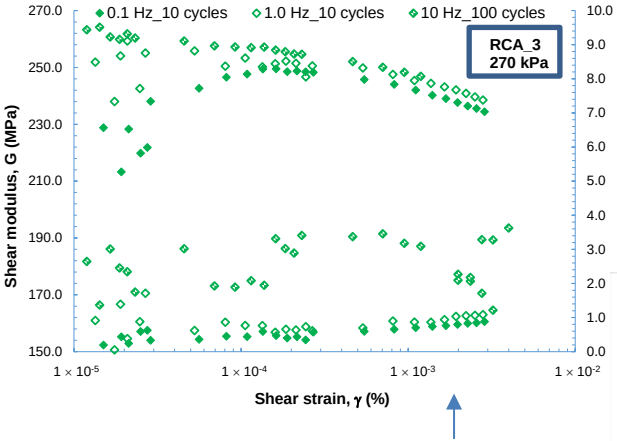
2. Secant shear modulus for f = 0.1 Hz



3. Damping ratio for f = 0.1 Hz



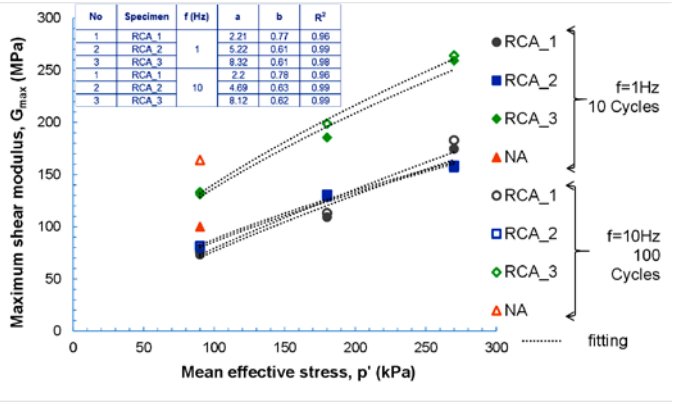
Selected Results 2



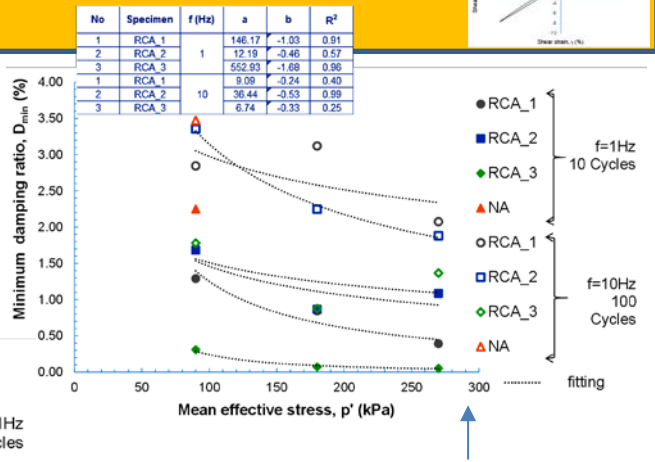
4. Effect of excitation frequency and number of vibration cycles on G – modulus and D - ratio

5. Maximum shear modulus vs mean effective stress

$$G_{max} = a \cdot (p')^b$$



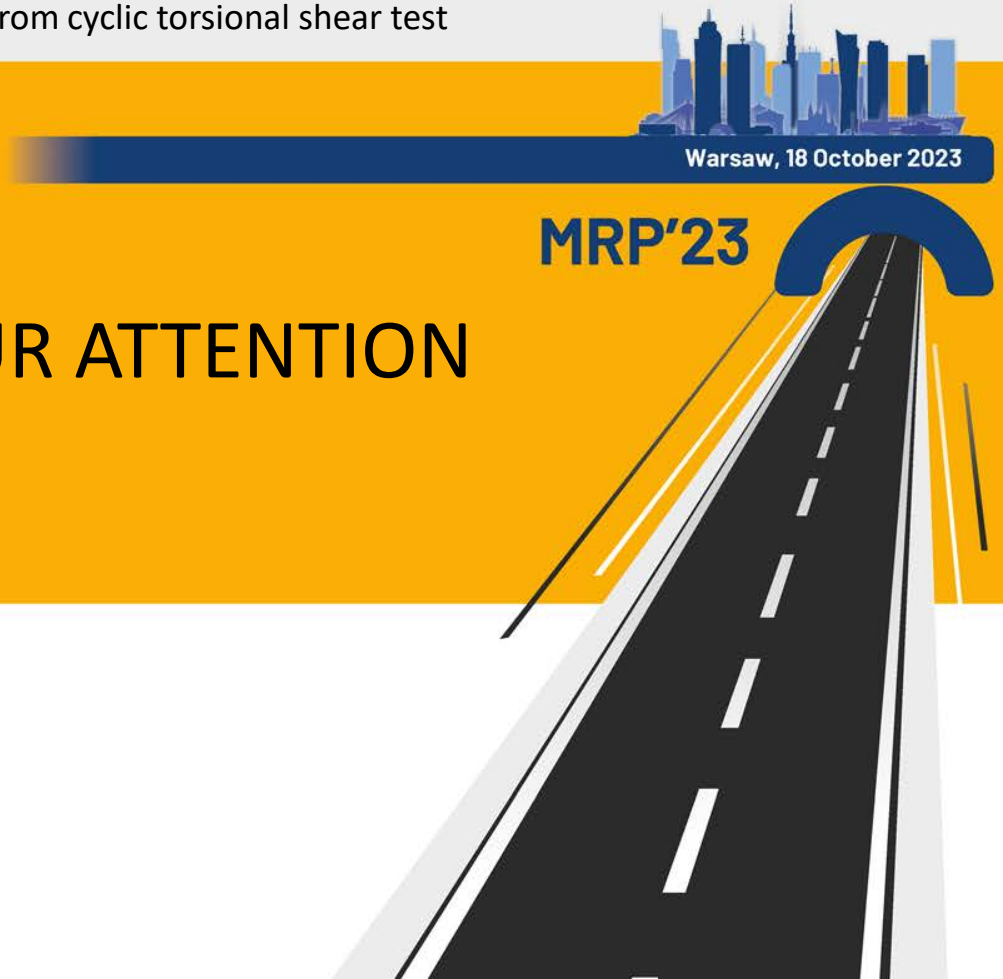
$$D_{min} = a \cdot (p')^b$$



6. Minimum damping ratio vs mean effective stress

Concluding remarks

1. Similar characteristics of man-made soils and their similar trends of change during cyclic loading as for natural material.
2. fRCAs do not meet the requirements of Polish, English, and American standards regarding the use of this particular material as road substructure. Coarser RCA fulfills the requirements.
3. fRCA mixtures are very effective in damping vibrations from passing vehicles but do not improve the rigidity of the roadbed. The tested coarse aggregate is characterized by a stiffness comparable to that of a natural aggregate.



THANK YOU FOR YOUR ATTENTION