Preface

According to statistics, collapse-related incidents are highly related to the safety of engineering structures. Several types of collapse-related incidents have been fatal, including collapse of construction site facilities and scaffolding (deaths caused by construction and scaffolding incidents constitute 32.6% of all collapse-related deaths), collapse during underground construction (32.6%), collapse of excavation and retention walls (23.9%), and collapse of structures (9.9%; e.g., road and bridges). Deteriorating bridges accounted for a major proportion among road and bridges, indicating the importance of their safety and risks. Deteriorating bridges aged less than 10 years accounted for approximately 20% of all bridges; those aged 10–20 years account for 24%; and bridges that were aged 20–30 years old accounted for 20%. Moreover, even roads and bridges in advanced countries such as those in Europe and North America have a structural defect as high as 11%. Statistics have indicated that fewer engineering problems were observed in structures with high effectiveness of capacity utilization of each structural part than did engineering problems in structures with low effectiveness. When the material property and microstructure of low effectiveness structures change, these structures do not satisfy the applicable conditions of deformation compatibility (DC) theory. Thus, only appropriate structures can be selected to satisfy structure deformation compatibility control (DCC) conditions. In other words, **an innovative DCC method** is required to solve engineering structure-related stable equilibrium problems. Otherwise, engineering structures may generate calculation results that differ considerably from actual results and likely cause safety risks.

Conventional "falling apple point prediction" (hereafter referred to as the apple problem) and "falling leaf point prediction" (hereafter referred to as the leaf problem) are theoretically identical in the sense that they both predict a point below the tree, but practically different. If "apple-based" DC theory is applied to solve "leaf-based" engineering problem, it easily causes the deformation state of a designed engineering structure to differ from that in practice and subsequently

creates quality and safety problems in engineering structures. Consequently, stable equilibrium, DCC methods, structural safety management, and the corresponding practices in transportation engineering are pressing research questions warranting immediate attention.

Existing engineering structure-related equilibrium stability theories are informative with respect to equilibrium aspects. Compatibility-based studies have largely focused on theories and assumptions related to DC. By contrast, few studies have systematically examined DCC methods based on the relationship between engineering structures and their mechanical behaviors. A portion of structures cannot ensure the suitability of force transmission in structures and prevent metastable structural equilibrium problems. Engineering structure-related stable equilibrium and DCC methods involve explicitation of the original DCC conditions implied in engineering structures. In other words, it entails changing mechanical control conditions that center on the stable equilibrium of a structure in the design and construction of engineering structures to dual control conditions that consider both stable equilibrium and DC of structures. This change facilitates the prevention of inconsistency in the stress–deformation state of a designed engineering structure with the stress–deformation state in practice. Such prevention protects the compatibility of force transmission media in a structure and avoids metastable equilibrium problems in the structure, thereby ensuring the safety of engineering structures.

Engineering mechanics is built on the foundation of confirmed material properties and microstructures. When exposed to stress, numerous actual engineering structures experience a change in material properties and microstructures. However, the methods and laws of change are unknown. Therefore, applied mechanics must be effectively used to solve safety problems of stress-deformed engineering structures. The keys to this approach are as follows: (1) Determine how to design structures through engineering structure-related measures, regulations, analogies, and tests. (2) Identify how to adopt assistive measures to control the stability of stress–deformation state in engineering structures and the changes in engineering material properties and microstructures within the acceptable safety limit of three elements of a structure (i.e., force, deformation, and energy) to satisfy three conditions: stable equilibrium and DCC, effective energy conversion, effective transmission or transfer of force.

Because the method by which people (childhood, adulthood, old age, etc.) maintain movement stability is the simplest way for solving "leaf problems," civil engineering designs and construction can be achieved by two types of method: (1) Engineering structure-related stable equilibrium theory can be adopted to solve **relatively mature engineering problems such as "apple problem" by employing precision analyses** ($F = P_0$, equation to calculate equilibrium). (2) Engineering structure-related stable equilibrium and DCC method can be used to solve **relatively complex engineering problems such as "leaf problem" by adopting an integrated approach that involves overall control and attention to detail** ($P + T = P_0$,

equation to examine equilibrium). The latter method involves **designing appropriate structures through engineering structure-related measures, regulations, analogies, and tests or adopting assistive measures to control the stability of stress–deformation state in engineering structures** ($P + T = P_0$, equation to examine equilibrium). In other words, after "leaf problems" are converted into "apple problems," precision analyses are applied to resolve engineering problems ($F = P_0$, equation to calculate equilibrium).

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