SEAONC Rating System for the Expected Earthquake Performance of Buildings

SEAONC Existing Buildings Committee
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Abstract

There is an unmet need for information and terminology that non-engineer stakeholders can use to compare the seismic performance of different buildings and to make facility-related decisions. This paper presents a ratings system under development by the Structural Engineers Association of Northern California (SEAONC) Existing Buildings Committee (Building Ratings Subcommittee) intended to communicate information about seismic risk of buildings to the general public. It utilizes existing evaluation methodologies, and translates their results into a format that is easily understood. Included are the findings from an ATC workshop held in March 2011, which gathered input from potential rating system users, including owners and individuals from the real estate and insurance industries. Also included is an outline of the rating system as it relates to the standard known as ASCE 31-03.

Introduction

In 2006, responding to a request from the Board of SEAONC, the Existing Buildings Committee formed a subcommittee to study the feasibility of, and develop an Earthquake Performance Rating System (EPRS). The feasibility and early development have been described elsewhere (SEAONC, 2008; 2009). This paper presents more details of Phase 2, the development phase, including findings from an ATC stakeholder workshop held in March 2011 (ATC, 2011).

The SEAONC EPRS uses a scale of 1 to 5 stars and separately considers three dimensions: Safety, Repair Cost, and Time to Regain Function. Importantly, it does not conflate these dimensions, as most existing seismic performance rating systems do. The rating is meant to be sufficiently simple to convey earthquake performance of buildings to a non-technical audience, but contain enough information for the user to meaningfully compare performance among buildings. The rating system is not a new evaluation methodology; rather, it specifies a procedure by which outputs from existing evaluation standards (e.g., ASCE 31) can be mapped to a rating value. The process by which a rating is assigned is intended to be transparent to the user and adaptable to multiple evaluation methodologies.

Objective of a Rating System

The objective of a system that rates the earthquake performance of buildings is to *communicate seismic risk to non-engineers*. The ultimate goal is for the rating system to spur action that will reduce seismic risk in the overall building inventory.

The audience for the rating system includes anyone who makes decisions about buildings, regardless of their earthquake or engineering expertise. This includes occupants, buyers, sellers, and tenants of a building, as well as insurers and lenders.

The EPRS is a set of definitions, rules, and procedures that leads to a concise characterization of earthquake performance of existing buildings. Standards such as Rapid Visual Screening of Buildings for Potential Seismic Hazards (FEMA 154, 2002) and Seismic Evaluation of Existing Buildings (ASCE 31 2003) are specifically intended for use by engineers, and each employs its own terminology and assumptions. An EPRS would be valuable for conveying information about safety, damage, and recovery in a way that addresses both new and existing buildings in consistent terms and more directly addresses stakeholder questions, which typically seek to contrast one building with another.

An existing EPRS that partially addresses the above is provided by the Probable Maximum Loss (PML) industry. However, the problems experienced in this industry have strongly motivated our committee to develop the SEAONC EPRS.

Applicability of the Rating System

The SEAONC EPRS should address all building types and occupancies, including single family residences. The committee considered excluding single family residences, mainly because the structures are largely non-engineered. However, specifically because single-family residences constitute such a large proportion of existing buildings and because the stakeholders are often non-experts, excluding them would miss a huge portion of our potential market. Influential input on this topic was obtained in the ATC 71-2 Workshop.

Obtaining a rating should be voluntary. However, we see greatest value in a system that meshes with economic decisions. Thus, we envision that one context for use would be a real estate acquisition (sale, lease, etc.), where a building rating would be one of many standard disclosures.

Context of a Rating System: the Rating Program

An EPRS will be feasible and valuable only if it is designed for the context in which it will be used. Development of the SEAONC EPRS has assumed a context in which ratings are produced voluntarily by the parties to a transaction and are not necessarily made public (SEAONC EBC, 2008; 2009).

