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A Study on Structural Strength of Solar-Powered Lighting Poles for use in Public Parks in Indonesia

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Abstract: Solar-powered lighting for public area have become more common today. However, unlike conventional lighting, solar-powered lighting system is heavier and thus, exerts more loads. The focus in this study is placed on the more popular configuration of integrated solar-powered lighting in which the solar panel, battery and LED are bundled together and installed at a single position on the pole. With the heavier load, it is of an utmost importance to analyze the structure of the poles, especially, the choice of height, diameter and material used. The analysis will be useful to avoid accident cases of falling poles due to strong winds at some places in Indonesia. This study focuses to the static loading analysis of the lighting in public parks with varied geometries and materials of the poles. The structural analysis is done through finite-element simulations.

Key words: Solar-powered, configuration, conventional, diameter, finite-element, pole

INTRODUCTION

Globally, outdoor lighting systems, mainly for street is reported to consume 43.9 billion kWh of electricity every year (Liu, 2014). As such there have been numerous attempts to reduce the number for the sake of the conservation of the environment; one of which is via. the utilization of solar-powered lighting systems for implementations ranging from streets to public parks (Cota and Kumar, 2015; Kumar *et al*., 2016; Khalil *et al*., 2017).

The design aspect of the street lighting systems, including the structure of the poles is of an utmost importance because it deals with the public safety. It is well understood that the failure of the lighting poles are a frequent occurrence across the globe. From the US, the National Highway Research Program (NCHRP) reported that most states have experienced some failure of support structures including sign, signal and luminaire structures (Hosseini, 2013). Also, to cite several examples from Indonesia, there was a report of such a case due to the rusted materials (Anonymous, 2016) or due to the failure of the base unable to withstand an excessive load (Anonymous, 2008), among others. Therefore, from as early as 1980's, people had already attempted the preparation of regulations and standards related to the design and geometry of street lighting poles (Fisher *et al*., 1981; AASHTO., 1984; CIE., 2017). In Indonesia, the standard that is being referred to is SNI. (2008). Additionally, researchers have also been investigating numerous aspects from the structural strength of the poles (Foley, 2004) to a more recent topic involving fatigue (Kaczinski *et al*., 1998) and wind-induced fatigue (Wieghaus, 2015).

In this study, the focus of the discussion is on solar-powered lighting system for public parks. It is worth noting that lighting for public parks is not as well documented and regulated as that of streets. This fact makes the study on structural strength of poles for public parks more important to conduct. The poles are the same with that for streets and hence, pose the same threat of failures. However, due to its nature of being considered trivial and insignificant, poles for public parks are often manufactured without complying to any standard. Additionally, there is a shift in trend from a solar-powered lighting system with separated components (LED, battery and solar panel) to an integrated design as shown in Fig. 1a and b. In this new configuration

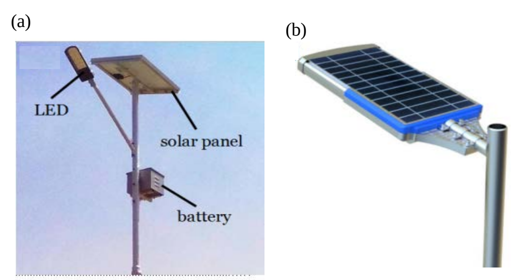

Fig. 1: Solar-powered lighting system with: a) Separated components and b) Integrated components

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design, since, all loads are concentrated on a single location on the pole, hence, a more careful designing shall be considered.

This study analyzes the structural strength of the second type of the solar-powered lighting system, i.e., in which all components are integrated into one. Since, the focus is the use of the lighting poles for use in public parks, the aspects of concern are also derived from similar systems commonly found in public parks in Indonesia. The study is limited to the impact of a static load exerted by the combined LED, solar panel and battery to the pole.

MATERIALS AND METHODS

Two different pole designs were considered in this study, i.e., straight and bent as shown in Fig. 2. The two designs are the most commonly implemented lighting poles for public parks.

Autodesk Inventor was used for the finite-element simulation. The base of the pole was fixed and a remote force was applied to the tip of the upper pole downward as given in Fig. 3. According to the Minister's Decree, the base of the structure shall be of concrete with with full frame with a base plate of a specified thickness and other geometrical requirements. For simplicity, this condition shall be represented by the fixed boundary condition to the base, although, in the future, more discussion shall be put on this matter as the base has become one crucial parts that may be severely affected in case of failures (Hosseini, 2013). In the simulation, a static load of 2-5 kg applied to the tip of the upper pole was considered. The magnitude of loads were chosen to reflect the weight of the commercial off-the-shelf products of integrated solar-based lighting. The height of the pole was varied from 2-5 m. Though the regulation for this matter for lighting of public parks is still unavailable, if the Minister's Decree is to be referenced, 5 m is the maximum allowable height for lighting in local roads. Additionaly, according to our observations, the most common poles for public parks are either 3 or 4 m. Therefore, the choices of height could be justified. Finally, for materials, three different materials were considered for the simulation, i.e., galvanized steel, carbon steel and stainless steel as per the guidelines in the Minister's Decree.

