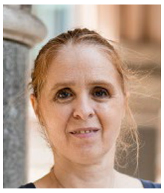
COMPARATIVE ANALYSIS OF FIRE CURVES AND STRUCTURAL PERFORMANCE: ISO 834, HYDROCARBON, AND ELECTRIC VEHICLE (EV) FIRES

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The increasing complexity of fire hazards in modern infrastructure, particularly in industrial environments and parking garages, demands a comprehensive understanding of fire behavior and its impact on structural materials. This study provides a detailed comparison of three critical fire curves: ISO 834, Hydrocarbon (HC), and Electric Vehicle (EV) fires, focusing on their effects on concrete, steel, and composite materials. While ISO 834 remains the standard for typical building fires, the rapid temperature rise of hydrocarbon fires, reaching 1100 °C in under five minutes, and the prolonged heat exposure of EV fires, exceeding 1200 °C, pose significant challenges for modern construction. Notably, the similarity between HC and EV fire behaviors allows for the adaptation of HC fire parameters for evaluating EV fires, offering a practical and efficient approach for assessing their effects on concrete structures. The findings reveal that hydrocarbon fires result in rapid spalling of concrete and buckling of steel, particularly in confined environments such as tunnels and industrial facilities, where heat buildup exacerbates structural vulnerabilities. EV fires, driven by the thermal runaway of lithium-ion batteries, cause prolonged material degradation, increasing the risk of structural collapse in parking garages and similar settings. To address these challenges, this study recommends the implementation of fireproof coatings, heat-resistant additives for concrete, and advanced ventilation and fire suppression systems. Furthermore, building codes and fire safety standards must be updated to reflect the unique risks posed by these fire scenarios, ensuring that modern structures are adequately equipped to withstand their demands. By adapting HC fire parameters for EV fire evaluations, engineers can streamline safety assessments while maintaining robust structural integrity, paving the way for safer and more resilient infrastructure capable of withstanding the evolving fire hazards of the modern world.

Keywords: Hydrocarbon fie, ISO 834 fire, electric vehicle fire

1. INTRODUCTION

Fire safety is a fundamental aspect of structural engineering, where the ability of materials and structures to withstand fire exposure can prevent catastrophic failures. Traditionally, fire resistance has been assessed using the ISO 834 standard fire curve, which simulates a relatively predictable building fire. The ISO 834 curve models a fire that gradually increases in temperature, reaching around 840 °C in the first 30 minutes and eventually rising to 1200 °C over several hours (ISO 834-1, n.d.). This curve is central to many building codes and forms the basis for evaluating how materials like concrete, steel, and composites behave when exposed to high temperatures. However, as industrial activities and emerging technologies such as electric vehicles (EVs) become more prevalent, new fire hazards have emerged that challenge the relevance of the ISO 834 curve.

The rise of hydrocarbon fires, commonly associated with environments such as chemical plants, tunnels, and refineries, represents a more aggressive fire scenario. The Hydrocarbon Modified (HC) fire curve is designed to model these extreme conditions, where temperatures can reach 1100 °C within just fifteen minutes (Caner et al., 2005). In addition to rapid temperature escalation, hydrocarbon fires place immense stress on building materials, causing spalling in concrete and rapid yield strength degradation in steel reinforcement. These fires pose an immediate risk to structural integrity, as materials degrade quickly and cannot withstand such intense heat for extended periods. In addition to hydrocarbon fires, the increased adoption of electric vehicles (EVs) has introduced a unique fire risk that differs significantly from traditional building or hydrocarbon fires. EV fires, particularly those involving lithium-ion batteries, present new challenges in fire safety. These batteries are prone to a phenomenon called thermal runaway, where an internal reaction causes the battery to rapidly heat and combust. The EV fire is characterized by a rapid rise in temperature, similar to hydrocarbon fires, but with added complexity due to prolonged burn times and the potential for re-ignition (Sun et al., 2020a). Once ignited, these fires can reach temperatures between 1000 °C and

1200 °C within a few minutes, generating significant amounts of heat and toxic gases.