Successful risk reduction programs are multidisciplinary, and SEAONC recognizes that its expertise is in structural engineering, not law or economics. The biggest challenges to earthquake risk reduction are not in engineering, but in finance, policy, and regulation (ATC, 2008). Therefore, the most effective rating system would be one that:

- fills existing knowledge gaps;
- leverages the interests of motivated stakeholders;
- does not mandate implementation without the needed resources;
- and involves minimal logistical costs to implement and regulate.

The ATC 71-2 Workshop with potential users of the system provided important and influential feedback regarding features of the development-phase EPRS.

ATC 71-2 Workshop

In March 2011, the subcommittee collaborated with ATC to hold a workshop to gather feedback from building owners, investors, and policy-makers regarding the utility of an EPRS (ATC, 2011). The workshop used electronic polling and a large group discussion to obtain input from potential users regarding the scope and structure of the ratings system.

As a result of the workshop, the subcommittee was able to make substantive decisions regarding the EPRS. The results from the participant input are summarized in the eight areas identified below.

Rating Dimensions. The consensus of the participants was that the rating system should include multiple dimensions (safety, repair cost, and time to regain function) that could be combined into a single rating for presentation. Preserving the individual dimensions will allow stakeholders to assess seismic performance based on their individual priorities.

Hazard Level. The consensus of the participants was that the same method that current codes use to measure seismic hazard for a new building should be used in determining the minimum requirement for safety in the rating system. Additionally, shorter earthquake return periods may be appropriate for the repair cost and downtime dimensions.

Rating Symbols. SEAONC sought to find a scoring system that could communicate the detailed dimensions of building performance in a simple and effective way. The workshop attendees preferred a symbolic system to a complicated point scale, strongly favoring either stars or qualitative descriptors like the LEED scale. An advantage of a simple system is that it avoids the misperception of undue precision.

Qualifications / Quality Control. The consensus of the workshop attendees was that a certified and *licensed* engineer should produce ratings for commercial buildings and a certified *credentialed* individual may produce ratings for residential buildings. The group also strongly favored the establishment of an independent organization to oversee the rating process and provide peer review in order to maintain long-term credibility of the system.

Absolute vs. Relative Ratings. The workshop attendees agreed that the rating system ought to predict or estimate performance on an absolute scale, as opposed to rating buildings relative to a standard such as a new code-designed building. Absolute ratings, because they are predictive and quantitative, might prove harder to generate than relative ratings, but the consensus of potential users was that absolute ratings will better support their decision-making.

Cost of a Rating. The workshop participants agreed that the cost of generating a rating will be key to its demand. Ratings provided by licensed engineers using thorough building analyses are likely to cost significantly more than the simple PML studies performed today by most private rating programs.

Although the cost of generating a rating and thus the demand for ratings is one of the later issues to address, the agreement during the discussion was that a rating should not be too expensive to obtain, particularly for single family residences and small commercial buildings, or else those structure types will not use ratings. Additionally, as each building is different, the market should decide the cost of using the system.

Mandatory vs. Voluntary. A key issue is whether the SEAONC rating system should be developed for a mandatory or a voluntary rating program. A mandatory program will require more detail and precision, whereas a voluntary program can be more flexible in its early phases of application. A mandatory rating system will more quickly "lift all boats" to improve seismic resilience, but is considerably harder to implement and adopt. A voluntary rating system will be slow to gain widespread adoption if it is not perceived as valuable. In our work so far, we have designed the SEAONC rating system for use in voluntary programs (SEAONC EBC, 2008; 2009).

The consensus from the workshop discussion groups was that the rating system should begin as voluntary. As its popularity grows, the system may be adopted by jurisdictions or companies as an industry standard, similar to the LEED system. However, we understand that a system designed for voluntary use might need to be altered or extended in order to support a mandatory program.

EPRS Development

The development phase involves two main steps: defining each rating value, and establishing a procedure by which to derive the rating value from outputs of various building evaluation standards. The initial focus has been on mapping a rating to the results of an ASCE 31 evaluation, which would include evaluations of a building's structural and non-structural elements, and evaluations of geologic hazards based on the building's location.

