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Ground transmitted vibrations in course of innovative vinyl sheet piles driving

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Ground transmitted vibrations in course of innovative vinyl sheet piles driving

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Abstract: The article presents field experiences in dynamic monitoring of vinyl sheet pile installation in close vicinity to various buildings. I summarizes experiences gained by student trainees in course of practical excursions and assignments on the building site. The presented case study is somehow unique due to unusual material and technology. Vinyl sheet piles used for the study are lightweight and extremely durable alternative to the traditional materials such as steel, concrete or wood. Application of vinyl sheet piles is an environmentally friendly solution, however, their installation is usually performed by means of vibratory driving. The paper presents basic advantaged of technology, examples of applications and sheet pile wall installing procedures. Result of continuous dynamic monitoring of piling works and observations of neighbouring structures technical conditions are presented, discussed with regard to other (formerly published) results and form the basis for conclusions about presented technology applicability.

1. Introduction – dynamic monitoring of geotechnical works

Conducting construction or mining works is inherently related to the impact on the environment [1,2]. This influence may be permanent due to the fact that a new object is created [3,4]. The impacts generated at the construction stage, related to air-born noise and mechanical vibrations transmitted through the ground to the environment, are also very important [5]. These influences are especially intense at the stage of earthworks [6], when significant energy is transferred to the ground during the driving of piles [7] or sheet piling [8], blasting works [9,10], as well as during the formation and compaction of embankments by means of Rapid Impulse Compaction [11,12].

The awareness of these influences should be built in young engineers already at the stage of their university education [13]. This is achieved through practical training in the form of apprenticeships on construction sites and the involvement of young adepts of engineering art in the work of engineering teams conducting a wide range of supervision on construction sites, including vibration monitoring. This paper presents examples of measurements of mechanical vibrations carried out on various objects in the vicinity of the driving of vinyl sheet piles using vibration methods.

The purpose of the monitoring was a technology calibration as proposed in references [13-16].

2. Materials and methods – applications of vinyl sheet piles and vibration testing methodology

Sheet piling made of vinyl (PVC Polyvinylchloride) sheet piles is a relatively new product on the market of geotechnical and engineering works (figure 1). The possibilities of their wide application, presented in the paper, and the relatively low cost (compared to steel sheet piles) make them more and more often found in contracts. Therefore, it should be checked what order of dynamic influences can be expected during their driving in various geotechnical situations (ground conditions), for different types of objects and at different distances from the site of the works.

Figure 1. Vinyl sheet piles with interlocks after driving.

Vinyl sheet piles are eco-friendly alternative for steel sheet piles and other vertical barriers for reducing the flow of water or contaminants and/or supporting vertical slopes. Technologies and various aspects of waterproof barrier applications can be found in reference [17]. PVC piles are used mostly for protection and regulation of river banks, ditches or channels. Due to limited stiffness and possibility of introducing inclination in interlocks, piling systems can easily adjust to the desired shape of construction (e.g. natural curvatures of the terrain). Vinyl sheet piles may be mechanically embedded into the soil by means of hammering or vibratory driving (usually along the pre-installed templates). Selection of the equipment used for vinyl pile driving depends on the ground conditions along driving depth and the stiffness of the sheet pile. In the case of hard cohesive soils and dense granular soils, steel mandrels are used to protect vinyl elements from bending. Mandrels are special guide bars of a shape and length reflecting the used PVC elements (figure 2).

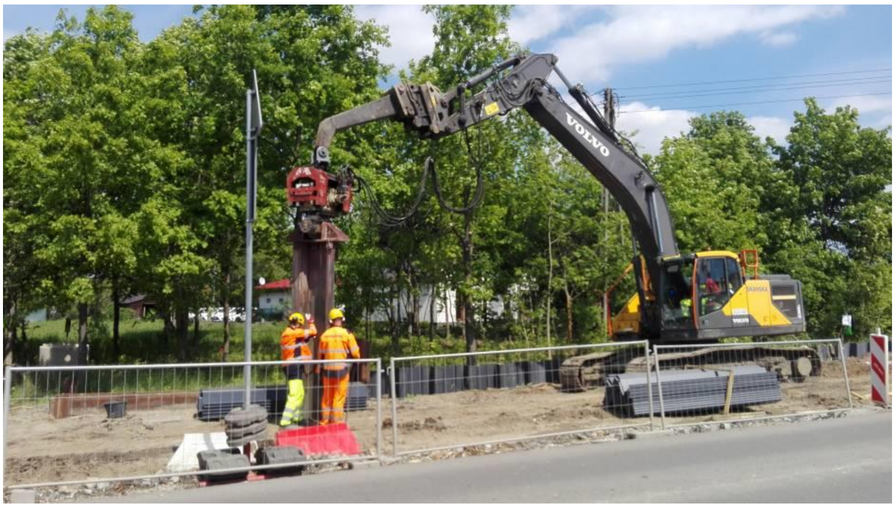

Figure 2. Steel mandrels used to protect vinyl elements in course of vibratory driving.