This presents serious risks in enclosed spaces such as underground parking garages or tunnels, where the heat and gases can cause severe structural damage. The EV fire thus, represents an evolving fire hazard that demands reconsideration of existing fire safety designs. The thermal runaway behavior and the challenges of extinguishing such fires make EV fires a particularly critical area for modern fire safety research. In comparison to the gradual temperature rise modeled by the ISO 834 fire curve, EV fires escalate rapidly, maintain high temperatures for longer, and present an ongoing risk even after initial extinguishment (Chen et al., 2021).

This shift in fire behavior, driven by hydrocarbon and EV fire scenarios, underscores the importance of updating fire resistance standards to reflect the more severe conditions posed by these modern fire types. The significance of comparing ISO 834, hydrocarbon, and EV fire lies in the vastly different temperature-time profiles and structural impacts each presents. The ISO 834 standard curve provides a gradual temperature increase, which allows for predictable modeling of how materials like concrete and steel degrade over time. However, this curve may not accurately reflect the more aggressive fire conditions found in industrial environments or the growing use of electric vehicles. These new fire types are marked by rapid temperature escalation and sustained high temperatures that can degrade materials much more quickly than anticipated under the ISO 834 curve when compared to the hydrocarbon fire scenario (Nguyen et al., 2025).

Understanding how each fire curve impacts material degradation is crucial for improving structural fire resistance in a wide range of environments. For instance, in tunnel fires fueled by hydrocarbons, the rapid heat escalation can cause concrete to experience spalling within minutes, significantly reducing its structural integrity. Similarly, the yield strength of steel decreases rapidly at temperatures above 500 °C, which can lead to catastrophic failures in steel-reinforced structures (Khoury, 2000; Zhao et al., 2025) but ultra-high-performance concrete behaves differently. A key property unique to concrete amongst structural materials is transient creep. Any structural analysis of heated concrete that ignores transient creep will yield erroneous results, particularly for columns exposed to fire. Failure of structural concrete in fire varies according to the nature of the fire; the loading system and the type of structure. Failure could occur from loss of bending or tensile strength; loss of bond strength; loss of shear or torsional strength; loss of compressive strength; and spalling of the concrete. The structural element should, therefore, be designed to fulfil its separating and/or load-bearing function without failure for the required period of time in a given fire scenario. Design for fire resistance aims to ensure overall dimensions of the section of an element sufficient to keep the heat transfer through this element within acceptable limits, and an average concrete cover to the reinforcement sufficient to keep the temperature of the reinforcement below critical values long enough for the required fire resistance period to be attained. The prediction of spalling – hitherto an imprecise empirical exercise – is now becoming possible with the development of thermohydromechanical nonlinear finite element models capable of predicting pore pressures. The risk of explosive spalling in fire increases with decrease in concrete permeability and could be eliminated by the appropriate inclusion of polypropylene fibres in the mix and/or by protecting the exposed concrete surface with a thermal barrier. There are three methods of assessment of fire resistance: (aIn the case of EV fires, prolonged exposure to extreme temperatures due to thermal runaway can weaken materials over an extended period, causing buckling, cracking, or even complete collapse (Chen et al., 2024) fire accidents due to impacts from the power battery located at the bottom of the electric vehicles are receiving increasing attention. Lithium-ion batteries, as the mainstream choice of power battery for electric vehicles solving the problem that they are prone to thermal runaway due to damage when impacted, are the key to preventing and controlling fire accidents in electric vehicles. To address the protective problem of the bottom power battery of electric vehicles when it is impacted by road debris, two new types of sandwich structures with an enhanced regular hexagonal structure and semicircular arch structure as the core layer, respectively, are innovatively proposed in this article. They are used to protect the bottom power battery of electric vehicles and are compared with the traditional homogeneous protective structure in terms of protective performance. A local finite element simulation (FEM. Comparing these fire curves also highlights the inadequacy of current fire safety standards in addressing the challenges posed by hydrocarbon and EV fires. Both fire types require new strategies for fire suppression, fireproofing, and material selection to mitigate the risks of rapid degradation and structural collapse.

This review aims to address gaps in current fire safety standards by conducting a detailed comparison of the ISO 834, Hydrocarbon, and Electric Vehicle (EV) fires, focusing on their temperature-time profiles, reduction factors, and structural impacts. The study integrates data from experimental results, case studies, and computational models to analyze how these fire scenarios affect essential construction materials such as concrete, steel, and composites.

