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Opinion

Can a Single Drone Strike Trigger the Progressive Collapse of a Building?

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Introduction

Since the early development of civil engineering, engineers have been engaged in the design and construction of residential buildings and various public facilities to accommodate human habitation requirements and provide protection against adverse environmental conditions. With the progressive increase in population, considerable efforts have been directed toward the development of accelerated concrete placement methods and advanced construction techniques to enhance the efficiency of structural construction processes. Technological advancements have profoundly influenced not only civilian infrastructure but also the design and construction of military facilities.

Engineers first confronted the phenomenon of progressive collapse in the late 1960s following the explosion at the Ronan Point residential tower in London, which initiated a cascading structural failure mechanism. Since this incident, extensive scientific investigations have been conducted to elucidate the underlying mechanisms governing the initiation and propagation of such disproportionate structural failures. These investigations have demonstrated that the sudden loss of a single load-bearing element under accidental explosive loading may initiate a rapid and potentially catastrophic collapse sequence. This phenomenon has subsequently prompted a fundamental reconsideration of structural vulnerability within both civil and military engineering disciplines, raising a critical question: Can relatively low-magnitude yet strategically significant loading actions precipitate the progressive collapse of an entire structure?

Moderate-magnitude loading actions may be sufficient to initiate structural collapse under certain conditions. Nevertheless, the effectiveness of contemporary military systems warrants rigorous evaluation, while active battlefields should be regarded as natural experimental environments in which the operational performance and structural consequences of such systems can be systematically observed and assessed. In this context, Kılıçer [1] investigated the progressive collapse resistance of a reinforced concrete structure using the Enhanced Local Resistance (ELR) method, conducting a comparative assessment of the provisions stipulated in UFC 4-023-03 and the Turkish Building Earthquake Code [2].

An investigation conducted by Kılıçer [3] examined structural damage sustained in Belgorod Oblast during the Russia–Ukraine conflict, critically evaluating the relationship between contemporary weapon systems, including unmanned aerial vehicles (UAVs), structural damage mechanisms, and progressive collapse phenomena. Although varying degrees of structural damage were identified, the study reported that instances of progressive collapse remained relatively limited. These findings underscore the necessity for more comprehensive investigations into the implications of UAV-induced localized damage for global structural integrity and the progressive collapse resistance of buildings. Grisaro et al.

[4] conducted experimental investigations simulating the explosive loading effects associated with weaponized UAVs, focusing on the localized damage mechanisms exhibited by conventional reinforced concrete and steel fiber-reinforced concrete slabs. Their investigation evaluated both the structural damage sustained by reinforced concrete slabs and the potential hazards posed to building occupants by concrete fragmentation and debris generated during explosive events. Although the study demonstrated that UAV-induced explosions could significantly compromise the integrity and safety of individual structural components, it did not explicitly investigate the potential for progressive collapse at the overall building level. Furthermore, Remennikov and Mentus [5] presented a comprehensive review of the structural implications of weaponized UAV threats and the passive protective systems developed to mitigate their effects. The authors emphasized that existing blast-resistant design standards may inadequately characterize the highly localized loading conditions associated with close-proximity UAV detonations, highlighting the imperative for further experimental and numerical investigations to establish more reliable frameworks for assessing structural vulnerability and resilience under such loading scenarios.

Discussion

Architectural design preferences may compel structural engineers to adopt alternative load-bearing system configurations and accommodate various forms of structural irregularity. In this context, aesthetic considerations may inadvertently introduce significant structural vulnerabilities, particularly in military facilities subjected to unforeseen or extreme loading conditions. Columns exhibiting eccentric alignment, together with load-bearing systems deliberately exposed to external actions for architectural or aesthetic purposes, represent critical design decisions that may compromise structural integrity and increase susceptibility to localized damage and disproportionate structural failure.

