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TECHNICAL WHITE PAPER

Material Selection and Long-Term Durability in Australian Outdoor Fibre Optic Cable Deployments

Environmental Stress Factors, Polymer Engineering and Lifecycle Performance Considerations

Prepared by

Anderson Corporation – Technical Engineering Division

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Anderson Corporation Pty Ltd

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Abstract

Outdoor fibre optic cable deployments in Australia are subject to elevated ultraviolet radiation, sustained thermal exposure and persistent moisture in buried conduit systems. In certain regions, termite activity also presents an additional risk factor for underground infrastructure. While optical fibres exhibit high intrinsic stability, long-term network reliability is frequently influenced by the performance of external jacket materials and their resistance to environmental degradation mechanisms.

This paper examines the primary environmental stress factors affecting outdoor fibre cable systems, including photodegradation, oxidative ageing and moisture related impacts on polymer stability. It outlines the role of polymer selection and engineered additive systems in mitigating these degradation pathways and supporting extended service life expectations. The discussion also considers bend performance in modern access networks and the lifecycle implications of material durability in long term infrastructure planning.

Disclaimer

This document provides technical discussion and general engineering analysis for informational purposes only. Performance characteristics referenced herein are indicative of material behaviour under typical conditions and do not constitute a product warranty or performance guarantee. Actual service life may vary depending on installation practices, environmental exposure, handling and operating conditions.

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Material Selection and Long-Term Durability in Australian Outdoor Fibre Optic Cable Deployments

1. Executive Summary

Outdoor fibre optic cable deployments in Australia are exposed to some of the most demanding environmental conditions globally. High ultraviolet (UV) radiation levels, elevated ambient temperatures, persistent moisture in buried and conduit environments and termite activity in rural and regional areas all contribute to long-term cable jacket degradation. While optical fibres themselves are highly stable, premature network failures frequently originate from jacket deterioration, mechanical damage, or environmental attack rather than intrinsic fibre performance.

Material selection and additive engineering therefore play a critical role in determining long term cable reliability. Polymer behaviour under UV exposure, thermal oxidation and moisture absorption directly influences mechanical integrity, flexibility and service life. In termite prone environments, additional risk factors must also be considered when specifying underground infrastructure. Modern outdoor cable design increasingly requires a combination of inherently stable base polymers and targeted stabilisation systems to mitigate these environmental stressors.

This paper examines the key environmental challenges affecting Australian fibre deployments, the mechanisms of polymer degradation in outdoor applications and the role of advanced material and additive technologies in improving long term performance. It outlines the engineering considerations necessary to support durable, low maintenance network infrastructure aligned with extended service life expectations.

2. Environmental Challenges in Australian Fibre Deployments

Outdoor fibre optic infrastructure in Australia operates under environmental conditions that can accelerate polymer degradation and reduce long-term cable reliability if not properly addressed during material selection. While optical fibres are inherently stable, the external cable jacket and associated components are directly exposed to environmental stressors that influence mechanical integrity and service life. Understanding these stress mechanisms is essential when specifying cable systems for long-term outdoor deployment.

2.1 Ultraviolet (UV) Exposure

Australia experiences some of the highest ultraviolet radiation levels globally. Prolonged UV exposure can initiate photodegradation in polymer jackets, leading to chain scission, surface cracking, embrittlement and gradual loss of tensile and impact strength. In partially exposed outdoor installations - such as boundary to boundary runs, pit transitions and risers – UV induced ageing may occur over extended periods. Without appropriate stabilisation systems, jacket materials can progressively lose flexibility and structural integrity.

2.2 Moisture and Buried Environments

Even in fully underground conduit systems, cable jackets are routinely exposed to moisture through condensation, groundwater ingress and pit flooding. Water absorption characteristics vary significantly between polymer types and influence dimensional stability and long-term mechanical performance. Elevated humidity and persistent wet conditions can accelerate certain degradation processes, particularly when combined with temperature fluctuations. For buried infrastructure, moisture resistance is therefore a primary material consideration rather than a secondary factor.

2.3 Thermal Ageing and Oxidative Degradation

Large regions of Australia experience sustained elevated ambient temperatures, particularly in northern and inland areas. Increased temperature accelerates oxidative reactions within polymer structures, contributing to gradual mechanical fatigue and loss of elasticity. Over time, thermal ageing can reduce a jacket’s resistance to impact, bending stress and handling during maintenance activities. Stabilisation against oxidation is critical to maintaining long term toughness and flexibility.