The primary objectives of this review are to analyse the differences in temperature-time profiles between hydrocarbon and electric vehicle (EV) fires compared to the ISO 834 standard, focusing on peak temperatures, time to peak, and the severity of thermal loads imposed on structures. It also aims to investigate the degradation of materials such as concrete, steel, and composites under varying fire conditions, evaluating the reduction in their strength, stiffness, and mechanical properties at elevated temperatures. Furthermore, the study examines the structural impacts of these fire curves in real-world settings, including tunnels, parking garages, and industrial buildings, highlighting specific failures like spalling, buckling, and cracking due to high-temperature exposure. By addressing these critical aspects, the review will offer recommendations to enhance fire protection design and update fire resistance standards to better account for contemporary fire risks, especially those posed by hydrocarbon and EV fires.

2. FIRE CURVES OVERVIEW

Fire curves are crucial for understanding how different fire scenarios affect structural materials. These curves simulate the temperature-time profiles of fires and are used to predict the degradation of materials when exposed to high temperatures. *Table 1* summarize the comparison between different fires, where F*igure 1* shows a visual representation

Table 1: Peak Temperatures, Time to Peak, and Fire Duration

No.	Fire Curve	Peak Temperature (°C)	Time to Peak (minutes)	Fire Duration (hours)	References
1	ISO 834 Standard Fire	Gradual rise to **1000 °C** over 60-90 minutes; stable peak temperature for 120-180 minutes.	Steady increase at 1-2°C per minute in the first 30 minutes, reaching peak temperature at 120-180 minutes.	2-3	(Beyler et al., 2007; Bwalya et al., 2004; Choe et al., 2022; La Scala, 2025; Wang et al., 2024)
2	Hydrocarbon Modified (HC)	Rapid escalation to **1100 °C** within the first 5 minutes; maximum temperature maintained for 15-20 minutes.	Escalates at a rate of 10-20°C per second, achieving peak temperature in just 5 minutes.	0.5-1	(Ping et al., 2023; Spearpoint and Dickson, 2023)such as electric vehicles (EVs
3	Electric Vehicle (EV) Fire	Peaks at **1200 °C**, with localized temperatures exceeding **1500 °C** in battery thermal runaway conditions.	Rapid thermal runaway causes a spike to peak temperature within 3-5 minutes; sustained maximum heat for 10 minutes.	1-2	(Zhou et al., 2026)

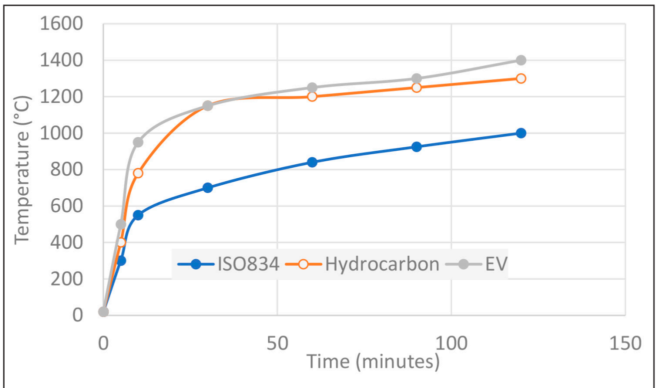
of the comparison. The ISO 834 standard fire curve is widely used in building codes and fire resistance tests, where it models a typical building fire with a gradual temperature rise, reaching 1200 °C after several hours. This curve is adequate for predicting the behavior of materials under relatively controlled fire conditions, such as those in residential or commercial buildings.

However, the Hydrocarbon (HC) fire curve, commonly encountered in industrial settings like chemical plants and tunnels, presents a more aggressive scenario. These fires can reach 1100 °C within less of 30 minutes, placing severe thermal stress on materials (Gravit et al., 2018). This rapid escalation leaves little time for materials to dissipate heat, leading to accelerated degradation, especially in concrete and steel structures.

With the rise of electric vehicles (EVs), the EV fire presents another challenge. Fires involving lithium-ion batteries can reach 1200°C quickly and have a prolonged burn time due to the potential for re-ignition ((“(PDF) Modern Vehicle Hazards in Parking Structures and Vehicle Carriers,” 2014) These characteristics make EV fires particularly dangerous in enclosed spaces such as parking garages, where the sustained high temperatures can severely compromise structural integrity.

