

# ATC 62: ADVANCED SEISMIC ANALYSIS METHODS

## Task 3: Nonlinear Degrading Response

### Project Description

This project is a part of the FEMA-funded project, “Advanced Seismic Analysis Methods – Resolution of Issues” (ATC-62 Project). The project will result in advanced guidance on three issues that have been previously identified (*FEMA 440*) as particularly important to seismic analysis. Initially, the effort will concentrate on a single issue: *expanding component and global modeling to include nonlinear degrading response*. A summary of current available research on the subject is planned. The effort will include a focused study to develop practical recommendations for improved application.

### Background

*FEMA 440* makes a distinction between two types of degradation of stiffness and strength of inelastic single degree-of-freedom oscillator (Figure 1). This distinction had not previously been addressed explicitly by guidelines for nonlinear static procedures. Independent studies demonstrate that if strength degradation occurs cyclically, dynamic response of single-degree-of-freedom (SDOF) systems is stable. In contrast, in-cycle loss of strength can lead to dynamic instability. In-cycle losses include P-delta effects. *FEMA 440* recommends a minimum strength limitation for an SDOF model of a structure as a function of period and the rate of in-cycle degradation (negative post elastic stiffness). If this limitation is not met, *FEMA 440* recommends nonlinear dynamic analysis be used to investigate the potential for dynamic instability explicitly. Current nonlinear static pushover procedures cannot fully distinguish between cyclic and in-cycle strength degradation. *FEMA 440* includes interim recommendations based on judgment for this purpose.

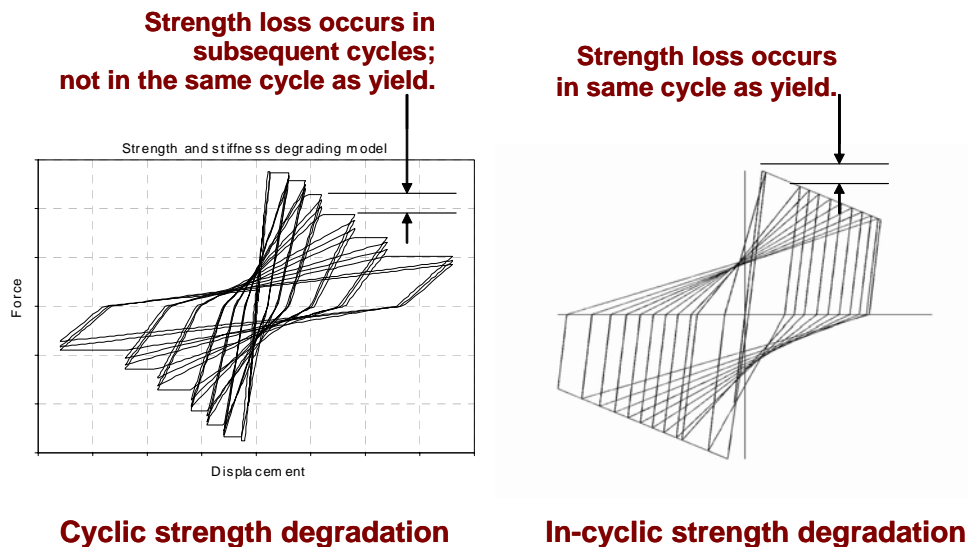


Figure 1: Two Types of Strength Degradation

**Key issues for investigation**

- What current data exists on force-deformation behavior and strength degradation of components subject to large ductility demands in a single cycle of loading?
  - How often (e.g. in how many specimens) in-cycle degradation (excluding P-delta) effects has been observed?
  - Are these effects present in all specimens where one would expect them or only on a small percentage (i.e. Has it not been observed when we might expect it)?
  - At what level of deformation (e.g., IDR) this has been observed (level of interstory drift in which negative stiffness was first observed)
  - What are the levels of negative stiffness that are observed in these tests?
  
- How does in-cycle strength loss in components affect the global dynamic stability of structural models?
  - What is the relationship between lateral deformation in which negative stiffness begins to occur and the ground motion intensity in which lateral instability is observed?
  - What is the relationship between the level of negative stiffness and the ground motion intensity in which lateral instability is observed?
  - What is the effect of the collapse mechanism?
  - How does vertical load carrying capacity interact with in-cycle lateral strength loss?
  
- Can this effect be adequately incorporated into nonlinear static analysis procedures?
  - Can a nonlinear static analysis (i.e., static pushover analysis NSP) capture the possible dynamic load deformation characteristic of a structure?
  - Can NSP combined with dynamic SDOF analyses provide some useful information or is this unreliable?
  - Can NSP be used as a way to build simplified models to be used in response history analyses (e.g., fishbone type models?)
  
- What practical guidance can be provided for the incorporation of in-cycle degradation into nonlinear response history analysis procedures?
  - Is it possible to establish parameters to be used in existing hysteretic models (capping deformation, capping slope, etc) to use in static analyses?
  - Is it possible to reliably establish parameters to be used in existing hysteretic models (deformation at which negative stiffness is expected to occur, magnitude of this negative stiffness, etc) to use in static analyses?
  - How should uncertainty in these parameters be considered in practical situations? (epistemic uncertainty)
  
- How can these effects be incorporated into simplified models?
  - Would fishbone models in combination with simplified models that include in-cycle strength degradation capture the response of structures?
  - What software currently available to practitioners can be used for this purpose?

## **Major subtasks**

### ***Subtask 3.1: Review Research***

The Degrading Response Working Group will solicit initial input from researchers on pertinent information related to the initial questions outlined above. This effort will begin by providing an opportunity for researchers to input information on their research results using the ATC web site. Follow-up interviews and discussions will be held with individuals with particularly applicable experience or qualifications. A literature search also will be conducted by the Working Group. The target emphasis will be on analytical studies and empirical tests relating to degradation of stiffness and strength of structural components and systems.

### ***Subtask 3.2: Conduct Focused Study***

Based upon the results of Subtasks 3.1, the Project Management Committee will conduct focused studies to address the key questions and ultimately to provide the basis for practical recommendations. The objective of these studies will be to bring the maximum amount of pre-existing or emerging information to bear upon the practical questions posed by the key issue. For example, it may be that studies by researchers at the NSF-funded Earthquake Engineering Research Centers (EERCs), participants in the NSF-funded Network for Earthquake Engineering Simulation, or others, are generating information that could be incorporated into practical advice with a relatively small amount of additional effort. Significant cooperative effort with other projects and programs is anticipated.

### ***Subtask 3.3: Prepare Response Degradation Draft Issue Report***

Based on information from the problem-focused studies (Subtask 3.2) and on guidance from the Project Management Committee, the Strength Degradation Working Group will generate a draft Issue Report. This document will summarize all of the work that was completed and culminate with recommendations for practice. Detailed information will be appended. Based on subsequent input received from the Project Review Panel and the FEMA Project Officer, the Working Group, in consultation with the Project Management Committee, will revise the draft Issue Report, as necessary, in preparation for issuance to participants in a future Issue Workshop.

## **Project personnel**

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## **Project schedule**

The draft issue report is anticipated in the Spring of 2006.