2.4 Termite Activity in Underground Infrastructure

In rural and regional environments, termite activity presents an additional risk factor for underground cable systems. Polymer jackets may be subject to physical attack, resulting in breaches that expose internal components to moisture and mechanical damage. While termite impact varies by geography, it remains a documented cause of infrastructure deterioration in certain deployment zones. Material selection and protective strategies should therefore consider biological as well as environmental stressors.

Collectively, UV exposure, moisture, thermal ageing and termite activity represent key environmental drivers influencing the durability of outdoor fibre optic cable systems in Australia. Effective long-term performance depends on aligning material properties and stabilisation technologies with these operating conditions.

Figure 1. Environmental Stress Factors Affecting Outdoor Fibre Deployments

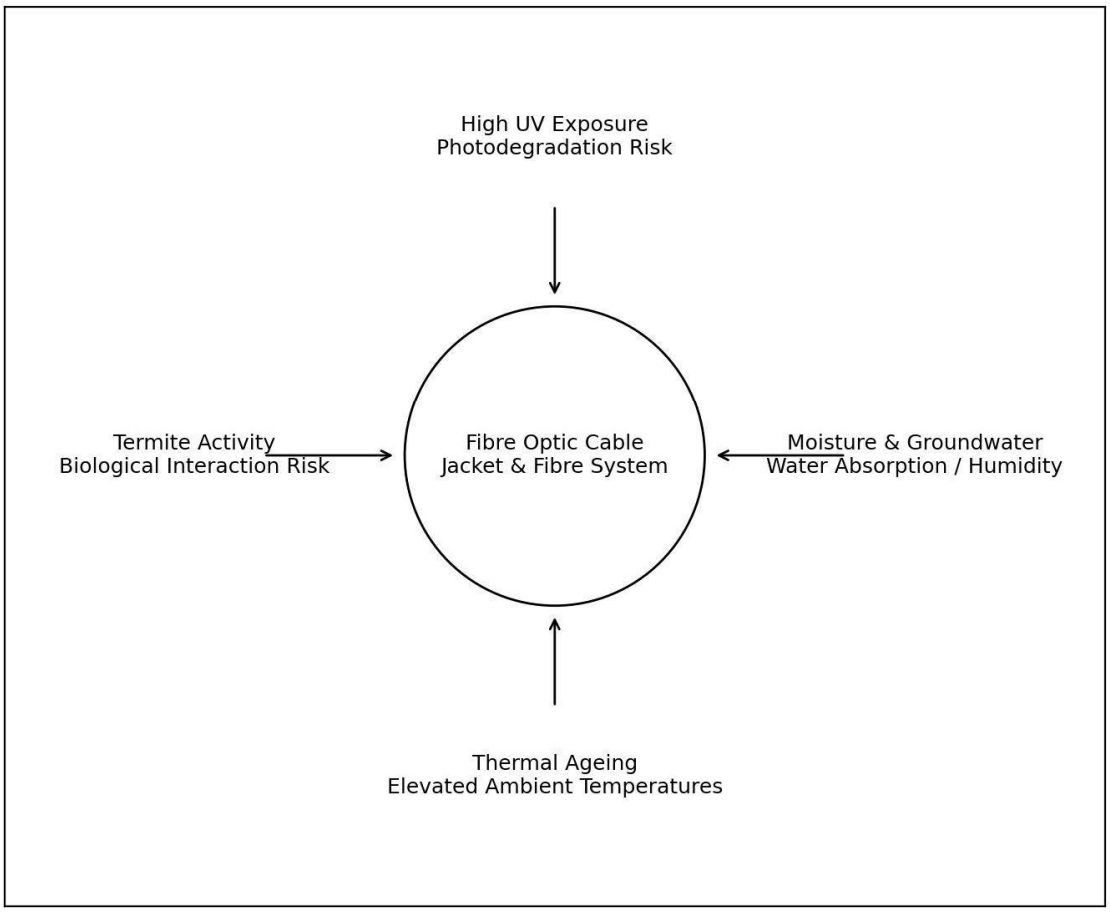

Figure 1. Environmental Stress Factors Affecting Outdoor Fibre Deployments. Illustrative representation.

