The Art of Bio-inspiration and Moment Frame Design

Mark Grigorian[1], Ali Biglari [2], Mozhgan Kamizi[3]

[1] MGA Struct Eng. Los Angeles, US

[2] Golestan University, Gorgan, Iran

[3] Golestan University, Gorgan, Iran

corresponding author: M.kamizi95@stu.gu.ac.ir

ABSTRACT

The concept of this article was prompted by the need to understand the level of compliance between manmade and natural structures, specifically Moment Frame (MF) and Green Tree (GT). None of the contemporary design concepts explain the methodologies involved in the realization of natural structures such as GT , can they fully address the design needs of modern engineering structures. The recently developed Design Led Analysis (DLA) incorporates both the essence of the classical concepts and the newer procedures and addresses the observed performance of the structure during its known history of loading. DLA attempts to mimic nature by applying the known theories of structures to the design of case-specific frameworks, rather than investigating their results for compliance against prescriptive criteria. It has been shown that an understanding of the structural performance of GT can enhance the structural design of MFs, and that bio-inspired DLA can lead to minimum weight MFs under lateral loading.

Keywords: Bio-inspiration, Green Tree, Moment Frame, Lateral Loading, Design Led Analysis

1. INTRODUCTION

Nature makes purpose-specific materials one atom at the time, such as spider silk, wood etc. Humans have mimicked nature by creating synthetic materials also one atom at the time, e.g. Nylon, Kevlar, etc. It is humans curiosity to understand how the natural materials are used to create such magnificent structures as spider webs, trees, etc. In the physical sense, the word 'structure' implies arrangement or putting together of material parts or elements in a purposeful manner; may apply to Nano systems, manmade objects as well as the entire universe. In the present context, structure is referred to manmade load bearing engineering frameworks. 'Design', in this context implies the thought or natural processes that may lead to the realization of a structure. Corporeal entities may therefore be characterized either as natural or manmade structures. Natural structures may be exemplified by such familiar objects as mountains and coral reefs, bird nests and eggshells, cobwebs and honeycombs, trees and plants, etc. Bridges, buildings, dams, transmission towers, pipelines, reservoirs, etc., are well known examples of engineering structures. While the history of earthly natural structures is as old as the planet itself, the history of modern structural engineering is hardly two centuries old [1, 2]. While the ancient Egyptians, Greeks and Romans are credited with establishing the art of structural engineering the analytic understanding of the physical phenomena, underlying structural theories began during the Renaissance.

Earthquake engineering, a sub-discipline of structural engineering, is only decades old and is still being evolved [3, 4]. Both natural and manmade structures are realized through evolutionary design scenarios, both systems obey the same laws of nature and are subject to the same environmental conditions [5]. Loading, specially seismic loading, energizes all structural systems, unloading discharges or reduces stored energy. All structures are expected to withstand lifetime normal (service) as well as extraordinary (survival) environmental conditions. They are expected to endure certain degrees of damage. Natural, design-build methods tend to result in the most desirable (optimal) structural systems with respect to their functional response and environmental conditions, whereas the same cannot be claimed for manmade systems. Matteck [6] has shown that, "Trees optimize their mechanical design by adaptive growth, and react by self-repair to loads disturbing their optimum mechanical state." The purpose of this article is not to present a discourse on natural systems, but rather to propose a basis for a parallel approach between natural and synthesized design methodologies for type and loading specific structures. Nature does not preplan construction as humans do; Nature simply creates or builds as needed. Nature imposes its own laws of physics creation. While humans follow their limited knowledge of materials and applied mechanics. Checking the validity of computed end-results against prescribed criteria is the last step in the human design approach. Natural designs do not depend upon number crunching. Nature provides what is best for the purpose under the prevailing environmental conditions. Contemporary structural engineering relies mainly on investigating design related computed output. The question which often arises is under what conditions and to what extent can humans mimic nature and impose their knowledge of engineering sciences to what they plan to build? In other words, what are the differences