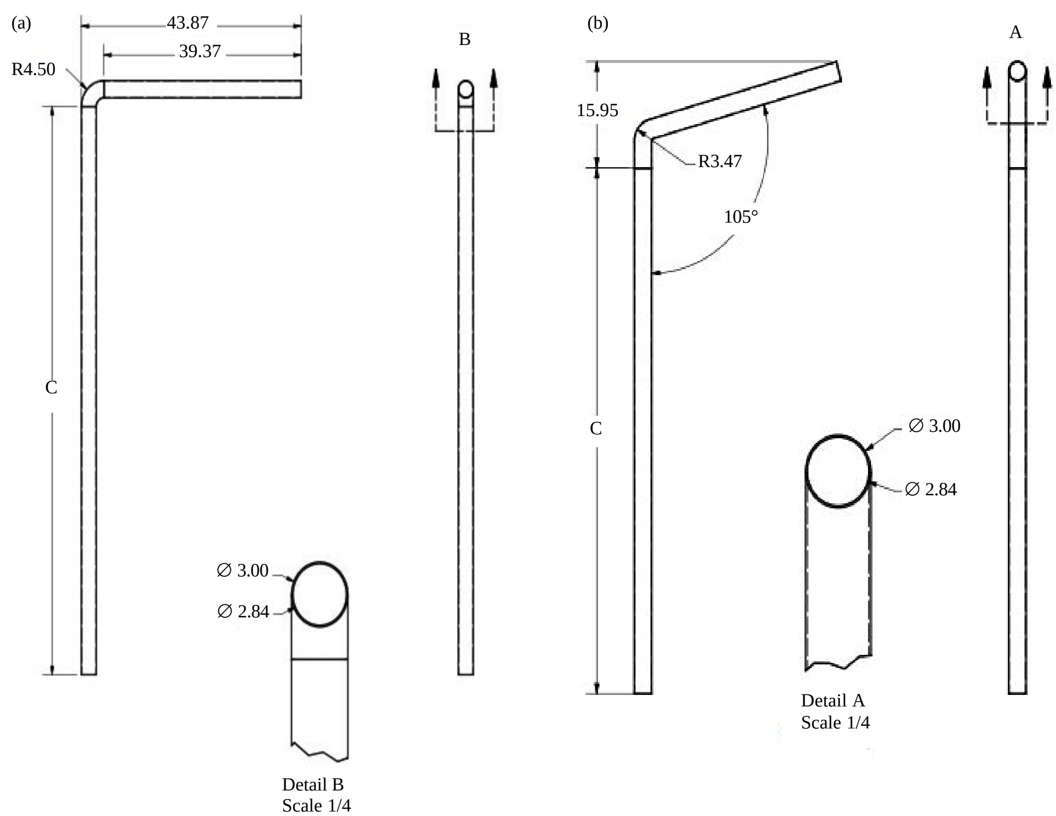

Fig. 2: a) Straight lighting pole and b) Bent lighting pole

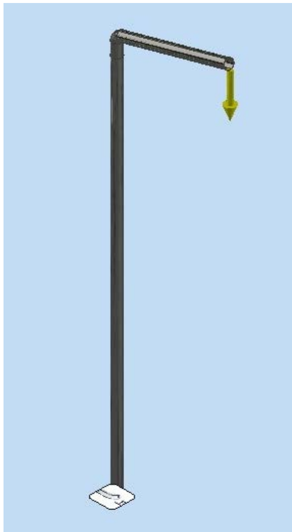

Fig. 3: Illustration of the boundary conditions for stress analysis

RESULTS AND DISCUSSION

Stress distribution of the pole when a load is applied at the tip of the upper pole is shown in Fig. 4. Figure 4a and b show the condition of a 3-m pole and its close-up view on the maximum stress values, respectively. For both conditions, the maximum value of von Mises stress is observed at the right angle part of the pole. This finding is consistent to the research of Hosseini (2013) which states that the most distinguishing locations of failures in support structures including lighting poles are at areas of stress concentrations such as welds, notches, holes and changes in section (Hosseini (2013). The maximum displacement observed under this condition was 2.29 mm.