3. Polymer Selection in Outdoor Fibre Cable Jackets

The long term durability of outdoor fibre optic cables is strongly influenced by the properties of the jacket material. The jacket serves as the primary environmental barrier, protecting internal optical components from mechanical damage, moisture exposure, ultraviolet radiation and biological attack. Selecting an appropriate polymer therefore requires balancing mechanical strength, environmental stability, processability and cost.

3.1 Polyethylene (PE) Jackets

Polyethylene is widely used in outdoor cable construction due to its cost efficiency, flexibility and ease of processing. It provides good baseline moisture resistance and mechanical performance in standard conduit environments. However, prolonged UV exposure can lead to photodegradation if not adequately stabilised, and PE materials may be susceptible to biological attack or surface damage in certain underground environments. Long-term thermal ageing performance depends heavily on additive systems incorporated during compounding.

3.2 Nylon Based Jackets

Nylon materials offer improved abrasion resistance and higher mechanical strength compared to many PE formulations. Their toughness and impact resistance make them suitable for demanding installation conditions. However, different nylon grades exhibit varying levels of water absorption, which can influence dimensional stability and long term mechanical behaviour in humid or buried environments. Polymer grade selection is therefore critical when specifying nylon based jackets for outdoor use.

3.3 Polyamide 12 (PA12) as a Jacket Material

Polyamide 12 (PA12) is a high-performance nylon grade recognised for its low water absorption, dimensional stability and mechanical retention over time. Compared to many other nylon variants, PA12 is widely recognised for low water absorption and strong dimensional stability. These characteristics make it particularly suited to underground conduit installations and environments subject to sustained humidity.

In addition to its inherent material properties, PA12 can be further enhanced through engineered additive systems designed to improve resistance to ultraviolet degradation, thermal oxidation and biological attack. When properly stabilised, PA12 provides a durable platform for long life outdoor fibre optic cable construction.

4. Additive Technology and Long-Term Stabilisation

Base polymer selection establishes the foundation of jacket performance; however, long term durability in outdoor environments is heavily influenced by the additive systems incorporated during compounding. Stabilisation technologies are designed to mitigate predictable degradation mechanisms such as ultraviolet exposure, oxidative ageing and biological interaction. In demanding climates, these engineered additive packages are essential to maintaining mechanical integrity over extended service periods.

4.1 Ultraviolet Stabilisation

Ultraviolet radiation initiates photochemical reactions within polymer chains, resulting in molecular breakdown, surface cracking, embrittlement and progressive loss of mechanical strength. UV stabilisers function by absorbing, dissipating, or neutralising high energy radiation before it can degrade the polymer backbone. The effectiveness of a UV stabilisation system depends on correct additive selection, dispersion and concentration within the compound. Properly engineered UV protection enables jacket materials to retain flexibility and tensile performance under prolonged outdoor exposure.

4.2 Antioxidant Systems and Thermal Ageing Control

Thermal ageing occurs when elevated temperatures accelerate oxidative reactions within the polymer matrix. This process can lead to chain scission, reduced elongation, increased brittleness and long term mechanical fatigue. Antioxidant packages are incorporated to interrupt oxidation pathways and slow degradation kinetics. By stabilising the polymer against thermal and oxidative stress, these additives help preserve impact resistance, flexibility and overall structural integrity throughout the service life of the cable.

4.3 Termite Deterrent Additives

In certain deployment regions, biological interaction presents a measurable risk to underground infrastructure. Termite deterrent additives are formulated to discourage polymer attack and reduce the likelihood of jacket penetration. While not altering the fundamental mechanical properties of the base polymer, these additives provide an additional layer of environmental defence in termite prone areas. Incorporating such protective measures into the jacket compound supports improved reliability in rural and regional installations.

Engineered additive systems, when combined with an inherently stable base polymer, provide a layered approach to environmental protection. Rather than relying solely on material selection, modern outdoor cable design integrates targeted stabilisation strategies to address the specific degradation mechanisms encountered in service.

