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A4_6 Patrick's Plan

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Abstract

Within this paper we aim to investigate the feasibility of Patrick Star's suggestion to save a submerged city by simply pushing it somewhere else. This was done by investigating the frictional force that needs to be overcome if London was located on sand. It was concluded that a frictional force of $4.732 \times 10^{13}N$ is required to move the city. Assuming an average human can push with roughly $123N$ this plan would take 5 times the population of Earth and hence would not be feasible.

Introduction

In the episode "Sandy, Spongebob and the worm" with the city of Bikini Bottom under threat of an Alaskan Bull Worm, Patrick Star suggests simply pushing the city out of harm's way in a stroke of genius. In this paper we aim to apply a similar method if the two inner boroughs of London, City of London and Tower Hamlet, were under the same level of danger.

We assume the city is lifted out of it's usual spot in South East England, and placed onto clean fine sand at the bottom of the Mariana Trench, that the bottom of the city is smooth and the city can be moved as one uniform unit. Throughout this paper we assume the city and it's inhabitants along with all their belongings were evacuated in light of the imminent threat to life.

Theory

In order to investigate the feasibility of this method of danger avoidance, we set out to find the force needed to push the two boroughs of London while at the bottom of the ocean. Firstly the frictional force caused by the sand was considered through the following equation,

$$F_f = \mu F_n \tag{1}$$

Where F_f is the frictional force, μ is the coefficient of friction of the sand and F_n is the forces acting on the city in the downward direction.

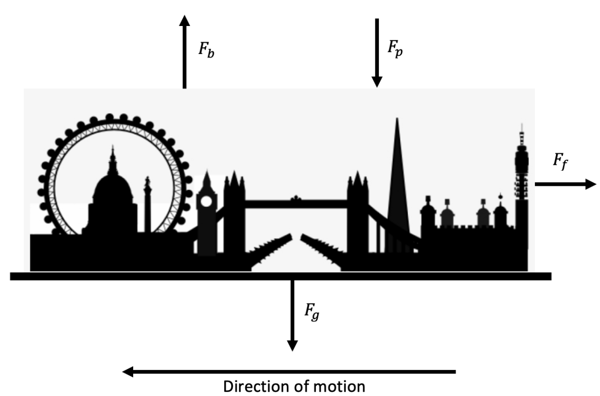

Figure 1: Force diagram depicting the forces acting on London

F_n is made up of F_g, the force on the city due to gravity, F_b, the buoyancy force acting due to the city being submerged in seawater, and F_p, the pressure acting downwards on the city due to the amount of seawater above it. All of which are denoted by the equations below respectively:

$$F_g = mg \tag{2}$$

$$F_b = \rho g V \tag{3}$$

$$F_p = h\rho g \tag{4}$$

Where m is the mass of the two boroughs, g is the acceleration due to gravity, and ρ is the density of seawater under standard conditions. V is the volume of displaced water by the city (under the assumption that the buildings are watertight) and h is the height of the water over of the city.

To find the mass and volume of the boroughs we must consider that London is not solely made up from buildings but also man-made geological deposits, for example road pavings. The mass of The City of London and Tower Hamlet's buildings was estimated to be 25 million tonnes, and the geological deposit mass was estimated at 100 million tonnes. Hence, a total mass of the city was taken as 125 million tonnes or $1.25 \times 10^{11} kg$. The volume of the buildings and deposits were estimated at 359 million m^3 and 67 million m^3 respectively. For a total volume of $4.26 \times 10^8 m^3$ [1].

The acceleration due to gravity and density of seawater are taken to be under standard conditions with $g = 9.81 ms^{-2}$ and $\rho = 1023 kgm^{-3}$ [6]. Due to the large scale nature of the mass and volume of the city, their effects are negligible if small fluctuations are made to g and ρ's values.

The height of seawater is taken as the depth of The Mariana Trench at $11034m$ [3] and the coefficient of friction (μ) due to sand is taken to be 0.4 for clean fine sand [4]. The effect of sand being wet is not analysed due to the simplistic nature of the paper and the lack of information on how the coefficient of friction changes between wet and dry sand.

Results

F_g is calculated to be $1.226 \times 10^{14} N$, F_b is calculated as $4.275 \times 10^{12} N$, and F_p is found to be $1.107 \times 10^8 N$. By considering these values for the vertical forces acting on the body the equation for F_n becomes,

$$F_n = F_g + F_p - F_b \tag{5}$$

Which gives a value of $F_n = 1.183 \times 10^{14} N$. When substituting F_n into Eq. 1 we get a value for frictional force of $F_f = 4.732 \times 10^{13} N$.

Discussion and Conclusion

To put the result for frictional force in perspective, taking results from a study on the strength in the workplace, an average standing push force for a male was found to be $122.63N$ [5]. This means that it would take more than 38.5 billion people to begin to start moving the city. Therefore, roughly 5 times the population of the human race is needed to carry out Patrick's plan of city preservation.

We find this result to not be feasible and suggest that if the inhabitants of London find themselves submerged at the bottom of the ocean with an imminent threat of city destruction to find a more practical solution.

Further to this, the inclusion of the inhabitants and their belongings would only increase the force due to gravity and thus the amount of people required making the result even less feasible.

References

[1] R.L. Terrington et al. *Quantifying anthropogenic modification of the shallow geosphere in central London, UK*

[2] `https://www.engineeringtoolbox.com/sea-water-properties-d_840.html`

[3] `https://www.nationalgeographic.org/activity/mariana-trench-deepest-place-earth/`

[4] `https://structx.com/Material_Properties_007.html`

[5] Biman Das Yanqing Wang *Isometric Pull-Push Strengths in Workspace: 1. Strength Profiles* [Data taken from Table 7 notes]

[6] `https://www.engineeringtoolbox.com/sea-water-properties-d_840.html`