The ISO 834 fire curve is designed for standard fire tests in building construction and allows for a gradual temperature rise, enabling materials to maintain structural integrity for

Figure 1: Comparison of Fire Curves



longer periods. This makes the ISO 834 fire curve suitable for traditional buildings where fire exposure is controlled, with concrete and steel able to absorb the heat before degradation occurs (ISO 834-1, n.d.). However, when applied to more extreme fire scenarios, such as hydrocarbon fires, the limitations of the ISO 834 curve become clear.

In hydrocarbon fires, particularly in environments like oil refineries and tunnels, the temperature rises much faster. Studies on hydrocarbon fire curves reveal that the Hydrocarbon Modified (HC) fire curve reaches 1100 °C in just a few minutes. This rapid increase causes materials like concrete to experience spalling, where the outer layers of the concrete crack and break away under extreme heat. The rapid loss of compressive strength in concrete and the quick deterioration of steel’s yield strength in such fires make them significantly more dangerous than those modeled by the ISO 834 fire curve (Ali et al., 2009).

For EV fires, which are becoming more frequent due to the rise in electric vehicle adoption, the fire presents even greater challenges. Lithium-ion batteries are prone to thermal runaway, where they reach extreme temperatures within minutes, and once ignited, EV fires can sustain temperatures above 1200 °C, with a risk of re-ignition (Okamoto et al., 2013, 2009) on the right side of the front bumper, or at the seat in the passenger compartment. We observed how the fire spread from the point of origin and investigated the effects of the location of the ignition on the burning behavior. The temperature inside the burning car and the mass loss rate were measured. The burning of a minivan was composed of three compartmental fires: the front compartment (front nose. In parking garages and tunnels, where such fires are more likely to occur, this poses significant risks for the structural stability of buildings (Olenick et al., n.d.).

When comparing the ISO 834, Hydrocarbon, and Electric Vehicle (EV) fires, the differences in temperature-time profiles become apparent in how quickly they impose thermal loads on structural materials. The ISO 834 fire curve models a slow temperature rise, which allows time for structural elements such as concrete and steel to gradually absorb the heat before reaching critical degradation points. This makes the ISO 834 suitable for traditional building fires, where the risk of rapid

Table 2: *Reduction in strength for concrete and steel at various temperatures*

No.	Material	Fire Curve	Temperature (°C)	Strength Reduction (%)	References
1	Concrete	ISO 834	300 °C	10%	(Chen et al., 2024; Kodur, 1999)
2	Concrete	Hydrocarbon Fire	600 °C	50%	(Buchanan and Abu, 2016; Poon et al., 2001)
3	Concrete	EV Fire	800 °C	30%	(Sun et al., 2020b)
4	Concrete	EV Fire	1200 °C	70%	(Sun et al., 2020b)
5	Steel	ISO 834	400 °C	20%	(Ali et al., 2009; Wong et al., 1998)
6	Steel	EV Fire	1000 °C	70%	(Sun et al., 2020b)
7	Steel	Hydrocarbon Fire	700 °C	40%	(Ali et al., 2009; Outinen and Mäkeläinen, 2004)

failure is minimized by the slow escalation of temperature (ISO 834-1, n.d.)

However, the Hydrocarbon fire curve exposes structures to much more intense heat within a short period, resulting in accelerated material degradation. Studies on hydrocarbon fires show that temperatures can reach 1100°C within five minutes, significantly reducing the time available for heat dissipation in materials such as concrete and steel. This leads to more rapid spalling in concrete and a quicker loss of steel's yield strength, which can cause critical structural failures (Morys et al., 2020; Oli et al., 2023).

The EV fire behaves similarly to hydrocarbon fires but presents unique challenges due to the behavior of lithium-ion batteries. These fires not only reach temperatures of 1200 °C but also maintain them for longer durations, with the risk of re-ignition adding to the severity of the fire. The extended exposure to heat makes EV fires particularly dangerous in confined environments like parking garages and tunnels, where prolonged heat can severely weaken reinforced concrete and steel structures (Sun et al., 2020a).

The significant differences between the ISO 834, Hydrocarbon curves, and EV fire are critical for understanding how structures perform under different fire scenarios. The ISO 834 fire curve, with its slow temperature rise, allows materials like concrete and steel to retain their integrity for longer periods. However, the rapid rise in hydrocarbon and EV fires presents much more aggressive thermal conditions.