In the design of public buildings and critical infrastructure facilities, the adoption of regular square or rectangular plan configurations should be prioritized over geometrically irregular arrangements, even where the latter satisfy prescribed structural irregularity limits. Departures from such geometrically regular configurations may increase the exposure of structural columns to external threats, particularly those associated with explosive-carrying platforms such as unmanned aerial vehicles (UAVs). Consequently, localized damage to exposed structural elements may potentially render an entire building inoperative without requiring additional explosive interventions, thereby demonstrating the vulnerability of certain structural configurations to comparatively low-cost threats. It should be emphasized that progressive collapse constitutes a structural failure mechanism in which the initial loss of one or more load-bearing columns may trigger a cascading sequence of failures throughout the structural system. Within this conceptual framework, the identification of critical columns assumes fundamental importance in evaluating structural vulnerability and potential collapse propagation. Accordingly, in addition to the established concepts of the Critical Column and Key Element commonly employed in the progressive collapse literature, this study proposes the introduction of the term “Kılıçer Column (KC)” as a distinct structural classification. Whereas the Key Element concept encompasses various load-bearing components whose integrity is essential for maintaining overall structural stability, the Critical Column designation generally refers to columns that exert a significant influence on the structural response and load redistribution capacity of a building. The proposed Kılıçer Column concept, however, is intended to establish a more specific classification applicable to structural configurations in which the loss of an individual column, under explicitly defined structural and loading conditions, has been demonstrated to initiate progressive collapse at the global structural-system level. This conceptual distinction places particular emphasis not merely on the severity of localized damage but also on the capacity of the remaining structural system to preserve global stability, maintain load-path continuity, and sustain alternative load redistribution mechanisms following the initial column failure. Nevertheless, the existence of a Kılıçer Column cannot be presumed to be an inherent characteristic of every structural system, as its identification necessarily depends on the structural configuration, loading conditions, redundancy and collapse resistance characteristics of the building under consideration. Thus, the Kılıçer Column concept, introduced for the first time in the present study, is proposed as a specialized terminological framework for investigating and characterizing the relationship between isolated column loss, structural integrity, and the potential initiation and propagation of progressive collapse.

Researchers and structural engineers may thereby identify individual columns whose failure could precipitate the collapse of an entire structural system. Such columns are proposed to be designated as Kılıçer Columns (KC). Under certain structural and loading conditions, the failure of a KC could potentially be induced by an unexpected loading event associated with a single unmanned aerial vehicle (UAV). The occurrence and severity of such damage depend on several interrelated parameters, including the payload capacity of the UAV and the location at which the resulting loading acts upon the structural element. Furthermore, the influence of the separation distance from the column surface and the angle of load application constitutes a distinct subject requiring comprehensive scientific investigation. In light of these considerations, the identification and structural characterization of Kılıçer Columns should be accompanied by a systematic evaluation of the governing loading conditions, structural response mechanisms and site-specific characteristics to establish a comprehensive understanding of progressive collapse vulnerability.

Conclusion and Recommendations

The influence of modern aerial platforms on contemporary battlefields has become increasingly pronounced, with their operational deployment producing substantial consequences across a wide range of military scenarios. Beyond the economic losses associated with their utilization, these systems may also result in human casualties, albeit to varying degrees. Furthermore, such advanced aerial platforms may induce secondary and indirect

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structural damage, potentially extending beyond the immediate area of impact. In light of these considerations, the identification of a Kılıçer Column (KC) may reveal critical structural vulnerabilities whose failure could compromise the operational functionality of strategically important facilities. The loss of functionality of such critical infrastructure may, in turn, exert considerable influence on the progression and operational dynamics of military engagements. As previously emphasized, the structural consequences of localized damage depend on several factors, including the orientation and spatial characteristics of the loading action relative to the KC. Consequently, these findings highlight the potential vulnerability of strategically significant structures to comparatively low-cost threats and underscore the necessity of incorporating progressive collapse resistance into the structural assessment and protective design of critical infrastructure.

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