Vinyl sheet piling used in place of steel retaining walls reduces the costs of transport (lower weight) and materials. As an alternative to wooden solutions, PVC piling ensures much higher durability and resistance to external factors (corrosion). Selected applications of PVC used for construction of hydraulic structures are presented on figure 3 and figure 4 (courtesy of S. I A. Pietrucha Sp. z o.o.).

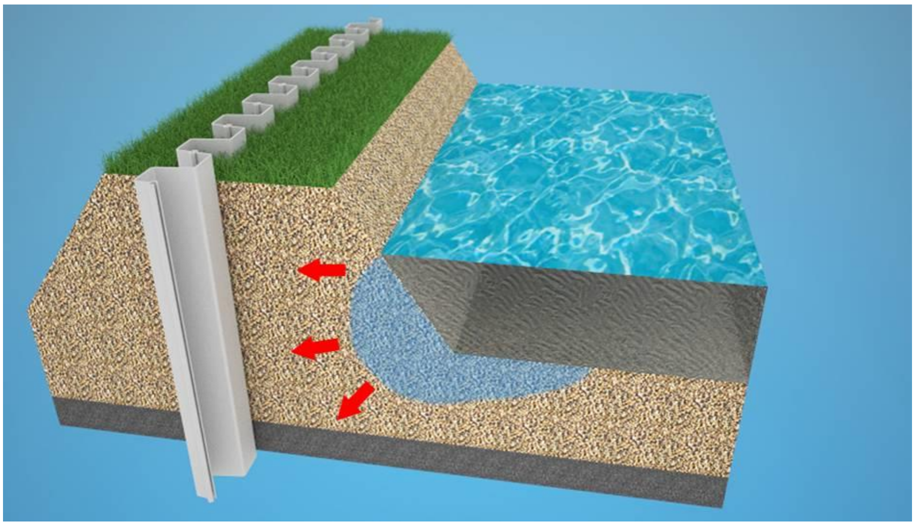

Figure 3. Strengthening and increasing durability of flood walls (river dikes)
https://www.pietrucha.pl/files/pietrucha/oferta/inzynieria_ladowa_i_wodna/grodzica5.jpg

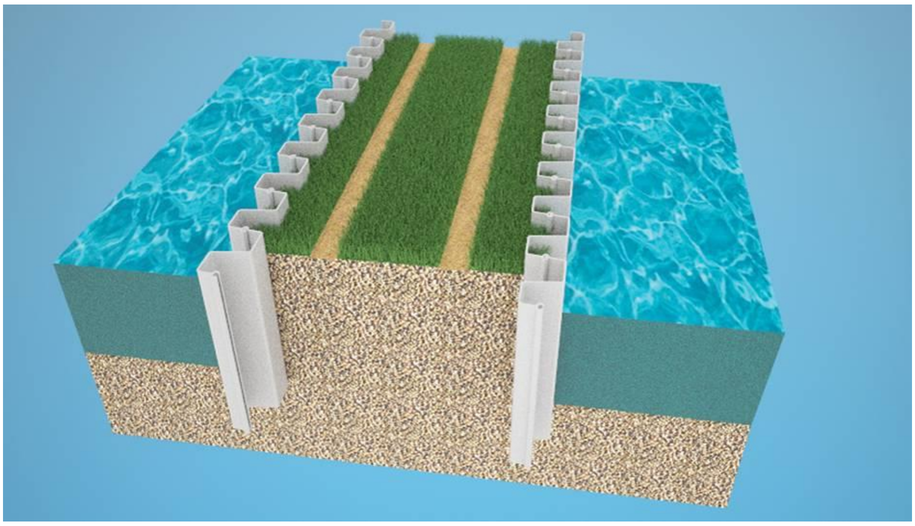

Figure 4. Construction of causeways on water reservoirs
https://www.pietrucha.pl/files/pietrucha/oferta/inzynieria_ladowa_i_wodna/grodzica4.jpg

Vinyl sheet piles may also form a waterproof barrier around contaminated areas to reduce the migration of groundwater and contaminants (see figure 5). In some cases, PVC sheet piles may crate a cut-off wall to protect construction of roads and pavements (figure 6). To some extent PVC sheet piles may create some kind of “diaphragm wall isolation of vibrations” from the road to neighbourhood.

The last mentioned case will be a subject of presented study. Vibration tests during driving of vinyl sheet piles in Wrocław (Poland), were performed in course of a large infrastructural road contract. Eight building structures (residential houses, office buildings, magazines and industrial buildings were monitored in course of driving works. The location of the sensor was dictated by the distance to the works carried out, allowing to assess the intensity of dynamic impacts transmitted to the object. Vibration monitoring was conducted following the rules given in works [19,20] describing range of dynamic impact of geotechnical works on structures. Vibration measurements were carried out continuously, registering the vibrations caused by construction works and the background (while the construction machines were not working).

