Fretting Fatigue and the Bridge over the Strait of Messina - Clarifications on Cable Technology and Standards

by C. Borri & A. Taras

In a recently circulated note on ResearchGate, the Associate Prof. Michele Ciavarella of the Department of Mechanics, Mathematics and Management at the Politecnico di Bari raises severe and undocumented concerns about fretting fatigue in the main cables of the planned suspension Bridge over the Strait of Messina. In the PS of his note (s. here below), he also characterizes the "Comitato Scientifico" (CS) tasked to guide the design process, , of being "*unbalanced and inattentive to issues of fatigue and fretting fatigue*", and so implicitly questioning the competence of all involved engineering professionals within the CS, Stretto di Messina s.p.a., the international design consortium and the various project control and supervision entities:

"*Dear Colleagues,*
please find a preprint about a serious problem. The biggest bridge in the world, announced in Italy recently, for a cost of 20 Billion Euros, has not been designed against fretting fatigue in the cables.

https://www.researchgate.net/publication/394886635

If you have comments or questions, please let me know.
Mike
Michele Ciavarella
Politecnico di Bari"

Such remarks deserve a response — not only because they unfairly diminish the standing of colleagues who have worked for years on the safe design of this project, but also because they rest on a severe misunderstanding of the cable system at stake.

The main cables of large suspension bridges are built and are loaded in a very specific way. They consist of tens of thousands of parallelly aligned, high-strength steel wires, each individually galvanized, which are "airspun" in place from individual wires or using prefabricated bundles of groups of parallel wires, so-called "Prefabricated Parallel Wire Strands" (PPWS), as used in the Messina project. The final assembly of many thousands of parallel wires are then compacted into a dense, sealed bundle. These cables then support the entire influence surface of the bridge deck, so their stress state is dominated by permanent load, with only very small variations of the stress state due to traffic or wind. In other words, they are essentially static elements subjected to very low cyclic stress ranges – a fact which is true for any large span suspension bridge, but is even more obvious in the Messina Strait's Bridge, for which the permanent loads due to the cable weight itself overshadows all other loads!

It is thus entirely unsurprising that, in more than fifty years of experience with very large suspension bridges of comparable scale and constructive typology — from Humber, Great Belt, Akashi Kaikyo and Çanakkale — fretting fatigue has never been observed as a service problem in main cables. The governing deterioration mechanism is corrosion and it is against corrosion that international practice has developed protective and dehumidification systems, which of course were considered and will be applied in the Messina Bridge.

In many mechanical cable applications such as ropes for cranes, lifts, or mining equipment, fretting fatigue is, of course, indeed a significant concern and thus a design criterion: those cables are made of helically wound strands designed to flex repeatedly over pulleys and are loaded almost entirely by variable, cyclic forces. Indeed, one can presume that this is the field where Prof. Ciavarella's expertise on fretting fatigue finds most applications.
In bridges, a somewhat comparable issue may also arise for some specific types of mid-sized cables — namely the stay cables of cable-stayed bridges when they pass over (small-radius) saddles. Such cables are typically composed of helicoidal (mostly 7-wire) strands or other prestressing steel systems bundled in a sheath. Unlike what is the case for suspension bridge main cables, each stay cable carries only a fraction of the deck; therefore, its load fluctuates significantly with the passage of individual vehicles or groups of vehicles. Their specific geometry and loading condition, when passing over saddles, may produce more significant bending and microslip , . For this reason, fatigue and fretting fatigue are design concerns for stay cables passing over saddles, and the fib Bulletins — fib Bulletin 30: "Acceptance of Stay Cable Systems using Prestressing Steels" and its successor Bulletin 89 — quite properly require full-scale fatigue testing for these cases. But those provisions do not apply to the main cables of suspension bridges, which – as was explained - are a completely different structural system. For the latter, when made of PPWS, the relevant production and acceptance standard is ISO 19427, which reflects decades of international experience in explicitly stating that fatigue testing of PPWS is not required in suspension applications, precisely because the loading is dominated by dead load and the compacted parallel geometry prevents microslip.

