Geological and geotechnical characteristics of the overburden disposal areas in lignite open pits in central Poland

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COOPERATION WITH AN ASSOCIATED PARTNER IN THE SUMAD PROJECT - Konin Brown Coal Mine owned by a large energy generation group, ZE PAK Capital Group.

ZE PAK is going to stop complitely mine operation before 2030. Therefore their activities in the nearest future will be focused mostly on post-mining land reclamation.

- ZE PAK Group is the owner of two coal mining companies (Adamów and Konin Brown Coal Mines) and two coal-fired power plants; also has a photovoltaic farm
- the last mining site of the Adamów Brown Coal Mine stopped excavating coal in early 2021
- still 3 mining sites operating within the Konin Brown Coal Mine
- the strategy of the Group is to replace coal with renewables
- ZE PAK Group is the largest employer in the region - 4,000 employees at the end of 2020; decrease in employment by 60% between 2011 and 2020
- Dependence of local governments on revenues from one taxpayer; in case of one municipality the ZE PAK's share in the municipality's own income is almost 60 %, in case of a few other municipalities - 40-45%.

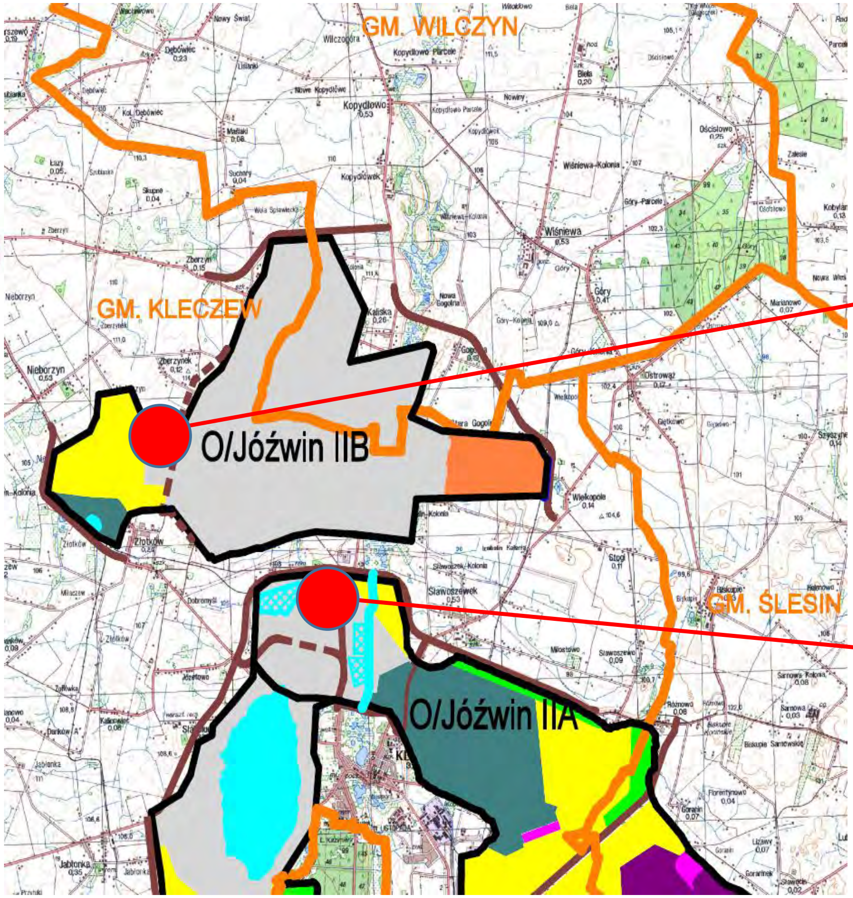
Sustainable Use of Mining Waste Dumps

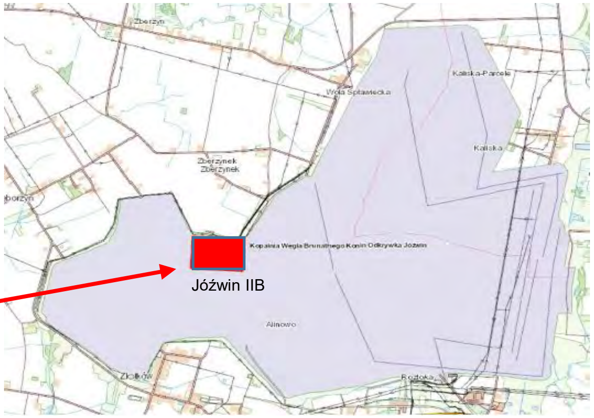
Location Jóźwin IIA and Jóźwin IIB

General view of the mining and reclaimed areas at the Jóźwin IIA and IIB open cast mines "PAK Konin S.A Opencast Mine"

Kleczew Commune;
Konin District;
Wielkopolskie Voivodeship

Legend:
Black line – borders of the excavation pit
Grey – excavation pit/overburden dumping site
Orange – coal deposit in the foreground of the excavation pit
Already reclaimed areas:
Light green – forest
Dark green – sport and recreation area
Blue- area of water reservoir
Yellow – agricultural area
Pink - municipal landfill
Purple - landfill for coal ashes from a power plant
Brown line – relocated local roads