3. MATERIAL DEGRADATION AND REDUCTION FACTORS

The degradation of structural materials, such as concrete, steel, and composites, under fire conditions depends significantly on the fire's temperature-time profile. Each material behaves differently when exposed to heat, and understanding how they degrade under different fire curves—ISO 834, Hydrocarbon, and EV fires—is critical for ensuring the integrity of structures in fire-prone environments.

Under the ISO 834 fire curve, where temperatures rise gradually over a few hours, concrete typically retains much of its structural integrity for longer periods. At temperatures below 300 °C, concrete's compressive strength remains relatively stable. However, as temperatures approach 600 °C, compressive strength begins to decline significantly, eventually leading to spalling at around 800 °C ("Eurocode 2," n.d.).

In contrast, hydrocarbon fires, with their rapid temperature rise to 1100 °C, induce much faster degradation. Concrete exposed to these high temperatures often suffers from immediate spalling, where the outer layers break away due to rapid thermal expansion. Steel in these conditions loses its yield strength rapidly, particularly when temperatures exceed 500 °C, and composite materials may start to delaminate due to the rapid heat exposure (M. Hedayati et al., 2015).

The EV fire presents a unique challenge, as it combines rapid temperature rise with prolonged exposure to extreme heat. The sustained high temperatures, exceeding 1200°C, lead to a prolonged degradation period, particularly in materials like reinforced concrete, where prolonged heat exposure can weaken the bond between steel reinforcement and concrete, leading to structural instability ("(PDF) Modern Vehicle Hazards in Parking Structures and Vehicle Carriers," 2014)

When exposed to fire, materials such as concrete, steel, and composites undergo significant reductions in strength, stiffness, and overall integrity. The rate and extent of degradation vary depending on the fire curve, with hydrocarbon and EV fires causing more rapid and severe damage than the ISO 834 fire curve. For concrete under hydrocarbon fire events, studies have shown that it begins to lose compressive strength at temperatures above 300 °C, with significant reductions occurring around 600°C and higher. At temperatures above 600 °C, concrete lose their load-bearing capacity, and under extreme conditions like those found in hydrocarbon fires, the rapid heating can cause spalling, where the outer layers of the material crack and break away as presented in *Table 2*. Steel, on the other hand, begins to lose yield strength at around 400 °C, with a 50% reduction at 500 °C (Khoury, 2000).

In electric vehicle (EV) fires, the sustained high temperatures of over 1000 °C can weaken steel to the point where it can no longer support structural loads, leading to buckling and potential collapse. Steel loses around 50% of its strength at temperatures above 600 °C, and prolonged exposure to the extreme heat typical of EV fires accelerates this weakening. One study on EV fires found that jet flames from lithium-ion batteries, combined with combustible materials in the passenger cabin, significantly increased the fire's heat release rate (up to 7.25 MW), threatening adjacent structures in parking garages, including steel and concrete components. These high heat levels promote fire spread and structural risks, especially in enclosed spaces such as parking structures (Kang et al., 2023).

Concrete, while generally resistant to fire, is not immune to damage in EV fire scenarios. The intense heat can cause spalling, where surface layers of the concrete explosively break away due to rapid temperature increases, reducing its

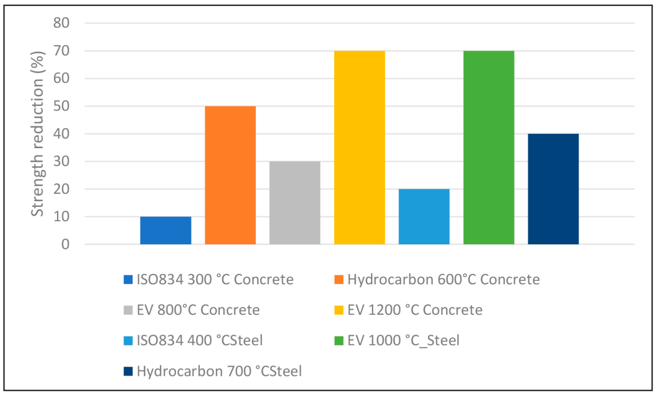


Figure 2: Comparison of Strength Reduction in Concrete and Steel at Various Temperatures

load-bearing capacity and exposing the steel reinforcements to further weakening. Additionally, composites used in modern construction and EV enclosures degrade more rapidly than traditional materials under fire conditions as shown in *Figure 2*. Delamination is a common failure mode for composites in EV fires, where layers of material separate under sustained heat exposure, compromising their structural bonds and accelerating failure (Guerrieri and Fragomeni, 2016). This degradation underscores the need for effective fire suppression systems and heat-resistant materials in parking structures designed for EV use.