The history of the Bridge over the Strait of Messina project itself reflects this distinction. In 2011, a non-conventional configuration with spliced saddles and individual bending grooves for a smaller number of wires was envisaged, and — prudently, but only by analogy with stay cables — the then Comitato Scientifico recommended additional tests on a small assembly of wires passing over a replica of what was then the design of the saddles. In the 2023 revision of the project, that configuration of the saddle was abandoned in favour of conventional single-groove saddles, of the same type and overall sizing successfully adopted in Akashi, Great Belt, and Çanakkale. With the updated, conventional and proven geometry, the prudential analogy with stay cables passing over saddles clearly no longer applies, and the specific risk that motivated the earlier recommendation is absent. In any case, the governing issue for the main cables' long-term durability and structural integrity remains corrosion, not fatigue and not fretting. This fact — that fatigue is in no way governing for main cables of large-scale suspension bridges, and that fretting is not a critical aspect thanks to the way such cables are constructed — is self-evident to qualified and experienced structural and bridge engineers. While we agree with Prof. Ciavarella that a major infrastructure like the Bridge over the Strait of Messina requires the involvement of specialists from many disciplines, it is precisely because an overview of what is and is not important is needed that bridge and structural engineers must play the key role. Too narrow a focus on a single scientific field can obscure the correct perspective on a certain problem's relevance — something that us academics must always strive to avoid but which, unfortunately, seems to have happened here in Prof. Ciavarella's note.

All this said, this does however in no way mean that fatigue is treated lightly or – as Prof. Ciavarella appears to suggest – would even have been neglected in the design of the Bridge over the Strait of Messina. On the contrary, it is a central theme across the design of the entire structure: from qualification tests on all relevant categories of welded details and joints in the

orthotropic deck, to product acceptance tests for hangers, fatigue is comprehensively addressed wherever it is relevant. But for the main suspension cables international experience and standards are unequivocal: corrosion governs longevity, not fatigue and not fretting. To suggest otherwise, or to portray the involved professionals as inattentive to fatigue, is misleading and unfair. To underscore this even further, qualification fatigue tests on the wires of the main cables have already been carried out in the past, and the current Comitato Scientifico has explicitly recommended that such tests on the wires (Italian: fili, non cavi!) be updated, for the case that the designer decided to adopt more advanced high-strength steels for the main cable's wires— materials that have become available since 2011 and have already been used, for example, in the Çanakkale Bridge.

Last but not least, we wish to draw the attention of the Reader on two examples of reckless and non-documented statements contained in Ciavarella's Note that are not supported by technical evidence and therefore risk being misleading:

> "Practical guidelines such as ESDU 90031 recommend drastic reductions in allowable cyclic stresses: by a factor of 4 at low slip, up to 10 at high slip. This is an order of magnitude higher than the classic safety factor of 1.35 used in Eurocode static checks. The implication is clear: under such hyperconservative assumptions, the Bridge could not be built at all."

> "Some will argue (perhaps colleagues in structural or bridge engineering) that only they are competent in bridge construction, and that specialists from other fields are not. A serious mistake of the past! The bridge ... is a system requiring broad expertise — civil, mechanical, aeronautical, materials, and electronic engineering. The current Scientific Committee is unbalanced, with little or no attention to the enormous issue of fatigue and fretting fatigue."

Rather than entering into detailed commentary and rebuttals on these sentences, we limit ourselves to recommending that the Author consult much more carefully the extensive project documentation, analyses, and experimental results carried out by hundreds of professionals over decades of work. We also invite him to inform himself about the broad range of expertise represented among the members of the design team (Stretto di Messina S.p.A., EUROLINK–WEBUILD S.p.A., COWI A/S in Lyngby, ED.IN. srl in Rome, and various more), SdM's Expert Panel, the Project Management Consultant, Parsons Corporation, the various validation and certification agencies, e.g. RINA s.p.a., and finally the Comitato Scientifico (https://strettodimessina.it/web/comitato-scientifico/).

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