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➢ Two case study areas in the Konin brown coal mining region

- the area within the Jóźwin IIA Mine inner dump, selected as a potential site for a solar power plant covering up to 30 ha,
- the area of within the Jóźwin IIB Mine inner dump, selected as a potential site for a wind power plant (one wind turbine), the site to be characterized covers less than. 0,1 ha
- the area of within the Jóźwin IIB Mine inner dump selected as a potential site for a solar power plant covering up to 22 ha

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- 49 Boreholes 3 to 10 m
- 1 borehole 40 m
- 49 tests Static SCPTU soundings
- 69 undisturbed soil samples

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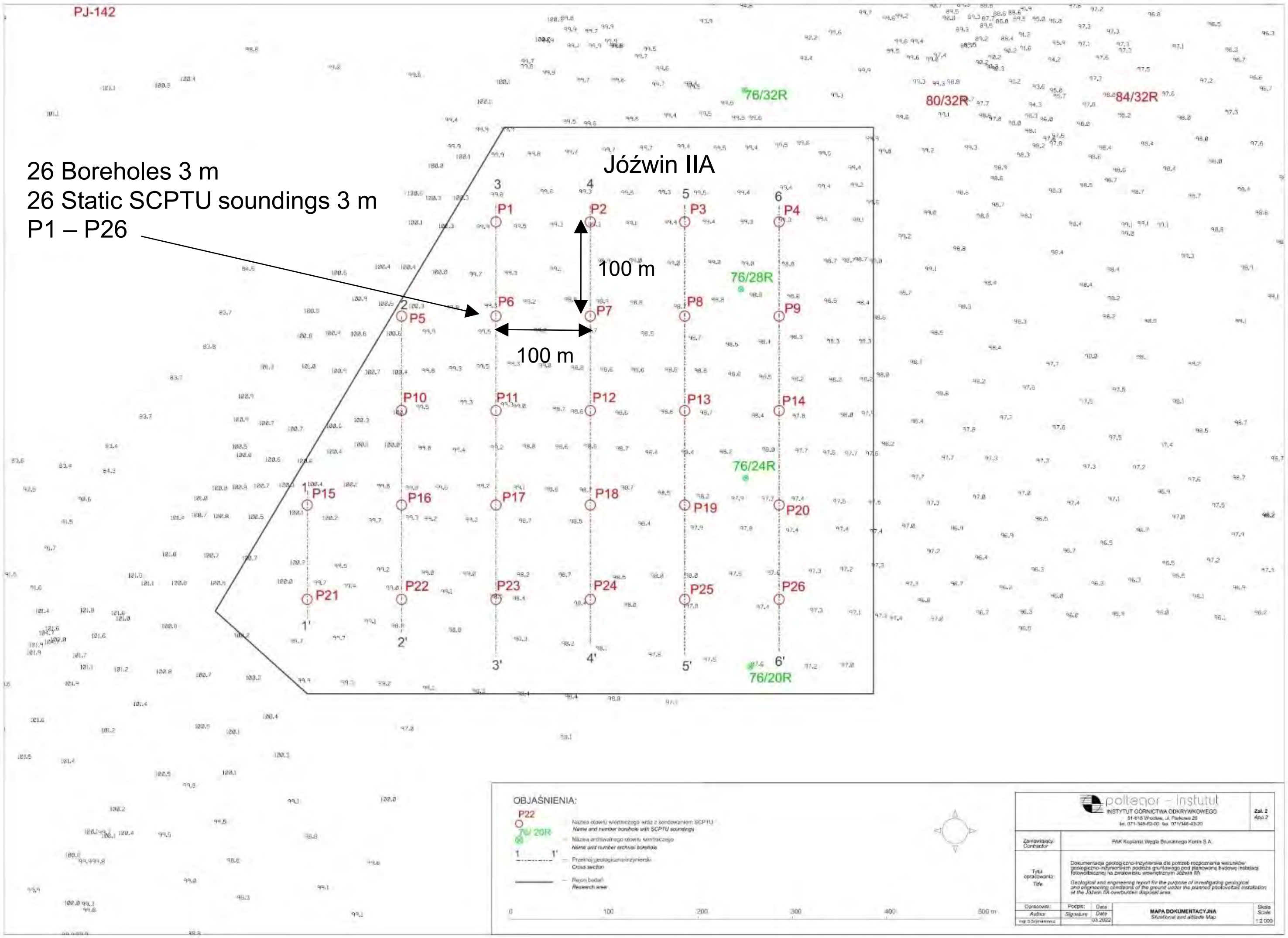

