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USING POSIDONIA OCEANICA FIBRES FOR THE MECHANICAL IMPROVEMENT OF SEDIMENTS

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Abstract: This study presents the first step of research aiming at investigating the potential use of Posidonia Oceanica (PO) as a natural additive for the mechanical improvement of dredged sediments or soils. Leveraging image analysis methodologies, the correlation between Posidonia needle ball (NB) diameter and fibre length is explored, which is crucial for sediment treatment optimisation. Fibre length estimation utilised imaging analysis, with methods focused on identifying the longest skeleton path in MATLAB[®] and the maximum length of the bounding ellipse in ImageJ[®]. Both approaches employed thresholding techniques as image pre-treatment. Results reveal a clear association between ball diameter and fibre length, with skeleton path techniques demonstrating superior precision in fibre length determination. This is important to be able to easily select PO fibres of specific lengths to be added for the mechanical improvement of sediments.

1. Introduction

In the contemporary world, there is a growing emphasis on conserving non-renewable resources and recycling waste materials for various applications, particularly in engineering. This contribution aims to assess the effectiveness of *Posidonia Oceanica*, an abundant waste of marine origin, as a natural additive for the mechanical improvement of fine dredged sediments or, more in general, soils. Sustainable and traditional binders have been applied to treat dredged sediments [1,2,3]. However, incorporating natural fibres could prove effective in enhancing the ductility of the treated sediment. *Posidonia Oceanica* (PO) is a natural fibre derived from the endemic Mediterranean seagrass, whose annual accumulation of leaves reaches the coastline between 5 to 50 M tons [4,11] also, found in the southern Hemisphere (Southern Australia) [10]. Posidonia needle balls (NB) structures vary in size, ranging from a few millimetres to hundreds in diameter up to 200 mm. The fibre cross-section in balls exhibits dimensions of 100 µm with an average length of 7.7 mm. The maximum tensile load capacity of Posidonia leaves (4 mm wide by 0.1 mm thick) and ball fibres (diameter 80 µm) is about 0.3 N and 0.025 N, respectively [5, 6]. Multiple reuses of PO have already been explored in the literature. Among the various applications, it is used to enhance the ductility of cement paste and mortar [5,7]. Pre-treating natural fibers like PO fibers in alkaline environments or through hydrothermal treatment greatly improves their durability and resistance to bio-deterioration [5]. Straw fibres have also been tested to improve the ductility of sediment-cement mixtures [8]. The literature on the use of either artificial (e.g., polypropylene fibre (PF), polyvinyl alcohol (PVA) fibre) or natural fibres as reinforcement of cement or soil-cement mixtures highlights the role of the fibre-length, fibre content, fibre composition on the overall mechanical efficacy of the treatment [8, 9]. This study explores the relationship between the ball diameters and fibre length in different NB Posidonia fibres with two techniques in two, i.e., MATLAB[®] image and ImageJ[®] platforms. This represents a first step of the research with the overarching purpose of quickly selecting a specific class of fibres based on the ball PO diameters, to be used with other additives and sediments for their mechanical improvement. The selection of fibre length range for reinforcing treated sediment is paramount in optimising the fibre's role within the matrix, especially when focusing on target hydro-mechanical properties like tensile strength, ductility, overall mixture strength, water retention and permeability properties.



2. Materials and methods

Figure 1 presents a representative image showcasing the fibres' collection location (Figure 1 a), as well as images depicting Posidonia leaves and balls utilised in this study (Figure 1 b). A comprehensive methodology, involving fibre opening, high-resolution scanning, and image processing techniques (all analysis based on 2D images) using MATLAB[®] and ImageJ[®], was conducted on twenty Posidonia balls of different sizes, with two samples taken for each diameter. To determine the fibre length distribution across various ball diameters of Posidonia, the initial step involves untwisting/opening the Posidonia NB fibres by hand (Figure 2 a), which were air-dried at room temperature of 22 °C for more than 3 month (with initial 18% water content at the time opening) and subsequently scanning the fibre distribution. Following this, the scan file, along with reference images (Figure 2 b), is uploaded into both platforms. This process sets the stage for analysing the fibre length distribution, leveraging long skeleton path in MATLAB[®]'s image processing capabilities to extract relevant data and insights regarding the distribution of fibre lengths across different ball diameters of Posidonia, followed by the utilisation of grayscale images (apply 8-bit image basis Figure 2 c) to delineate particle shapes. Subsequently, a threshold of 200 is applied to demarcate boundaries in both ImageJ[®] and MATLAB[®] (Figure 2 d). Additionally, during the original image cutting process, certain fibres may be truncated, necessitating their removal from the image borders. Furthermore, the spatial resolution is 0.126 mm², so fibres smaller than 100 px² are deemed insignificant and thus removed, thereby eliminating noise and small particles, resulting in a cleaner image. In the revised version of the image, only particles exceeding a certain area threshold remain. Moreover, many fibres have a curved shape (Figure 4 a, b), prompting an assessment of their actual length. It is noteworthy that some processes similar in both techniques are illustrated in Figure 2 b, c, and d.