Figure 2. Primary Polymer Degradation Mechanisms in Outdoor Environments

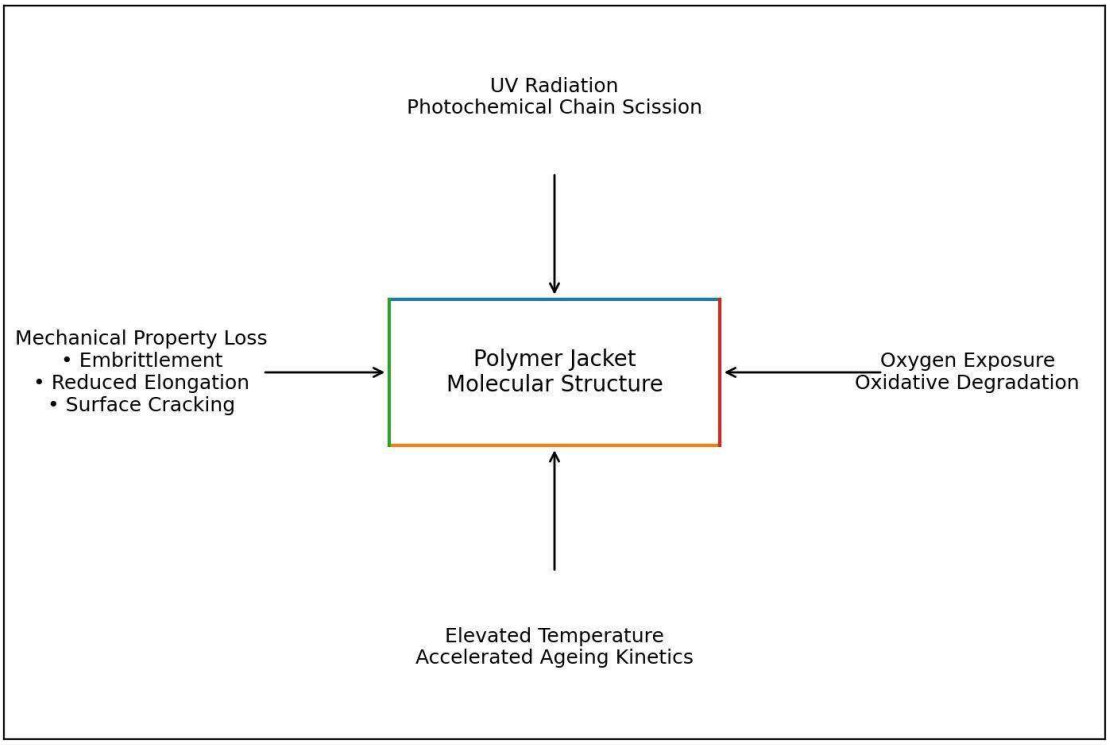

Figure 2. Primary Polymer Degradation Mechanisms in Outdoor Environments (Illustrative representation).

The stabilisation approaches discussed are consistent with established polymer engineering practices for improving environmental durability.

5. Optical Performance and Installation Considerations

While jacket durability is critical to environmental resilience, overall cable performance also depends on optical fibre selection and installation practices. Modern access and enterprise networks increasingly require compact routing, higher fibre densities and faster deployment cycles. These trends place additional mechanical and optical demands on cable systems beyond traditional long haul applications.

5.1 Bend Performance in Access Networks

Fibre to the Premises (FTTx) and urban distribution deployments frequently involve tight pits, small conduits, building risers and congested pathways. In such environments, reduced bend radii can increase attenuation in conventional Singlemode fibres due to macrobending effects. Bend insensitive fibre designs, such as those conforming to G.657.A2, are intended to improve tolerance to tight routing conditions by reducing macrobend related signal loss. This can enhance installation flexibility and help reduce the risk of bend related attenuation in space constrained routing scenarios.