Subsequently, simulations were carried out as per the conditions outlined in Chapter 2 whose results are shown in Fig. 5. For the first simulation, height of the pole was varied and the result is shown in Fig. 5a. Maximum values of von Mises stress is observed to increase as the height

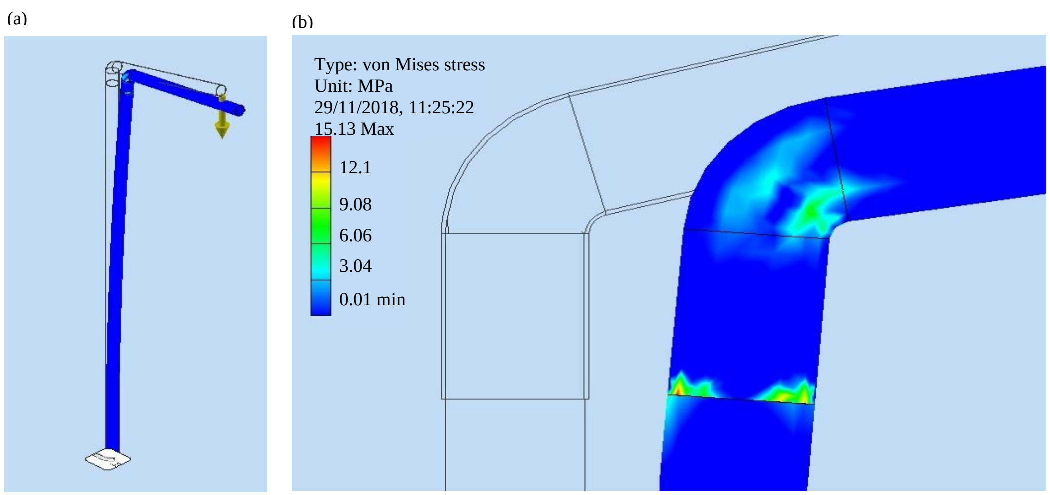

Fig. 4: a) Stress distribution given a load ofa 3 m height pole and b) The close-up view on the right angle part of the poles

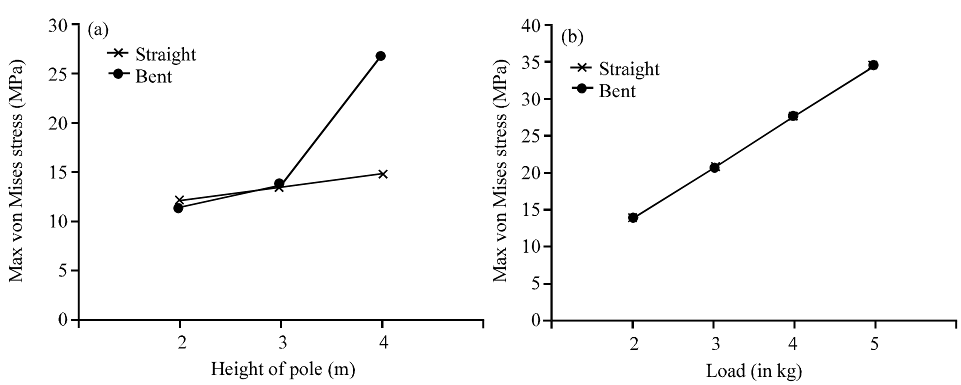

Fig. 5: Continue

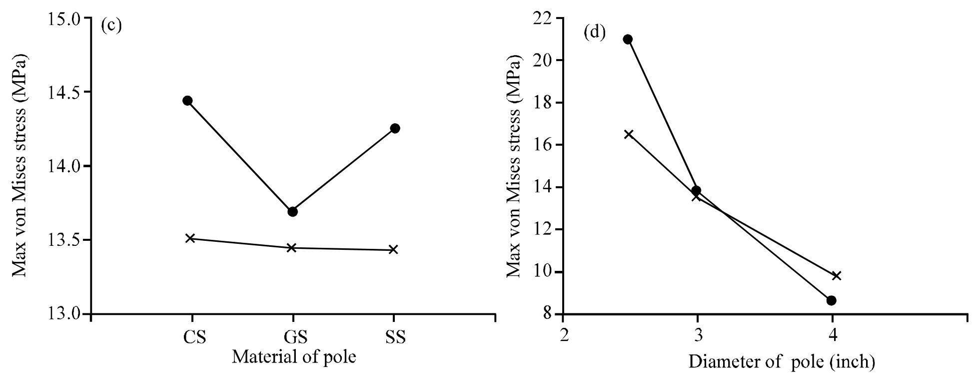

Fig. 5: Maximum values of von Mises stress in the pole when: a) The height of the pole is varied; b) The load is varied; c) The material of the pole is varied and d) The diameter of the pole is varied