As the temperature increases in fire scenarios, the degradation of structural materials becomes more pronounced. In hydrocarbon fires, for example, the rapid rise to 1100 °C not only affects concrete through spalling but also drastically reduces the structural performance of steel and composites. In these scenarios, steel can lose up to 70% of its yield strength within a few minutes, leading to structural failure if the fire persists. This is particularly dangerous in structures like tunnels or industrial facilities, where the high heat from hydrocarbon fires can quickly compromise load-bearing elements (Guerrieri and Fragomeni, 2016).

Under ISO 834 fire conditions, structural materials degrade gradually, allowing more time for elements to absorb and redistribute heat. However, limitations in the ISO 834 fire curve become clear when predicting performance in more severe fire scenarios, such as hydrocarbon and electric vehicle (EV) fires. Studies indicate that while ISO 834 serves as a baseline for fire resistance, hydrocarbon fire conditions reach significantly higher temperatures and cause faster degradation. For example, research shows that the fire resistance rating of Ultra-High Performance Fiber Reinforced Concrete (UHPFRC) beams decreased by 30 minutes under hydrocarbon fires compared to ISO 834, highlighting the inadequacy of ISO 834 in such aggressive conditions (Simwanda et al., 2022). Furthermore, recent analyses recommend adopting custom fire curves beyond ISO 834 for high-risk infrastructure assessments, especially for localized, high-temperature fires from EV or fuel tanker incidents as shown in *Table 3*. This approach supports performance-based fire design, enabling more accurate hazard responses in critical infrastructure (Hu, 2020).

When comparing the degradation of materials under the ISO 834, Hydrocarbon, and Electric Vehicle (EV) fires, the structural impact on concrete, steel, and composite materials becomes more evident. In ISO 834 fire conditions, materials experience slower degradation, with concrete retaining a substantial amount of its compressive strength up to 300 °C. At this temperature, concrete's strength reduction is relatively minor, and steel loses around 20% of its yield strength ("Eurocode 2," n.d.). This gradual degradation allows more time for structural fire resistance measures to mitigate damage, making the ISO 834 fire curve suitable for traditional building fires

However, under hydrocarbon fires, the rapid rise to 1100 °C within just a few minutes causes much more aggressive degradation. Concrete spalling occurs almost immediately, and steel experiences rapid loss of yield strength, reducing by as much as 50% at temperatures above 600 °C. This sudden degradation poses a significant risk to structures like tunnels, industrial facilities, and oil refineries, where fire hazards are more extreme. Without adequate fireproofing, such structures can suffer catastrophic failure in the early stages of a fire(Kumar et al., 2021; Wan et al., 2014).

For EV fires, the sustained exposure to 1200 °C or higher temperatures leads to prolonged degradation of both concrete and steel, as well as composite materials. In enclosed spaces such as parking garages, the continuous heat load can weaken steel reinforcement in concrete, causing spalling and delamination in composite materials. This sustained exposure increases the risk of structural collapse, particularly in locations where fire suppression is delayed, or re-ignition occurs due to the nature of lithium-ion battery fires (Hertz, 2003; ISO 834-1, n.d.; Kodur, 1999).

4. COMPARATIVE ANALYSIS OF FIRE SCENARIOS

In this section, we will focus on comparing the different fire scenarios (ISO 834, Hydrocarbon, and EV fires) in terms of their effects on structural materials, such as concrete, steel, and composites *(Table 4)*. The comparison will include factors like, Temperature-Time Profiles to observe how quickly each fire type reaches peak temperature and sustains it, heat release rates (HRR), in which the rate at which energy is released in the form of heat, crucial for assessing the severity of the fire and reduction Factors, where the extent to which key material properties, like yield strength and compressive strength, are reduced.