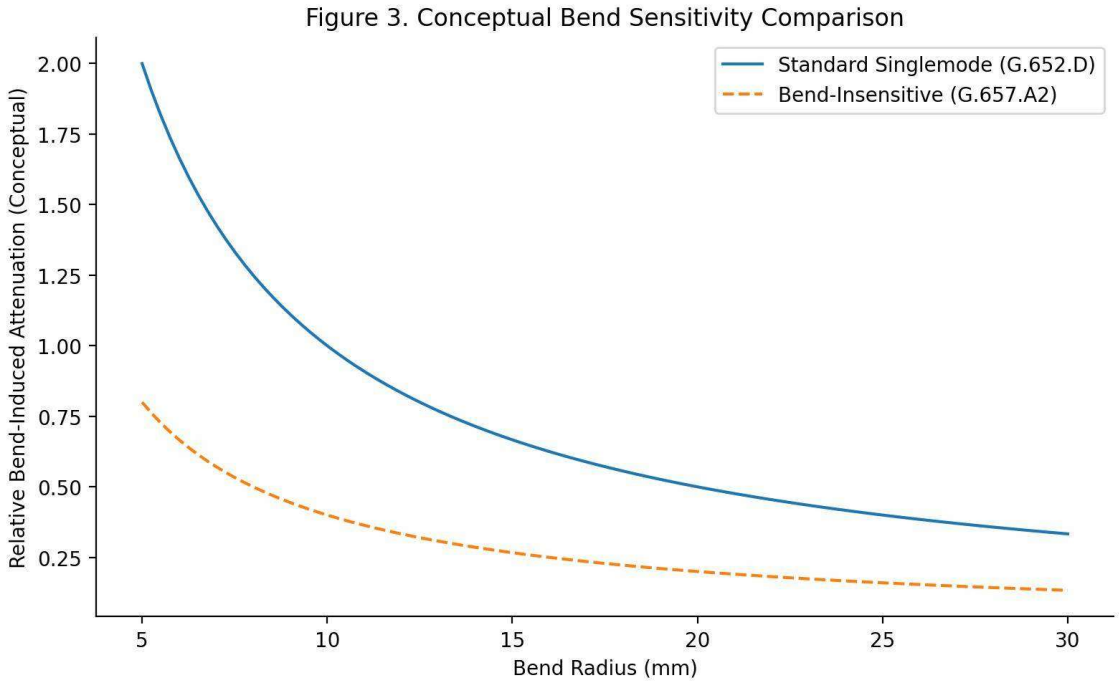

Figure 3. Conceptual Bend Sensitivity Comparison. Illustrative representation.

5.2 Multimode Performance in Enterprise Environments

Multimode fibres, including OM4 classifications, are widely deployed in enterprise, campus, and data centre environments where high bandwidth over shorter distances is required. These installations often prioritise high data rates, dense cable management systems and controlled indoor conditions. In such applications, mechanical robustness during installation and consistent optical performance are essential to maintaining link reliability.

5.3 Installation-Induced Stress Factors

Mechanical stresses during installation - such as pulling tension, sidewall pressure, bending and handling - can influence both jacket integrity and optical performance. Excessive tensile loads or repeated flexing may contribute to microbending or long term mechanical fatigue if design tolerances are exceeded. Clean, predictable stripability and stable material interfaces between jacket and internal components can help reduce the likelihood of installation related damage.

In contemporary fibre deployments, optimal performance depends on the integration of environmentally stable jacket materials, appropriate fibre selection and installation practices aligned with design specifications. When these factors are considered collectively, they can contribute to improved consistency in field performance and support long-term network reliability across both access and enterprise environments.

6. Lifecycle, Reliability and Asset Management Considerations

Fibre optic infrastructure is generally installed with an anticipated service life extending over several decades. Although the optical fibres themselves are inherently stable, the long-term performance of the asset is often influenced by the durability of the external protective materials and the cable's ability to withstand environmental and mechanical stressors. Degradation of the outer jacket, exposure-related damage, or installation-induced weaknesses may contribute to earlier-than-expected maintenance requirements, potentially increasing operational costs and network disruption.