The subcommittee elected to initially design the ratings system for use in California. However, it is expected to be applicable in other areas of high and moderate seismicity.

Content of a Rating

The subcommittee developed an EPRS to provide comparative information on the seismic risk posed by a building. The system uses a scale of 1 to 5 stars, in each of three dimensions: Safety (deaths, injuries and entrapment), Repair Cost (dollars), and Time to Regain Function (downtime). Descriptions of each star-value are provided in Table 1. The SEAONC EPRS does not predict precise numerical values for deaths, damage, or downtime. Rather, it assigns a rating category based on definitions and expectations stated by the underlying evaluation methodology.

Definitions and Commentary for Each Rating Value

The definitions provided in Table 1 are meant to define distinctly different limit states for each star rating. The ratings are quantitative to the degree that the underlying methodology allows, and they are predictive in the sense that they try to convey a real world meaning, as opposed to an arbitrary categorization. For rating Safety, this is akin to using performance-based, as opposed to compliance-based terminology. For rating Repair Cost, this means aligning the rating categories with industry-standard decision points. For Time to Regain Function, no strong precedents exist, so useful but approximate categories are defined.

In the Safety dimension, the ability to assign a rating value exceeding 3 stars requires knowledge of factors typically excluded from conventional structural analyses, including falling hazards (structural and nonstructural), and jamming of doors and elevators, since these affect entrapment and egress. Consequently, a conventional structural evaluation is expected to only allow a maximum of a 3-star Safety rating to be achieved. An analysis capable of accurately determining expected building drifts and deformations will thus usually be necessary to achieve more than a 3-star Safety rating.

In the Repair Cost dimension, the thresholds for percentage of replacement value were selected to correspond to typical stakeholder decision points. For example, the 5% threshold between 4 and 5 stars is meant to correspond to the funds typically allocated to a building maintenance budget, which can be liquidated and disbursed immediately. The numerical value for this threshold needs further research. The 10% threshold between 3 and 4 stars is meant to correspond to the low end of an earthquake insurance deductible, and the 20% threshold between 2 and 3 stars is meant to correspond to the maximum losses required when securing financing (in the absence of insurance). Finally, the 50% threshold between 2 stars and 1 appears in historic code provisions, in FEMA feasibility criteria for repair funding, and in addition, may be a conventional threshold for an owner to "walk away."

In the dimension for downtime, the committee debated whether this should correspond to the time it would take a) to re-enter safely for activities such as contents retrieval and repairs, b) before the building is substantially functional, or, c) for full recovery (Bonowitz, 2011). The definitions provided in Table 1 correspond to the middle of these three options, termed Time to Regain Function, which the committee agreed was the most broadly useful metric. For instance, substantial functionality of an engineering office would require electricity but would not generally be impeded by damages to building finishes. The definition excludes externalities that may affect a building's functionality, such as performance of the electrical grid serving the building.

Rating	Safety
★★★★★	Building performance would not lead to conditions commonly associated with earthquake-related *entrapment.*
★★★★	Building performance would not lead to conditions commonly associated with earthquake-related *injuries*.
★★★	Building performance would not lead to conditions commonly associated with earthquake-related *death.*
★★	Building performance in select locations within or adjacent to the building leads to conditions known to be associated with earthquake-related *death.*
★	Performance of the building as a whole leads to conditions known to be associated with earthquake-related *death.*

Rating	Repair Cost
★★★★★	Building performance would lead to conditions requiring earthquake-related repairs commonly costing less than 5% of building replacement value.
★★★★	Building performance would lead to conditions requiring earthquake-related repairs commonly costing less than 10% of building replacement value.
★★★	Building performance would lead to conditions requiring earthquake-related repairs commonly costing less than 20% of building replacement value.
★★	Building performance would lead to conditions requiring earthquake-related repairs commonly costing less than 50% of building replacement value.
★	Building performance would lead to conditions requiring earthquake-related repairs costing more than 50% of building replacement value.