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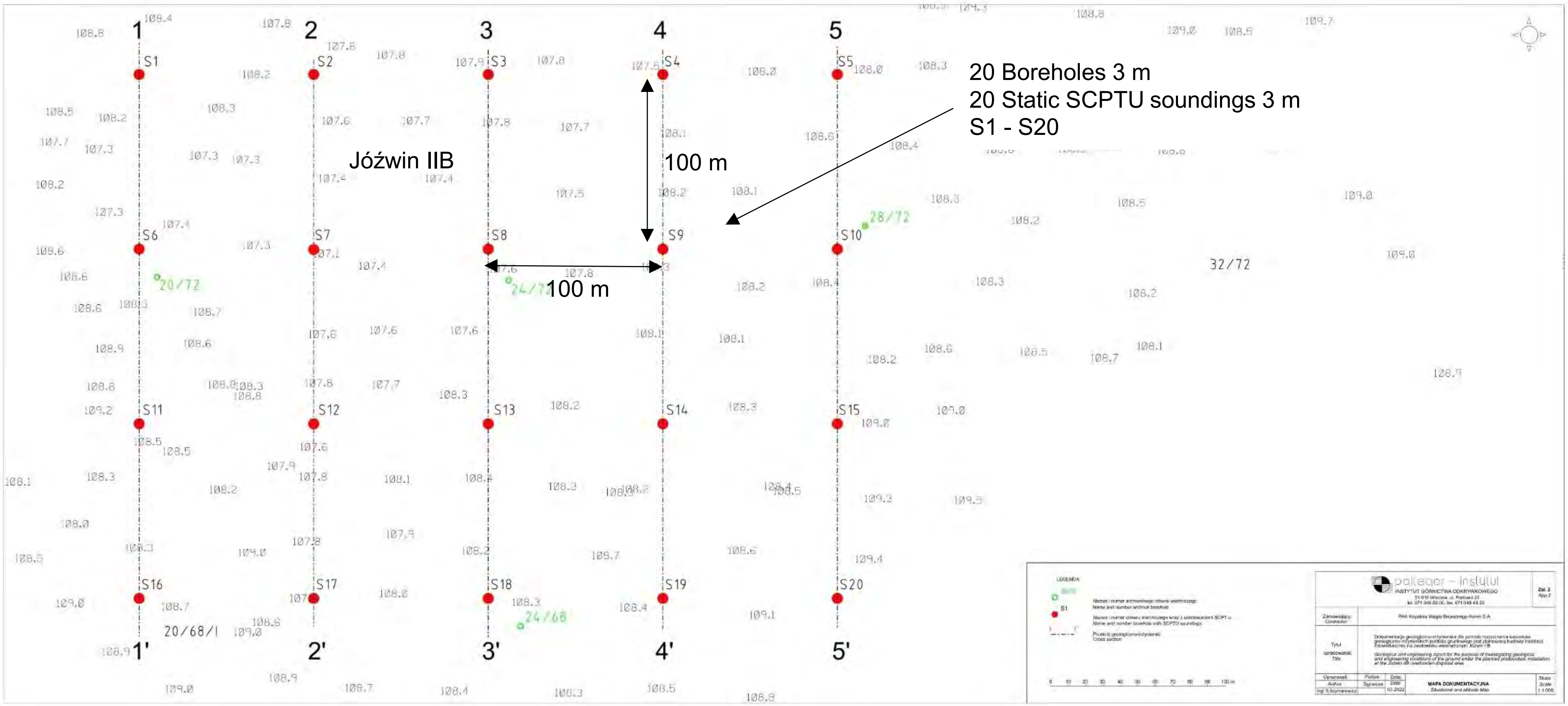

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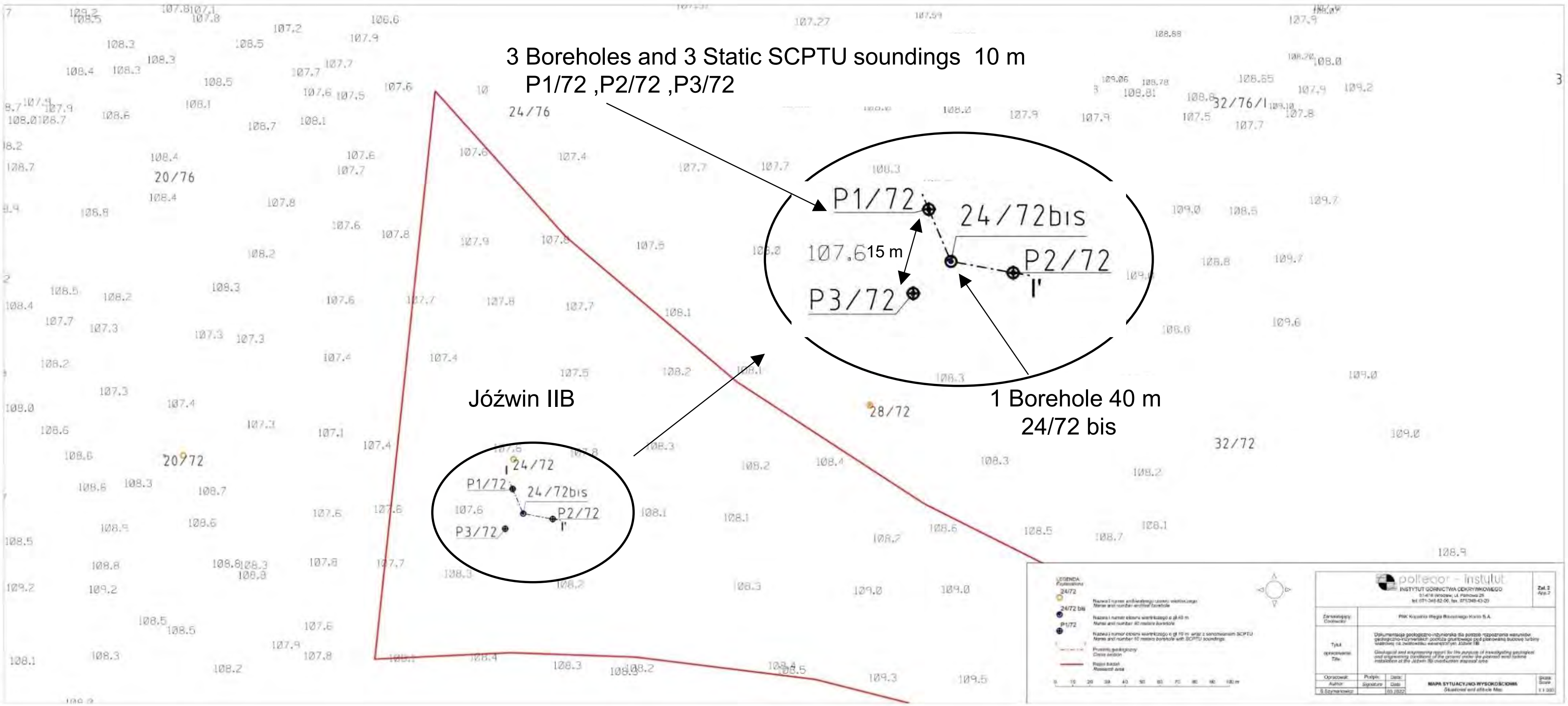