Figure 5. Cut-off walls in ecologically threatened areas
https://www.pietrucha.pl/files/pietrucha/oferta/inzynieria_ladowa_i_wodna/grodzica7.jpg

Figure 6. Vinyl sheet pile applied as Cut-off wall to protect construction of road
https://www.pietrucha.pl/files/pietrucha/oferta/uslugi/grodzica6.jpg

Detailed description of material data applicable to all types of vinyl sheet piles are given in table 1. To protect sheet piles from possible damage, steel mandrels were used in course of vibratory driving.

Table 1. Data applicable to all types of vinyl sheet piles (according to www.pietrucha.pl/en/)

Parameter	Unit	Standard	Value
Density	kg/m^2	PN-EN ISO 1183-3:2003	1400-1480
Charpy impact test	kJ/m^2	PN-EN ISO 179-1:2004	>30
Shore durometer	Shore'a D	PN-EN ISO 868:2005	>75
Softening point Vicad method	°C	PN-EN ISO 868:2004	>77
Tensile strength	MPa	PN-EN ISO 527-2:1998	>44
Tensile modulus of elasticity	MPa	PN-EN ISO 527-2:1998	>2600
Bending modulus of elasticity	MPa	PN-EN ISO 178:2006	>2600
Bending strength	MPa	PN-EN ISO 178:2006	>65
Resistance to climatic ageing. Energy radiation of 2.6 GJ/m^2 - resistance to changes in the surface colouring - Change in the impact resistance (the Charpy test)	%	PN-EN 513:2002 PN-EN ISO 4892-2 met A PN-EN 20105-A03-2 :1996 PN-EN ISO 179-1:2004	Not less than 4 in gray scale <30

3. Exemplary results of field testing of ground transmitted vibrations

In Poland, various standards are currently used in order to determine safe vibration levels. The choice is usually motivated by the kind of the structure and available software to be used for postprocessing of data achieved in course of monitoring. These standards define safe vibration levels for dynamic effects on large-scale buildings, their equipment (e.g. machinery and equipment) and people staying in them. They also provide safe vibration levels for other engineering structures. In this study, due to the method of calibrating the vibration sensor and recorder, the limits described in DIN 4150 (figure 7) were used to determine the limit vibration levels affecting various objects. In this standard, the limit vibration velocity levels are described in relation to the type of object and the frequency of the measured vibrations. According to the nomogram on figure 7, 3 categories are distinguished: category L1: industrial objects and similar facilities, category L2: residential buildings, category L3: particularly sensitive structures that cannot be classified in the above two categories, such as structures under conservation protection.

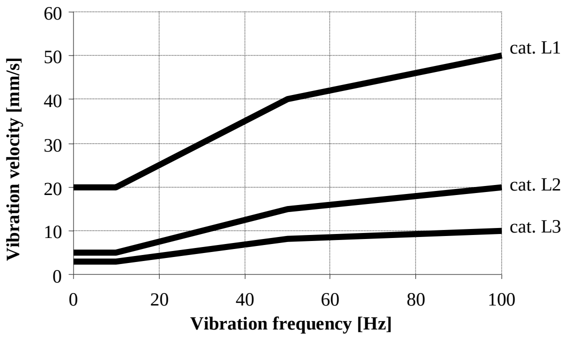

Figure 7. Safe levels of vibrations described in DIN 4150.

The Minimate® Pro4 sensor from Instantel® with a sampling frequency of 2048 Hz was used to measure the vibrations. During the measurement, velocity values greater than 0.1 mm/s were observed in 15 s intervals. The Minimate® Pro4 sensor was placed on the structural elements of the monitored buildings and structures or directly on the site from the works side. Detailed information about sensor locations with average distance from the works, measured values of vibration velocity and corresponding frequency are given in Table 2.

Table 2. Data measured in course of vibration monitoring of various buildings

Building No.	B1	B2	B3	B4	B5	B6	B7	B8	Average
Distance from vinyl sheet piling works, m	25	33	21	18	25	35	41	25	27.9
Magnitude of vibration velocity, mm/s	1.87	1.39	2.63	3.08	1,65	1,46	1.36	2.25	1,96
Corresponding frequency, Hz	36	36	40	38	38	37	36	33	36,75

4. Discussion on presented results and final conclusions

The aim of the research was ongoing control by comparing the level of dynamic effects of the works (related to vinyl pile driving) on the surroundings with the values specified in the standard DIN 4150 as safe for L3 category objects. The assessment of the harmfulness of the vibrations transmitted through the ground to the structure was carried out by measuring the vibrations as well as by current, direct observation of the technical condition of visible structural elements.

The procedure of limiting the risky impacts on the environment, related to the monitoring of vibrations, allows in principle to exclude the possibility of occurrence of safety-related damage to the technical condition of the structure of monitored buildings. The vibrations were slightly felt, decreasing with distance of the source (piling rig) as seen in table 2, but according to DIN 4150, the level of observed vibrations would not pose a threat even to the structures of historic buildings. Vibrations with frequency ranging 33-40 with velocities not exceeding approx. 2÷3 mm/s would also not constitute an impact that could cause accelerated wear of objects (apart from the possible disclosure of earlier scratches). However, the works carried out were associated with nuisance noise.

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