When comparing ISO 834, Hydrocarbon, and EV fires as shown in *Table 4 and Figure 3*, it becomes evident that the more severe fire conditions of hydrocarbon and EV fires result in faster material degradation and greater structural challenges. The Heat Release Rate (HRR) is a key factor that distinguishes these fire scenarios. While ISO 834 fires exhibit a slow and gradual rise in HRR, both hydrocarbon and EV fires demonstrate a much more aggressive heat release, which in turn accelerates the degradation of structural materials (Alvares et al., 2016; La Scala et al., 2023).

In hydrocarbon fires, the HRR can reach values as high as 350 kW/m² within 5 minutes, exposing structural materials like steel and concrete to extreme heat and pressure. This rapid escalation results in spalling in concrete and buckling in steel, particularly in tunnels and confined environments. In contrast, ISO 834 fires produce significantly lower HRR, which allows structures more time to resist failure. The prolonged heat exposure seen in EV fires not only increases the HRR but also sustains it at high levels for longer periods. This sustained exposure leads to composite material delamination and prolonged degradation of reinforced concrete, increasing

Table 3: Material Integrity and Time to Failure under Different Fire Scenarios

No.	Fire Curve	Material	Impact on Material Integrity	Time to Failure	References
1	ISO 834 Standard Fire	Concrete	Gradual strength reduction; spalling at temperatures >600°C	2-3 hours	(Kodur, 1999; M. Hedayati et al., 2015; Wang et al., 2024)
2	Hydrocarbon Modified (HC)	Steel	Rapid yield strength loss; structural buckling at >700°C	30-60 minutes	(Ali et al., 2009)
3	Electric Vehicle (EV) Fire	Composites	Delamination; loss of structural bonds under intense heat	1-2 hours	(Kang et al., 2023)

Table 4: Comparative analysis of fire curve

No.	Fire Curve	Peak Temperature (°C)	Time to Peak Temperature (minutes)	Heat Release Rate (kW/m²)	Structural Degradation Speed	References
1	ISO 834 Standard Fire	1000	120-180	100-150	Slow	(Held et al., 2022)
2	Hydrocarbon Fire	1100	5	200-350	Rapid	(Held et al., 2022)
3	Electric Vehicle (EV) Fire	1200	10	250-400	Prolonged	(La Scala, 2025)

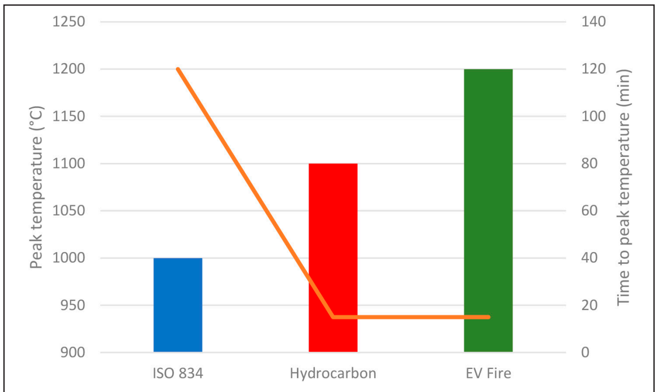


Figure 3: Comparative Analysis of Fire Curves

the likelihood of structural failure in parking garages and tunnels where lithium-ion battery fires are a growing concern (Liu et al., n.d.)

In the comparative analysis of fire scenarios, understanding the temperature-time profiles is critical for assessing how quickly materials reach their failure points. Hydrocarbon fires reach peak temperatures much faster than ISO 834 fires, and EV fires demonstrate an even more sustained high-temperature profile due to the nature of lithium-ion batteries. This creates unique structural challenges, as steel and concrete are exposed to prolonged extreme heat. Under ISO 834 fire conditions, materials like concrete and steel undergo gradual degradation. Concrete typically experiences spalling after a few hours of exposure, and steel retains up to 50% of its yield strength at 600 °C. However, hydrocarbon fires reduce this timeframe dramatically, with temperatures reaching 1100 °C in less than 5 minutes. The rapid rise in temperature causes steel to buckle and concrete to spall almost immediately, posing a significant risk in industrial facilities and tunnels (Oli et al., 2023).