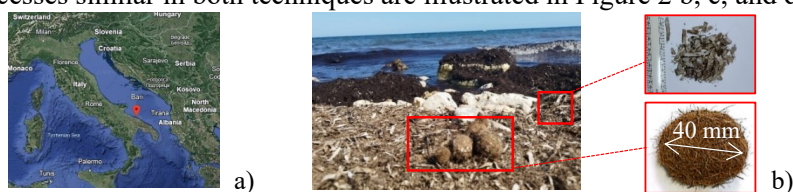


Figure 1. Location of different fibres, Posidonia leaves, Posidonia needle balls (NB).

3. Results

Fibre length analysis: Skeleton path method in MATLAB[®]

Skeleton path techniques in image processing generate various branches to identify the object's axis, then calculate different possible lengths to determine the longest object skeleton path. Despite the varying shapes of the fibres, the algorithm assesses their alignment with the axis, which aids in identifying the longest fibre path (Figure 2 e, f). Figure 2 f illustrates the longest path within the fibre, depicted by red pixels, denoting the actual length. Figure 3 a shows that the particle length histogram experiences a slight shift towards shorter lengths after the "pruning" of branches, characterised by a smaller A parameter. Notably, the histogram's shape remains consistent, with unchanged B parameter. Moreover, Figures 3 a and b exhibit a Weibull distribution pattern, characterised by a diminutive distribution at the outset, followed by a peak, and subsequently returning to a diminutive level. The main advantage of this technique is its ability to handle bifurcations in fibres (Figure 4 a (3)), which can inflate length calculations. The skeleton path technique identifies the longest path along the fibre skeleton from end to end, providing a more accurate approximation of the actual fibre length.

Fibre length analysis: Bounding ellipse method in ImageJ

The bounding ellipse method is a geometric technique used to approximate the overall shape of an object by fitting an ellipse around it. The major axis of this ellipse is then used as an estimate of the object's length. While this method can be effective for simple, elongated objects, it fails to provide

accurate measurements in the presence of fibre bifurcations. The workflow for image processing using bounding ellipse techniques in ImageJ® to find the maximum length (Figure 4 b) consisted first in scanning fibres, then in the conversion to a grayscale image and applying a threshold. Notably, selecting the threshold was critical to prevent the fragmentation of fibres into disparate segments. Upon analysing all particles in ImageJ® and MATLAB®, the resulting distribution, depicted in Fig. 4 c, revealed a prevalence of small particles, approximately 10 pixels in size initially, transitioning to a Weibull distribution post-threshold application. However, certain limitations inherent to bounding ellipse were observed, underscoring the advantages of skeleton path techniques. Firstly, applying the threshold in ImageJ® often led to the fragmentation of fibres. Secondly, when the image was cropped, certain fibres were inadvertently truncated, yet boundary fibres could not be removed in ImageJ®. Lastly, the calculation of the actual length of fibres with some structural branches (fibre bifurcations) posed challenges in ImageJ®, as it failed to account for branching (1, 2, and 3 in Figure 4 a).

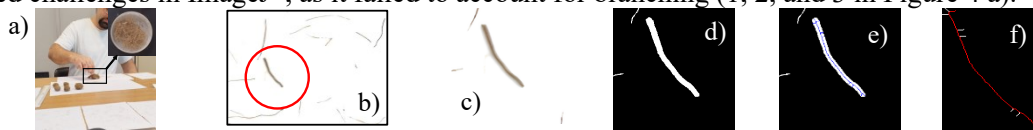


Figure 2. Different steps followed to measure the actual length of PO NB fibres.