The scope and number of laboratory tests performed

Test type	Number of the performed laboratory tests
Soil macroscopic description	23
Water content	25
Bulk density	22
Particle density	22
Aerometric (hydrometric) analysis	23
Liquidity index	23
Consistency	23
Oedometric modulus of primary compression and secondary compression	8
Total angle of internal friction	6

Part of the core from borehole

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Test type	Methodology
Soil macroscopic description	PN-EN ISO 14688-1:2018-05 Geotechnical investigation and testing- Identification and classification of soil- Part 1: Identification and description PN EN ISO 14688-2:2018-05 Geotechnical investigation and testing- Identification and classification of soil- Part 2: Principles for a classification

Test type	Methodology
Water content	PN-EN ISO 17892-1:2015-02 Geotechnical investigation and testing- Laboratory testing of soil- Part 1: Determination of water content
Bulk density	PN-EN ISO 17892-2:2015-02 Geotechnical investigation and testing- Laboratory testing of soil- Part 3: Determination of bulk density
Particle density	PN-EN ISO 17892-2:2016-03 Geotechnical investigation and testing- Laboratory testing of soil- Part 3: Determination of particle density

Soil from borehole S-2 collected with a bulk density ring

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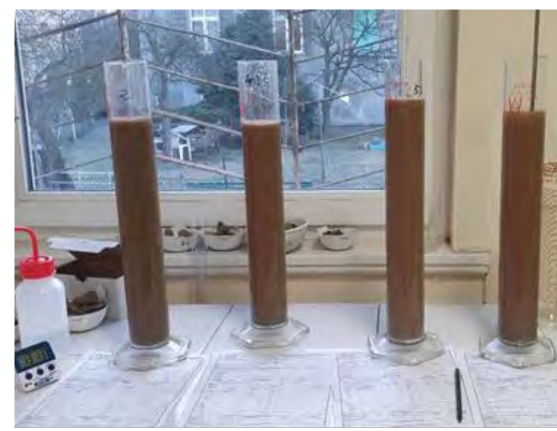
Test type	Methodology
Aerometric (hydrometric) analysis	PN-EN ISO 17892-2:2016-03 Geotechnical investigation and testing- Laboratory testing of soil- Part 4: Determination of particle size distribution
Liquid limit	PKN CEN ISO/TS 17982-12:2009 Geotechnical investigation and testing – Laboratory testing of soil - Part 12: Determination of Atterberg limits.
Consistency	
Plasticity limit	

Liquid limit



Hydrometric analysis

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Test type	Methodology
Oedometric modulus of primary compression and secondary compression	PKN-CEN ISO/TS 17892-5:2009 Geotechnical investigation and testing – Laboratory testing of soil - Part 12 Oedometer test
Total angle of internal friction	PN-EN ISO/TS 17892-9:2018 Geotechnical investigation and testing-Laboratory testing of soil-Part 9: Consolidated triaxial compression test on water saturated soil.