increases, arguably because the longer the pole, the higher the torque will be exerted as a result. Though the values seem to overlap for both straight and bent types when the height is 2 and 3 m when the height changes to 4 m, the bent type shows a significantly larger value of the stress. In the second simulation whose result is shown in Fig. 5b, the load was varied from 2-5 kg. As expected, the maximum values of stress show a linear fashion as the load increases. There is no noticeable difference between the straight and bent type as both exert overlapping stress values throughout. In the third simulation, three types of materials, i.e. Carbon Steel (CS), Galvanized Steel (GS) and Stainless Steel (SS) were tried (Fig. 5c). The range of stress values resulted from the materials variation is not significant. Finally, the diameter of the pole was varied and the result is shown in Fig. 5d. Smaller diameter provides a better option for the pole as the stress values exerted for both straight and bent types are smaller.

When compared to the values of yield stress of carbon steel/CS (349.98 Mpa), galvanized steel/GS (206.98 MPa) and Stainless Steel/SS (250 MPa), it is worth noting that all simulation results show a substantial room for safety. Taking the worst case from simulation number two when the load is 5 kg for instance, the safety factor obtained with respect to the yield stress of a galvanized steel is around 6. The value can be deemed sufficient for most cases but further analysis has to be made.

CONCLUSION

A series of simulation was conducted to investigate the structural strength of a solar-powered lighting pole for the use case of public parks. Several parameters such as the height, diameter and material of the pole were varied and the result has been shown and discussed. The main finding is that under the static load, all common variations of the pole could withstand it with a safety factor of at least 6.

RECOMMENDATIONS

However, further analysis has to be conducted, especially, considering other factors contributing to the addition of load such as winds. Additionally, fatigue has to be considered as well to obtain a more realistic analysis under the real condition.

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REFERENCES

AASHTO., 1984. An informational guide for roadway lighting. American Association of State Highway and Transportation Officials, Washington, DC., USA.

Anonymous, 2008. PJU roboh, vehicle through UPPKB Bengkok. Nusa Bali.com, Badung, ?Indonesia. (In Indonesian)

Anonymous, 2016. [PJU pole collapsed, injured a citizen]. Poskota News, Jakarta, Indonesia. (In Indonesian) http://poskotanews.com/2016/12/21/tiang-pju-roboh-lukai-seorang-warga/

CIE., 2017. Road transport lighting for developing countries. International Commission on Illumination, Vienna, Austria.

Cota, O.D. and N.M. Kumar, 2015. Solar energy: A solution for street lighting and water pumping in rural areas of Nigeria. Proceedings of the International Conference on Modelling, Simulation and Control (ICMSC-2015) Vol. 2, October 1, 2015, Coimbatore, India, pp: 1073-1077.

Fisher, J.W., R.G. Slutter and C. Miki, 1981. Fatigue behavior of steel light poles. California Department of Transportation, Sacramento, California, USA., Pages: 70.

Foley, C.M., 2004. Structural Analysis of Sign Bridge Structures and Luminaire Supports. Wisconsin Highway Research Program, Wisconsin, USA., Pages: 230.

Hosseini, M.S., 2013. Parametric study of fatigue in light pole structures. Ph.D Thesis, University of Akron, Akron, Ohio.

Kaczinski, M.R., R.J. Dexter and J.P. Van Dien, 1998. Fatigue-Resistant Design of Cantilevered Signal, Sign and Light Supports. Vol. 412, Transportation Research Board, USA., ISBN:9780309062749, Pages: 176.

Khalil, A., Z. Rajab, M. Amhammed and A. Asheibi, 2017. The benefits of the transition from fossil fuel to solar energy in Libya: A street lighting system case study. Appl. Solar Energy, 53: 138-151.

Kumar, N.M., A.K. Singh and K.V.K. Reddy, 2016. Fossil fuel to solar power: A sustainable technical design for street lighting in Fugar city, Nigeria. Proc. Comput. Sci., 93: 956-966.

Liu, G., 2014. Sustainable feasibility of solar photovoltaic powered street lighting systems. Intl. J. Electr. Power Energy Syst., 56: 168-174.

SNI., 2008. [Specification of street lighting in urban areas]. Badan Standardisasi Nasional, Indonesia. (In Indonesian)

Wieghaus, K.T., 2015. Mitigating wind-induced fatigue in steel traffic signal support structures. Ph.D Thesis, Texas A&M University, Station, Texas.