Correlations between PO ball diameter and fibre length ranges

Figure 5 shows a histogram of normalized fibre counts for various ball diameters from MATLAB® skeleton path techniques. The literature indicates that natural straw fibers of three lengths 2-5 mm, 5-10 mm, and 10-30 mm were studied, with the 5-10 mm range showing optimal reinforcement in cement-treated dredged sediment [10]. In this research, within the 10.1-15 mm and 15.1-25 mm length ranges, more fibres appear as the ball diameter increases. However, there are fewer fibres between 2.5-10 mm long as the ball diameter grows. In a broader context, upon selecting the most suitable fibre length for various ball diameters of *Posidonia Oceanica* (PO) and needle balls (NB), the data in Figure 5 show that ball diameters of 20 mm, 25 mm, 30 mm, and 35 mm are more likely to correspond to the 2.5-10 mm length range, whereas diameters of 40 mm, 45 mm, 50 mm, 55 mm, 60 mm, and 65 mm are associated with a higher probability within the 15.1-25 mm length range.

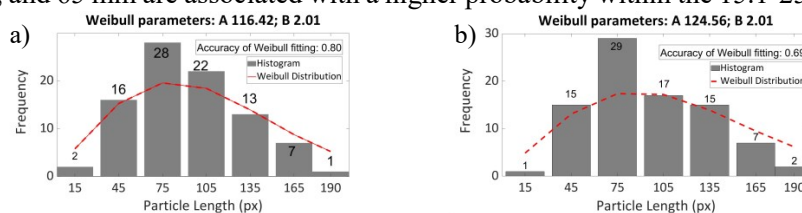


Figure 3. Fibre length distribution histogram before and after pruning the skeleton branches.

4. Conclusion and perspectives

This research used two techniques to estimate the length of NB fibres of PO: MATLAB® for the longest skeleton path and ImageJ® for the bounding ellipse maximum length. Bounding ellipse techniques estimate trends, but skeleton path techniques provide more precise results. The data show that by increasing the ball diameters from 20 to 65 mm, the number of fibres with a range length between 2.5-10 mm decreases, while that with fibre lengths of 10.1-15 mm and 15.1-25 mm increases. The research is still in progress, with ongoing analysis at the microscale and hydro-mechanical testing on the fibres. This analysis encompasses examining the sensitivity of the fibres to water content and assessing the impact of their length and content on the geotechnical properties of sediment mixtures. Future research perspectives entail microscale characterisation studies and the incorporation of the

fibres into other waste materials such as shells and sediments. This phase of the research will involve examining the microstructure of the fibres and assessing their compatibility with shells and sediments, to further enhance the properties of the resulting sediment-based mixtures.

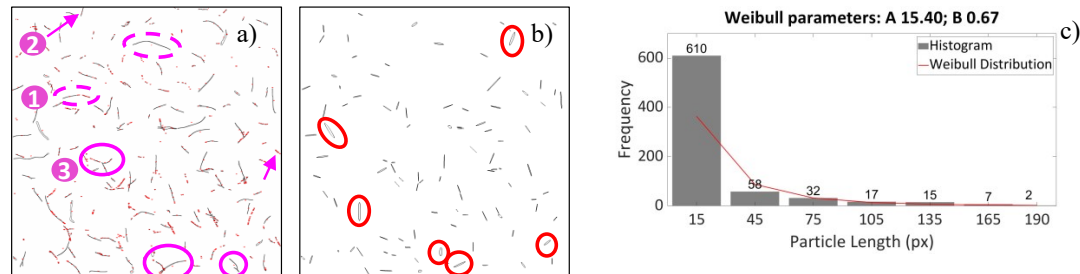


Figure 4. a) Problems with ImageJ®, b) bounding ellipse, c) pre-fibre breakdown cleaning.

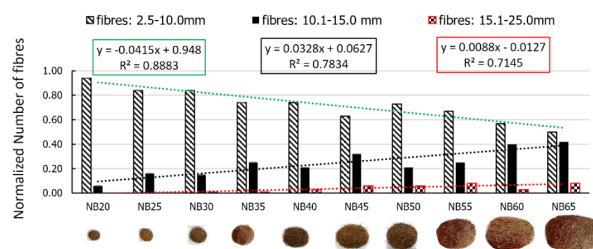


Figure 5. Correlation between the Posidonia NB diameters and normalised number of the fibres.

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