GDS 76TC3

Oedometers EL-1

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Geological structure

The investigated soils are a composite of sediments originating from the overburden of the Pątnów pit

Cohesive soils

- sandy loams
- clayey sand
- clays so-called Poznan clays

admixture of gravel and stony fractions

Non-Cohesive soils

- silty sands, occasionally fine and medium sands

Soil particle size distribution based on aerometric analysis according to PN-EN ISO 17892-4:2017-01

Part of the core from borehole S-5

Borehole No.	Overburden disposal area	Sampling depth [m b.s.l.]	Macroscopic description PN-EN ISO	Macroscopic description PN-88/B-04481	Particle size distribution in % >2.00 mm	2.00-0.063 mm	0.063-0.002 mm	<0.002 mm
P1	Jóżwin IIA	2.3-3.0	orgrsiclSa	Pg+Ż+Or	2.0	62.0	24.0	12.0
P4		2.0-2.7	grsiclSa	Pg+Ż	1.0	67.0	25.0	7.0
P10		2.0-2.6	siclSa	Pg	1.0	60.0	30.0	9.0
P11		2,6-3,0	siSa	Ppi	6,0	67,0	23,0	4,0
P14		2.0-2.4	orsiclSa	Pg+Or	4.0	64.0	23.0	9.0
P21		2.3-3.0	cogrsiclSa	Pg+Ż+KO	4.0	67.0	22.0	7.0
P26		2.3-3.0	cogrsiclSa	Pg+Ż+KO	2.0	64.0	27.0	7.0
S2	Jóżwin IIB	1.6-2.0	grclsaSi	Gp+Ż	10.0	46.0	30.0	14.0
S5		2.4-3.0	grclsaSi/saSi	G/Pip(pył p) +Ż	5.0	50.0	34.0	11.0
S12		2.3-3.0	orgrclsaSi	Gp+Ż+Or	5.0	51.0	31.0	13.0
S16		2.4-3.0	clsaSi	Gp+Ż	2.0	53.0	32.0	13.0
S20		2.4-3.0	clsaSi	Gp+Ż	3.0	52.0	32.0	13.0
24/72bis		7.6-9.1	cogrclsaSi	Gp+Ż+KO	5.0	46.0	38.0	11.0
24/72bis		10.6-12.1	coorclsaSi	Gp+Ż+KO+Or	3.0	48.0	36.0	13.0
24/72bis		13.6-15.1	coorclsaSi	Gp+KO+Or	1.0	51.0	35.0	13.0
24/72bis		16.6-18.1	cogrclsaSi	Gp+Ż+KO	2.0	51.0	36.0	11.0
24/72bis		22.6-24.1	cogrclsaSi	Gp+Ż+KO	1.0	51.0	34.0	14.0
24/72bis		27.1-28.6	cogrclsaSi	Gp+Ż+KO	2.0	51.0	33.0	14.0
24/72bis		31.6-33.1	orCl	I//wb	1.0	11.0	42.0	46.0
P1/72		6.0-6.7	grclsaSi	G+Ż	7.0	45.0	33.0	15.0
P1/72		9.3-10.0	clsaSi	Gp+Ż+KO	3.0	53.0	32.0	12.0
P2/72		9.3-10.0	sisaCl	Gpz+Ż+KO	3.0	45.0	35.0	17.0
P3/72		9.3-10.0	clsaSi	Gp+Ż	3.0	50.0	34.0	13.0

Division of the ground into geotechnical layers

Cohesive soils

- account soil consolidation, liquidity index (I_L)
- consistency index (Ic).

Non-Cohesive soils

- density index (I_D)

symbol „1” – loose and very loose non-cohesive soils (I_D=0.0÷0.35).

symbol „2” – medium dense non-cohesive soils (I_D=0.35÷0.65).

symbol „3”– dense and very dense non-cohesive soils (I_D=0.65÷100)