In EV fires, the prolonged exposure to 1200 °C creates even more severe conditions. The thermal runaway effect not only results in rapid temperature rise but also sustained heat exposure. This leads to more significant structural challenges in parking garages and tunnels, where prolonged exposure to high heat weakens reinforced concrete and causes delamination in composite materials (Chen et al., 2021)

The next graph will visually compare the temperature-time profiles for ISO 834, Hydrocarbon, and EV fires, showing the steep rise in temperature for hydrocarbon and EV fires compared to the gradual rise in ISO 834.

The final part of the Comparative Analysis focuses on the structural responses to these varying fire scenarios. Each fire type - ISO 834, Hydrocarbon, and EV fires - affects structural materials differently based on how quickly the fire escalates and how long it sustains extreme temperatures. These factors play a crucial role in determining how structures such as parking garages, tunnels, and industrial buildings withstand fires and what measures are required to prevent catastrophic failure.

In ISO 834 fires, which simulate typical building fires, reinforced concrete and steel perform better due to the slow temperature rise. The gradual heating allows the structure to resist collapse for longer, often giving enough time for fire suppression or evacuation (ISO 834-2, 2019). However, hydrocarbon fires and EV fires expose materials to far greater thermal stresses in much shorter periods. Concrete undergoes rapid spalling in both fire types, which compromises its compressive strength. Steel suffers from buckling and yield strength loss under hydrocarbon and EV fire conditions, particularly in confined spaces like tunnels and parking garages (Ariyanayagam and Mahendran, n.d.).

In EV fires, the sustained exposure to high temperatures poses a unique threat, as the thermal runaway from lithium-ion batteries can cause multiple reignition events, further weakening the structural integrity of both concrete and steel. Composite materials used in modern construction also degrade faster under these conditions, with delamination occurring as the adhesive bonds fail at high temperatures (Mellert et al., 2018).

5. CONCLUSION

This study provides a comprehensive comparison of the ISO 834, Hydrocarbon (HC), and Electric Vehicle (EV) fire curves, emphasizing their impacts on structural materials such as concrete, steel, and composites. The findings demonstrate that while the ISO 834 fire curve remains effective for moderate-risk scenarios, such as those in residential and commercial buildings, it fails to account for the aggressive nature of HC and EV fires. These fires are characterized by rapid temperature escalation and prolonged high-temperature exposure, which impose severe thermal loads on structures. Moreover, due to the notable similarities between HC and EV fire behaviors, the HC fire curve can serve as a basis for evaluating EV fires, enabling a practical approach for assessing their effects on concrete structures.

The traditional ISO 834 fire curve is suitable for typical building fire scenarios where the gradual temperature increase allows materials like steel and concrete to maintain their integrity for longer periods. However, in environments exposed to extreme fire scenarios, such as tunnels, industrial facilities, and parking garages, the limitations of this curve become apparent. Hydrocarbon fires, with temperatures reaching 1100 °C in under five minutes, cause rapid structural degradation, including concrete spalling and significant reductions in steel strength, increasing the likelihood of structural collapse. EV fires, on the other hand, pose unique challenges due to thermal runaway in lithium-ion batteries, which leads to sustained temperatures exceeding 1200 °C. This prolonged exposure weakens reinforced concrete and delaminates composite materials, significantly heightening the risk of failure, particularly in confined spaces such as parking garages.

Adapting the HC fire curve for EV fire evaluation provides a valuable framework for addressing these risks. By leveraging the thermal similarity between HC and EV fires, it becomes feasible to streamline safety assessments and design measures for structures exposed to these fire types. Enhanced fireproofing strategies, including fire-resistant coatings for steel and heat-resistant additives for concrete, are essential to mitigate the rapid degradation caused by HC and EV fires. Additionally, advanced ventilation systems and fire suppression technologies must be incorporated into structural designs to manage the unique risks posed by these fire scenarios.

The need for updated fire safety standards and building codes is clear. Existing standards, primarily designed around ISO 834 fire scenarios, must evolve to incorporate the thermal and structural demands of HC and EV fires. Revising these codes to mandate the use of fire-resistant materials and the implementation of thermal modeling for high-risk environments will ensure greater safety and resilience. Recognizing the parallels between HC and EV fires and adapting HC fire evaluations for EV-specific scenarios offer a cost-effective approach to improving fire safety while maintaining robust structural performance. This study underscores the importance of addressing modern fire hazards through enhanced materials, updated codes, and innovative design adaptations, ensuring safer and more resilient structures capable of withstanding the challenges of contemporary fire risks.

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