Figure 4. Conceptual Lifecycle Performance Comparison

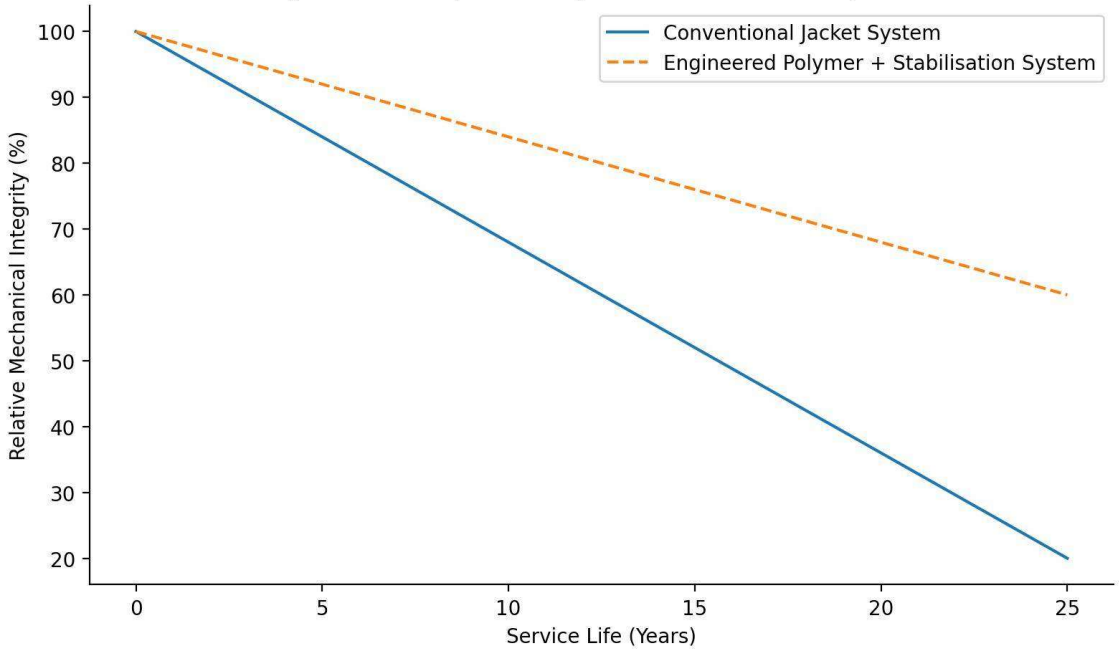

Figure 4. Conceptual Lifecycle Performance Comparison. Illustrative representation.

Material selection and stabilisation strategies therefore have direct implications for asset management outcomes. Jacket systems that maintain mechanical integrity under UV exposure, moisture, thermal ageing and potential biological interaction can reduce the risk of cracking, embrittlement, or breach over time. Lower degradation rates can contribute to reduced risk of jacket-initiated failure modes, less frequent remediation, and improved network availability. In geographically dispersed or regional networks, minimising maintenance interventions can also deliver meaningful cost and logistical benefits.

From a total cost of ownership perspective, specifying materials that are aligned to the expected environmental operating conditions can support more predictable lifecycle performance. While initial procurement decisions often focus on unit cost, long-term infrastructure planning increasingly considers durability, consistency of service life, and risk exposure over time. Combining stable base polymers with engineered stabilisation and protective additive systems provides a structured approach to mitigating key degradation mechanisms and can contribute to extended network reliability.

7. Conclusion and Engineering Implications

Outdoor fibre optic cable deployments in Australia are subject to a combination of environmental stressors that can significantly influence long term reliability. Elevated ultraviolet radiation, sustained thermal exposure, persistent moisture in buried infrastructure and termite activity in certain regions collectively create a demanding operating environment for polymer based cable jackets. Addressing these factors requires a considered approach to both base material selection and stabilisation engineering.

The analysis presented in this paper highlights the importance of selecting polymers with inherently stable moisture and mechanical characteristics, supported by targeted additive systems designed to mitigate UV degradation, oxidative ageing and biological risk. Rather than relying on a single protective attribute, durable outdoor cable design increasingly reflects a layered protection model - combining material properties with engineered stabilisation strategies aligned to local environmental conditions.

In practical terms, fibre optic cable platforms that integrate low water absorption polymers with ultraviolet stabilisers, antioxidant packages and termite deterrent additives are intended to support improved long-term mechanical integrity and reduced degradation risk. When paired with appropriate fibre selection and installation practices, this approach supports extended service life expectations and more predictable asset performance.

