Toward Framework Development for Design and Maintenance Planning of Seismic Isolators/Dampers Subject to Wind-induced Fatigue

○Kazuyoshi NISHIJIMA, Daiki SATO

1. Introduction

Seismically isolated buildings render displacement and energy absorption limited to a seismic isolation layer. It has the advantage, among others, that dampers can be replaced or repaired easily if necessary. Isolators that carry building masses are less easy to replace yet possible.

Current design practice for seismically isolated buildings follows the principle that wind action effects on isolators and dampers should not exceed their elasticity limits. This is mainly due to the fact that extreme wind in a storm can sustain relatively long compared to seismic actions and the fatigue behaviors of isolators and dampers in the plastic domain are not well understood.

Since the principle in the current design practice tends to result in higher yield resistances of isolators and dampers, it does not fully exploit their seismic performances. Thus, an alternative principle, which allows the plasticization of isolators and dampers under wind actions, may lead to a more rational design of seismically isolated buildings.

2. Aim of the study

In general, two approaches are available for design and maintenance of structures, see Fig. 1. Namely,

(1) approach where sufficient safety margin is secured at the construction, assuming no maintenance work during the service life.

(2) approach where design is made taking into accout appropriate repair and/or replacement during the service life.

Whereas the second approach may lead to a more efficient life cycle management of seismically isolated buildings, the knowledge and models therewith required for this approach are currently not available. To precise, these are:

(a) Determination of wind actions to consider in design for wind-induce fatigue.

(b) Modeling of the probability of detection of fatigues with certain inspection measures.

(c) Modeling of the physical fatigue development.

The aim of this study is to propose a rational framework for the design and maintenance for isolators and dampers. The proposed framework is illustrated with an example, whereby probabilistic models for (b) and (c) that will be required to make the proposed framework operational are presented. Note that the determination of the wind actions, i.e. (a), requires consideration not only of the maximum wind speed but also of the duration of strong wind, which is investigated in Nishijima (2015).

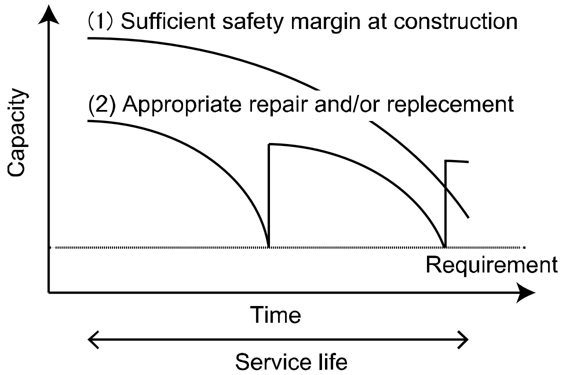

Fig.1 Two principal strategy for design and maintenance of seismic isolators and dampers subject to wind-induce fatigue.

3. Framework for design and maintenance planning

A number of frameworks for the design and maintenance have been developed for different types of infrastructure, e.g. see Straub and Faber (2004) and Moan (2005) for offshore structures, and Sorensen (2009) for wind turbines. The proposed framework here takes its basis in those existing works.

Fig. 2 shows a generic procedure for reliability-based inspection planning (see. e.g. Straub and Faber (2004)). In this procedure, the inspection timing is determined in a way that the calculated annual probability of failure does not exceed the given acceptable probability of failure. The design is then optimized considering the developed inspection plan.

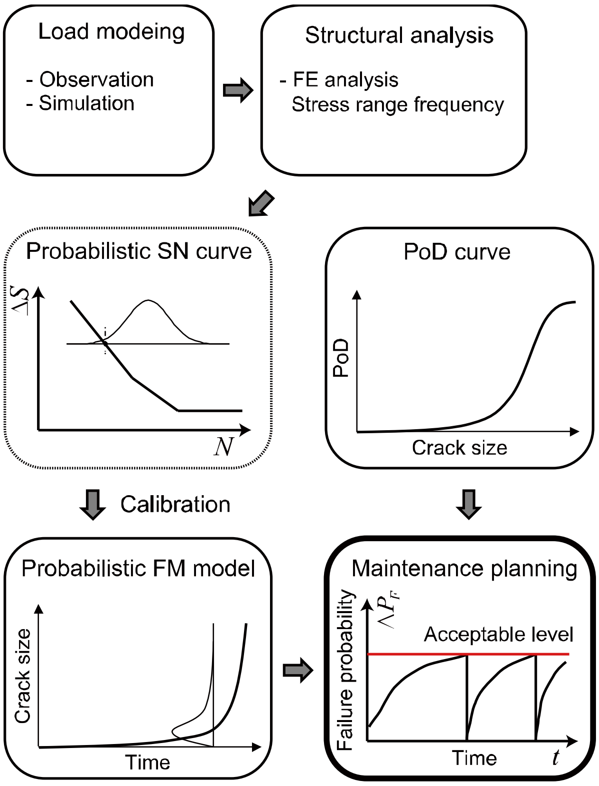

Fig.2. Procedure for maintenance planning.

4. Example

An illustrative example is considered in order to demonstrate how the annual probability of failure can be updated, as a function the calculated damage degree D, based on the inspection outcomes; i.e. damage detected or damage not detected. The detail of the example is found in Nishijima and Sato (2015).

As can be seen in the figure, the updated probability of failure is differentiated according to the inspection outcome – which is made possible to calculate with a postulated PoD (Probability of Detection) curve and a postulated relationship between the damage degree and the damage size.

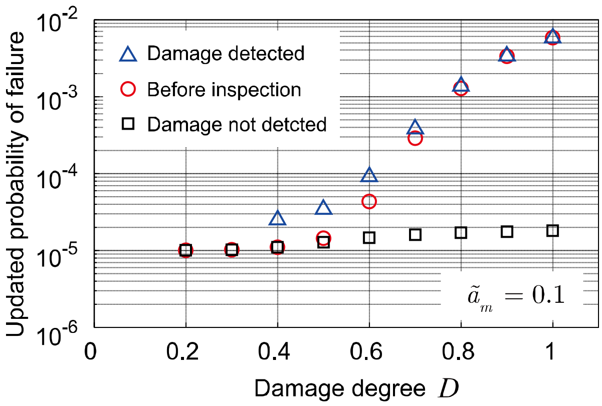

Fig.3. Updated annual probability of failure as a function of calculated damage degree D.

5. Conclusion

A generic procedure for reliability-based inspection planning is introduced. An illustrative example is shown in order to demonstrate that with a PoD curve and the relationship between calculated damage degree and damage size the probability of failure can be updated – by using which the inspection plan can be optimized.

Reference

1) Nishijima, K. (2015). Probabilistic Investigation on Wind Speed Time Series in Typhoon Events for Fatigue Damage Assessment, JCOSSAR 2015, CD-ROM.

2) Straub, D. and Faber, M.H., (2004) System Effects in Generic Risk Based Inspection Planning, Journal of Offshore Mechanics and Arctic Engineering, ASME, 126(3), 265-271.

3) Moan, T., Reliability-based management of inspection, maintenance and repair of offshore structures, Structure and Infrastructure Engineering: Maintenance, Management, Life-Cycle Design and Performance, 1:1, 33-62, DOI: 10.1080/15732470412331289314, 2005.

4) Sorensen, J.D. (2009) Framework for risk-based planning of operation and maintenance for offshore wind turbines, Wind Energy, 12, pp.493-506.

5) Nishijima, K. and Sato, D. (2015) A Preliminary Study for Development of Framework for Design and Maintenance Planning of Seismic Isolators/Dampers Subject to Wind-induced Fatigue, JCOSSAR 2015, CD-ROM.