symbol „1” – very stiff cohesive soils (I_L)<0 and consistency index (Ic)>1

symbol „2” – very stiff cohesive soils (I_L)=0 and consistency index (Ic)>1

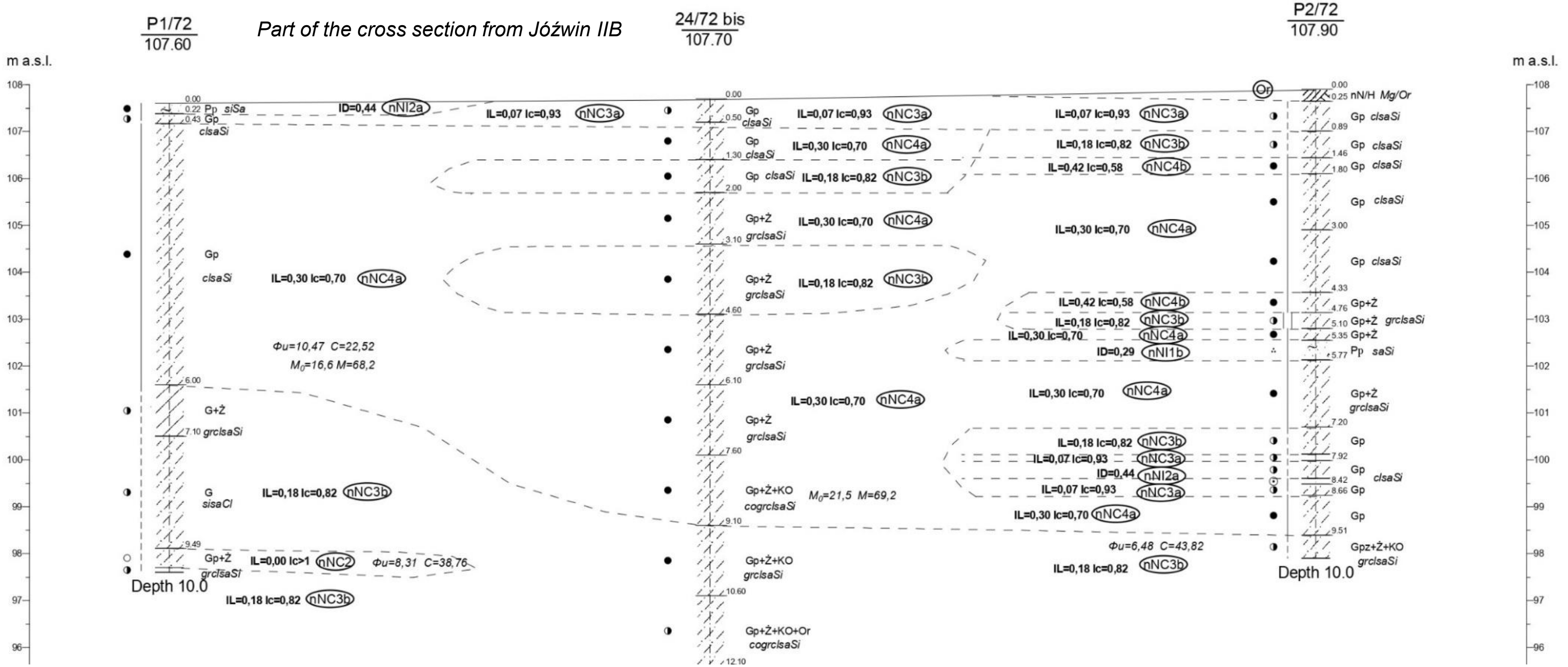
symbol „3” – stiff cohesive soils (I_L)=0.00-0.25 and consistency index (Ic)=0.75-1.00

symbol „4” – firm cohesive soils (I_L)=0.25-0.50 and consistency index (Ic)=0.50-0.75

symbol „5” – soft cohesive soils (I_L)=0.50-0.75 and consistency index (Ic)=0.25-0.50

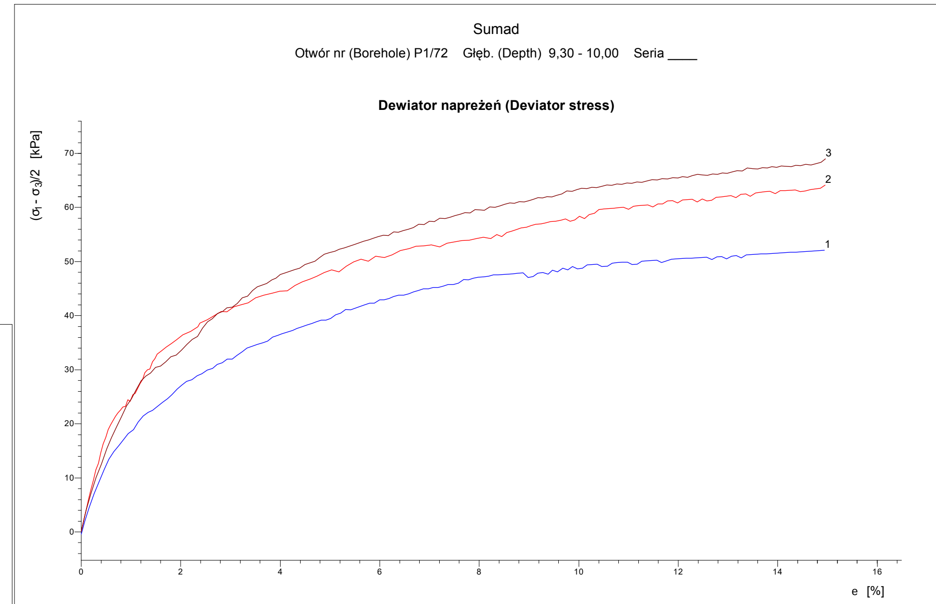
Geotechnical layer symbol	Division of the ground into geotechnical layers
UNCONTROLLED CONSTRUCTION EMBANKMENT nN (Mg)	
OR	Sandy top soil, layer not suitable for direct foundation
Cohesive soils	
nNC1a	Loamy sands with sandy loam intercalations . Liquidity index I_L=-0,19 (Ic>1) – very stiff state
nNC1b	Sandy loams and loamy sands with boulders. Liquidity index I_L=-0,05 (Ic>1) – very stiff state
nNC2	Loamy sands . Sandy loams with intercalations of medium and loamy sand. Liquidity index I_L=0,00 (Ic>1) – very stiff state
nNC3a	Sandy loams and loamy sands with gravel and boulders. Liquidity index I_L=0,07 (Ic=0,93) – stiff state.
nNC3b	Sandy loams and loamy sands with gravel and boulders. Liquidity index I_L=0,18 (Ic=0,82) – stiff state.
nNC4a	Loamy sands with sandy loam intercalations. Sandy loams with intercalations of loamy sand with gravel, boulders and locally with an admixture of organic matter . Liquidity index I_L=0,30 (Ic=0,70) – firm state.
nNC4b	Sandy loams and loamy sands with gravel and boulders . Sandy silts. Liquidity index I_L=0,42 (Ic=0,58) – firm state .
nNC5a	Sandy loams with intercalations of loamy sands. Loamy sands with gravel and boulders. Liquidity index I_L=0,55 (Ic=0,45) – soft state
nNC5b	Loamy sands with sandy loam intercalations, sandy loams with intercalations of loamy sand with boulders and gravel. Liquidity index I_L=0,74 (Ic=0,26) – soft state
nND3a	Clays. Sandy clays. Clays with lignite intercalations. Liquidity index I_L=0,07 (Ic=0,93) – stiff state
Non-cohesive soils	
nNI1a	Silty sands being almost loamy sands. Density index I_D=0,13 – loose state.
nNI1b	Silty sands. Silty sands being almost sandy silts. Density index I_D=0,29 – loose state
nNI2a	Silty sands. Silty sands being almost loamy sands with boulders and organic matter. Density index I_D=0,44 – medium dense state
nNI2b	Silty sands. Silty sands being almost loamy sands with gravel and boulders . Density index I_D=0,56 – medium dense state
nNI3a	Fine sands. Silty sands. Silty sands being almost loamy sands with gravel and boulders . Density index I_D=0,71 – dense state
nNI3b	Silty sands with gravel and boulders . Density index I_D=0,77 – dense state

