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Mechanical characteristics of Raschel mesh and their application to the design of large fog collectors

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ABSTRACT

Fog collection can alleviate water scarcity in certain arid regions of the World. However, large fog collectors frequently fail under the load of strong wind events. This is mainly due to lack of engineered design and the absence of data on mechanical properties of the meshes used as collecting surface. Indeed, engineering methods permit to design a structure to withstand any desired wind speed. In this study we obtained the mechanical properties of a particular Raschel mesh, the most commonly used material for fog collection, by means of tensile tests. We found that Raschel mesh is very anisotropic, having a stiff and elastic behavior in the knitting, or longitudinal direction, whereas in the transverse direction has an extremely flexible (virtually no stiffness), nonlinear behavior. Using a relatively simple 2-D structural model, we show that the maximum wind pressure a mesh can withstand is inversely proportional to the distance between the sides of the frame that supports the mesh. As a consequence, we recommend installing this mesh with the longitudinal direction aligned with the shortest dimension of the mesh-holding frame, if maximum strength and minimum deformation are desired. The structural model also indicates that the mesh can withstand very strong winds, over 50 m/s assuming a steady wind velocity for the typical large fog collectors as presently installed. Possible reasons why the mesh has been observed to break at weaker winds are then discussed.

1. Introduction

Fog collection can alleviate water scarcity problems in certain arid areas. It has been studied and proved for decades as a feasible alternative source of fresh water in arid areas with the presence of suitable persistent fog (Klemm et al., 2012; Lummerich and Tiedemann, 2011; Schemenauer and Cereceda, 1991, 1994; Schemenauer et al., 1988). This fog is common in arid and semi-arid areas close to the ocean, where clouds are formed over the sea and then pushed by predominant winds towards the continent, where they turn into fog when intercepted by high lands. This kind of fog is addressed as 'Advection fog', although sometimes orographic fog also contributes to fog water collection (Cereceda et al., 2002, 2008b). Several studies have recognized the potential of fog collection for human consumption around the world, in places such as: Pacific coast of central South America (Cereceda et al., 2008a, 2008b, 2002; Larrain et al., 2002; de la Lastra, 2002), the Canary Islands (Marzol, 2002, 2008), Morocco (Marzol and Sánchez, 2008), South Africa (Olivier, 2002; Olivier and de Rautenbach, 2002; Louw et al., 1998), Oman (Abdul-Wahab and Lea, 2008; Abdul-Wahab et al., 2010), Saudi Arabia (Al-hassan, 2009; Gandhidasan and Abualhamayel, 2007), western Mediterranean basin (Estrela et al., 2008), and Namibia (Shanyengana et al., 2002).

Since the first studies made by Carlos Espinosa in Chile (Gishler, 1991), fog collection projects had relied on different designs of fog collection devices, where the flat screen Large Fog Collector (LFC, see Fig. 1) is the most common type of design used in the last decades (Schemenauer et al., 1988; Schemenauer and Cereceda, 1994; Gischler, 1991). The

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Fig. 1. Failure of large fog collectors: (top; Peña Blanca, Chile) failure of the supporting structure; (bottom, left; Anagua project — Canary Island, with permit by Carlos Sanchez Recio) failure of the foundation; (bottom, right; Peña Blanca, Chile) breakage of the mesh.

materials used for the LFC are usually simple components, locally available, because the main focus of fog collection projects has been to provide fresh water to small, poor communities around the world. These projects have been mainly supported by non-governmental organizations (NGO), which are responsible to install the system (Klemm et al., 2012; Schemenauer et al., 2005).

One of the main problems that affects the sustainability of fog collection projects is the maintenance of LFCs that are frequently damaged by strong winds events, the sun (UV radiation) and other environmental factors which affect the structure, mesh and other components (Schemenauer et al., 2005). Indeed, when subjected to extreme wind loads (the only relevant load on LFCs), many LFCs fail and/or lose functionality. Some representative examples can be seen in Fig. 1. In some cases, LFCs collapse because of failure of the supporting structure (Fig. 1, top), whereas in some other cases they collapse because of failure of the foundation (Fig. 1, bottom left). Finally, in most other cases LFCs lose functionality because the mesh breaks and hence loses its ability to collect water (Fig. 1, bottom right).

Recently, Klemm at al. (2012) made a thorough review of existing LFC installations around the world. However, they did not analyze in detail the effects of wind pressure on the mesh and the supporting structure, and the effect of design variables on water collection efficiency. Indeed, it is noteworthy that, as far as we know, no peer review publication has dealt with the currently observed mesh breakage or structural collapse of LFCs caused by extreme winds.

The reason why LFCs exhibit such a poor reliability is undoubtedly the lack of a rational (i.e., “engineered”) design process. In other words, most existing LFCs are non-engineered structures. Thus, the implementation of structural engineering principles is then clearly necessary in order to extend the life cycle of LFCs and, consequently, to make them more cost-effective. In this regard, it is interesting to note that, although various geometric layouts have been proposed and implemented, the load path in LFCs is always the same: wind imposes pressures on the mesh, which in turn impose forces on the supporting structure, and these forces are ultimately transferred to the foundation. If the load is known, forces on the mesh and on the supporting structure can be easily calculated through the