Response of pierced fixed corrugated steel roofing systems subjected to wind loads

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ARTICLE INFO
Article history:
Received 2 November 2010
Received in revised form
31 July 2011
Accepted 2 August 2011
Available online 29 September 2011

Keywords:
Wind
Load
Roof
Cladding
Cyclone
Fatigue
Test
Damage
Housing

ABSTRACT
The low-cycle fatigue response of corrugated metal roof cladding to fluctuating wind loads was studied by subjecting cladding specimens to a series of static, cyclic and simulated “real” cyclonic wind loads using a Pressure Loading Actuator (PLA), and measuring fastener response using a x-y-z load cell. The overall performance of cladding including crack initiation, propagation and patterns, and cycles to failure was found to be similar to previous tests that used line-loads to simulate wind pressure. The reaction at a fastener to spatially varying pressures was assessed by analysing the influence coefficients, to show that it is predominantly influenced by local loads acting along the screwed crest. In addition, the response of roofing specimens subjected to fluctuating cyclonic wind pressures replicated failures observed in the field. The fastener response varied with the load level and the response spectrum followed the wind load spectrum up to 5 Hz even with deformation and cracking of the cladding showing that these higher frequency wind “load cycles” were transferred into the supporting structure via the fastener.

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1. Introduction

Roofing of low-rise buildings (e.g., houses, warehouses, industrial sheds) are subjected to large temporally and spatially varying wind pressures during wind storms such as a tropical cyclone. These fluctuating pressures are generated by turbulence in the approaching wind flow and flow around the building. The pressures on parts of the roof vary with the changes in wind speeds and directions as a cyclone tracks past the building. Roofs clad with light gauge profiled metal sheeting are susceptible to low-cycle fatigue, as was seen in Darwin, Australia after Cyclone Tracy in 1974, where more than 90% of houses and 70% of other structures suffered significant loss of roof cladding [1]. Following Cyclone Larry which impacted on Innisfail, Australia in 2006, some cases of fatigue failure of metal cladding were also observed [2].

A component fails in fatigue following the application of fluctuating loads of lower magnitude than the component’s static load capacity (strength). Metal roof cladding is susceptible to low-cycle fatigue cracking at the fastener with failure by the cladding disengaging over the head of the screw. Fatigue failure may occur from a large number of low level load cycles or from a few cycles at a level near the ultimate static capacity. The number of cycles to failure is also dependent on the load ratio defined as $R = S_{\text{min}}/S_{\text{max}}$, where the load varies between a maximum, $S_{\text{max}}$ and a minimum $S_{\text{min}}$. Low-cycle fatigue is commonly defined as failure within 10,000 load cycles [3] with the magnitude of loading cycles exceeding the yield stress.

The fatigue performance of roof cladding has been studied by Beck and Stevens [3], Mahendran [4], and Xu [5], by subjecting specimens to cyclic loads. The data was analysed in terms of the peak reaction at the fastener ($S_{\text{max}}$) vs number of cycles to failure (N) or S–N curves. They found that the fatigue behaviour of the thin (0.42 mm BMT) but high yield strength G550 grade cladding is dependent on the load causing local plastic deformation (LPD), seen as dimpling under the screws around the fastener holes, shown in Fig. 1. The fatigue life of corrugated cladding increases markedly if the load per fastener is kept below this local plastic deformation load [3–5].

The interaction between the cladding and fastener is a crucial part of the cladding’s fatigue response to the applied load [6, 7] and is affected by the thinness of the material relative to the large region of plastic deformation near the screw, the load history, and the range of stresses applied spanning the non-linear S–N curve. Hence, typical predictive or analytical tools such as Miner’s Rule, linear elastic fracture mechanics (LEFM) or crack tip opening methods (CTOD/CTOA) have limited capability for estimating fatigue performance [8–10]. Physical testing of cladding...