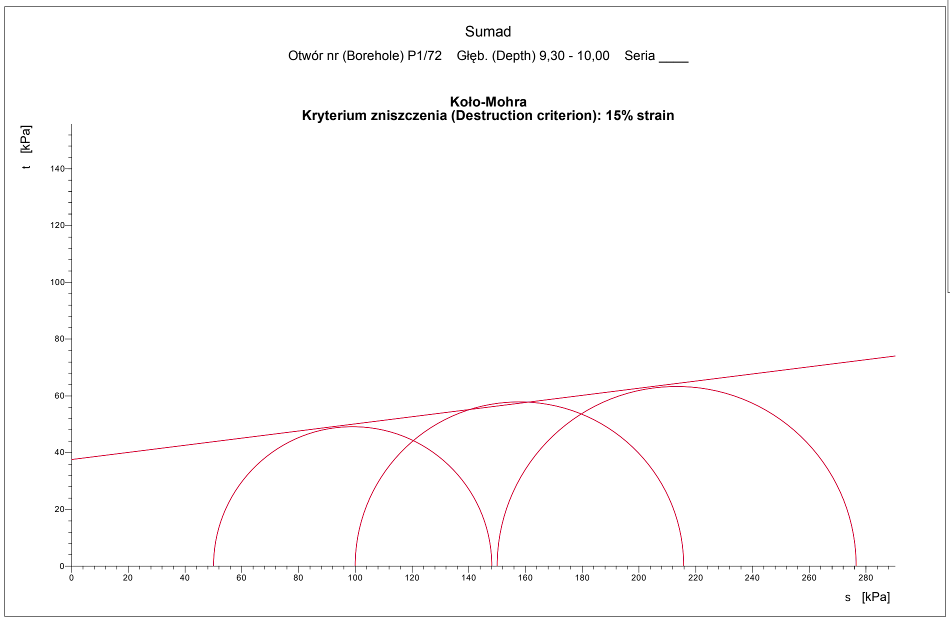
Sustainable Use of Mining Waste Dumps



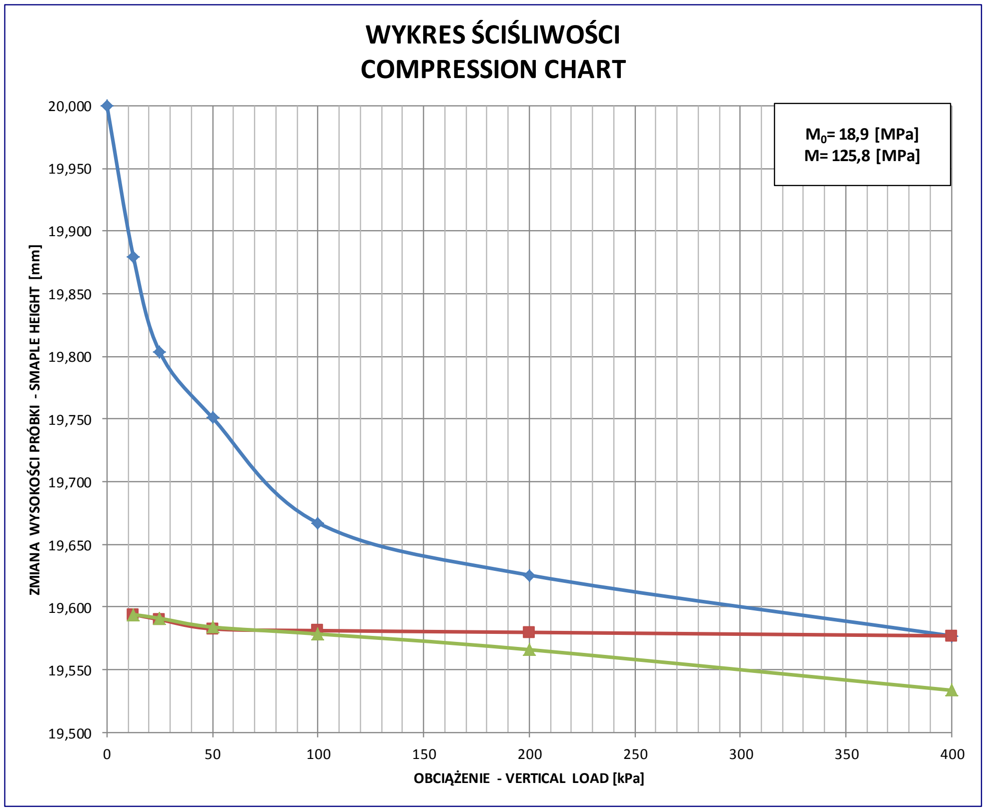
Unconsolidated undrained triaxial test

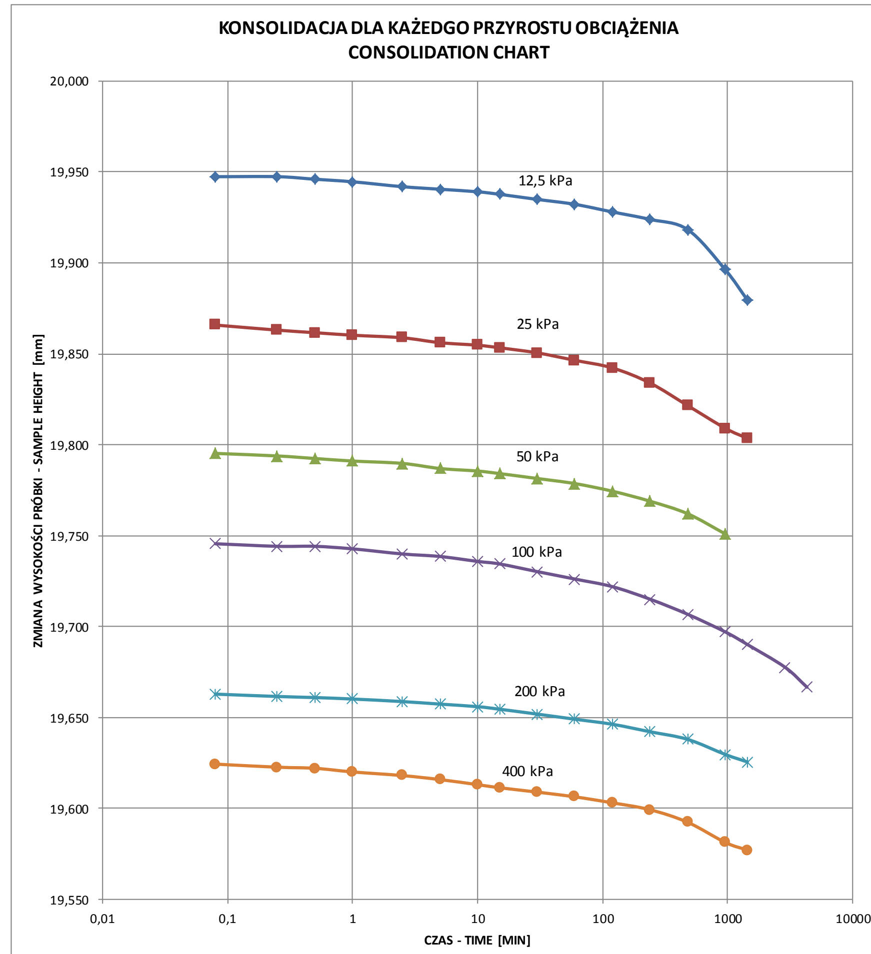
Strength parameters	Total
C [kPa]	**38.76**
Φ [deg]	**8.31**





Oedometer test





Soil from borehole P-10 collected with a bulk density ring

Averaged main geotechnical parameters based on laboratory tests

- Total angle of internal friction Φu=9,46 [deg
- Total Cohesion c=38,77 [kPa]
- Oedometric modulus of primary compression Mo=14,18 [Mpa]
- Oedometric modulus of secondary compression M=41,15 [Mpa]

The main aim of the tests conducted in different parts of Jóżwin IIA and Jóźwin IIB pits was to define physical and mechanical parameters of the dump materials

- the tests showed that due the dumping process a significant variability of parameters is visible. And there is a significant degradation of physical and mechanical parameters of the dumped soils.

- the tests showed that the dumped samples compared to natural soils have more than 70% worse parameters (for example fraction angel equal of 28 deg comparing to 9.46 deg)

- the water content in the tested boreholes varied between 9,6% and 22,5%.

Thank you for your attention