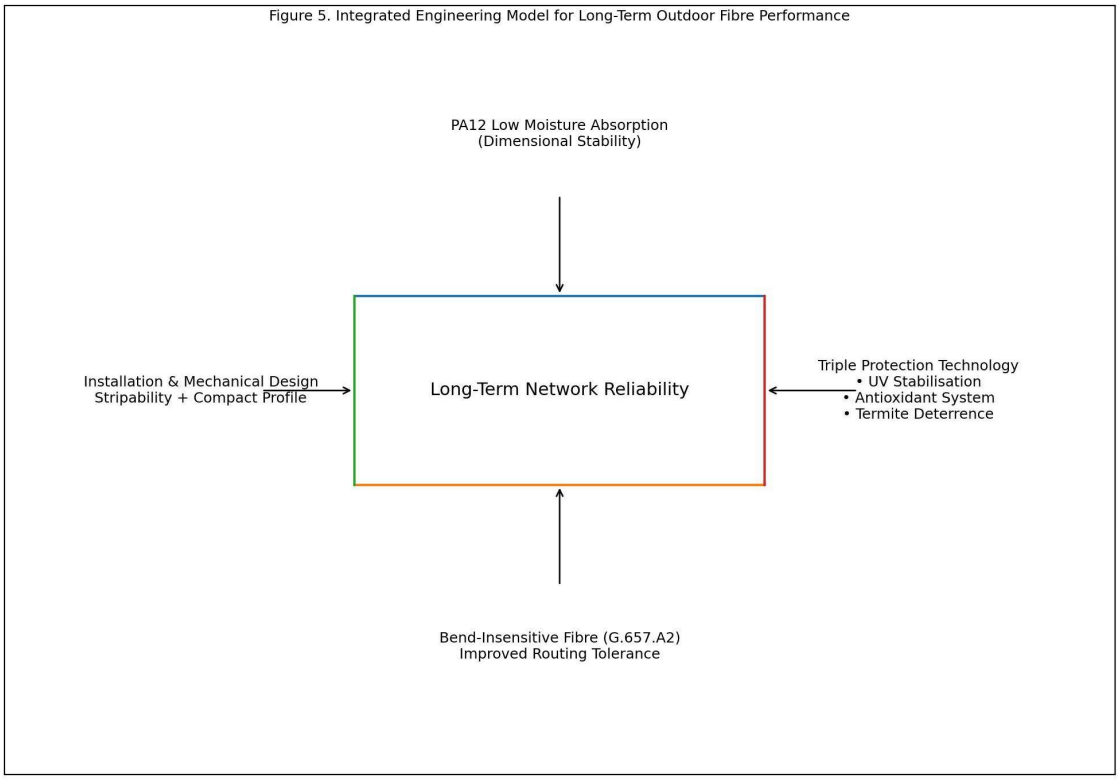

Figure 5. Integrated Engineering Model for Long-Term Outdoor Fibre Performance. Illustrative representation.

Applied Engineering Implications: RapidConnect TR-Series

The RapidConnect TR-Series Mini Loose Tube Fibre Optic Cable reflects the engineering approach outlined in this paper by applying material selection principles and stabilisation strategies aligned to the operating conditions commonly encountered in Australian outdoor deployments. The platform is built around a PA12 based jacket system, selected for its inherently low water absorption and dimensional stability in wet, humid and buried conduit environments. This inherent moisture performance is complemented by a targeted stabilisation approach intended to address key external stressors associated with long-term jacket degradation in service.

To support outdoor durability, the TR-Series incorporates an additive protection model comprising UV Protection, Antioxidant Protection and Termite Deterrent Additives, implemented through engineered compounding rather than reliance on base polymer behaviour alone. UV stabilisation is intended to reduce the risk of photodegradation related cracking and embrittlement in exposed or partially exposed pathways. Antioxidant stabilisation is intended to improve resistance to thermal ageing and oxidative degradation, helping to maintain jacket flexibility and mechanical toughness over extended service periods and variable temperature conditions. Termite deterrent additives provide an additional protective measure in termite prone deployment zones, reducing the likelihood of biological interaction becoming an initiating factor in jacket damage for buried infrastructure.

In parallel with environmental resilience, the TR-Series construction emphasises practical installation outcomes. Cable systems are routinely exposed to installation induced stresses - including pulling loads, bending, handling impacts and preparation/termination effects - which can introduce early life damage that may affect long-term reliability. A controlled stripability profile and stable internal interfaces are therefore key engineering considerations, as they can reduce the likelihood of inadvertent damage during preparation and support consistent field workmanship. As standard, bend insensitive Singlemode fibre (G.657.A2) can further support modern routing constraints in access networks, pits, risers and space constrained pathways, while OM4 multimode variants support high-bandwidth enterprise and campus environments.

Taken together, the TR-Series design represents an applied implementation of the layered protection model discussed in this paper: selecting a base polymer platform aligned to moisture exposure realities, applying stabilisation additives targeted to UV and thermal ageing mechanisms and incorporating biological deterrence where regional deployment risks warrant it - while maintaining a construction profile intended to support efficient installation and reduced rework. This integrated approach is intended to support long-term mechanical integrity, reduce the risk of jacket-initiated failure modes and contribute to more predictable lifecycle performance in Australian outdoor fibre network infrastructure.