Rating	Time to Regain Function
★★★★★	Building performance would support the building's basic intended functions within *hours* following the earthquake.
★★★★	Building performance would support the building's basic intended functions within *days* following the earthquake.
★★★	Building performance would support the building's basic intended functions within *weeks* following the earthquake.
★★	Building performance would support the building's basic intended functions within *months* following the earthquake.
★	Building performance would support the building's basic intended functions within *years* following the earthquake.

Table 1: SEAONC Definitions for Star Rating Values for Each of Three Dimensions

These definitions exclude performance of typical contents (furniture, office equipment, etc.), since their value and vulnerability may vary widely with the particular occupancy of the building.

Rating Determination

As previously noted, the SEAONC EPRS is not an evaluation tool. Rather, it is a translation of separate evaluation results into consistent and pragmatic terms. The task of our subcommittee is to develop the rules by which a given methodology's outputs can be translated consistently into the defined rating categories. Importantly, the SEAONC EPRS does not introduce new evaluation criteria. It relies, by intention, on the criteria of the underlying methodology. The rating system reflects the limits of the underlying evaluation but cannot control its quality. Nevertheless, the process by which a rating is derived from evaluation results must be transparent and well enough defined to provide consistent, reproducible ratings.

Currently, the rating system provides a procedure for producing a rating from the outputs of an existing evaluation standard, ASCE 31-03. Tables 2 through 4 provide mapping from ASCE 31 levels of performance, obtained from the ASCE 31 structural, nonstructural and geotechnical evaluation statements, to the ratings.

ASCE 31 Evaluation

Ratings for Safety, Repair Cost and Time to Regain Function can be derived from a new or pre-existing ASCE 31 evaluation. Any of ASCE 31's tiered procedures may be used. (ASCE 31 is a tiered methodology based on sets of evaluation statements. This paper presumes a basic understanding of ASCE 31.) Ratings derived from ASCE 31 findings are independent of whether those findings came from a Tier 1, Tier 2, or Tier 3 evaluation. That is, to the extent that ASCE 31 findings might change as more analysis is performed, so might the rating derived from those findings

Tables 2, 3, and 4 display the subcommittee's mapping of ASCE 31 Performance Levels to the dimensions of Safety, Repair Cost, and Time to Regain Function respectively. Note that Table 2 has entries indicating "Life Safety Selection". This indicates that only certain Life Safety evaluation statements need be satisfied to merit the rating in question. These select evaluation statements represent the committee's judgment in interpreting the stated intentions of ASCE 31 as needed to fit the generic rating definitions, which accommodate any evaluation methodology.

Non-structural elements compliant with ASCE 31's Tier 1 Life Safety statements are mapped as 3 stars for the Safety and Time to Regain Function dimensions; however, for the Repair Cost dimension, compliance with IO (determined with a Tier 2 evaluation) is required for 3 stars. The committee felt that the mapping to Repair Cost should be conservative, because ASCE 31 is primarily a tool to assess life safety and not damageability.

The subcommittee also determined that the most effective approach to mapping the ASCE 31 evaluation statements to the individual ratings is to consider the damage and performance they generally suggest, not an extreme or worst-case performance they could represent. It is the duty of the engineer or qualified person generating the individual ratings to understand the interaction of various non-compliant evaluation items and resolve them into a rating based on the description of each rating.

To the extent that a building can be "deemed to comply with ASCE 31 by virtue of design to certain past building codes, ratings can also be based on benchmarking. Table 5 indicates the applicable model building code for various building types. Note, however, that because ASCE 31 benchmarking only applies to structural performance at the Life Safety performance level, benchmarking can only achieve ratings associated with those constraints (as shown in Table 1).

Though not shown in Table 5, ASCE 31-03 also allows benchmarking for IO-level performance based on OSHPD requirements from the California Building Code. In concept, buildings whose nonstructural components were designed to the 1995 OSHPD amendments and reviewed and inspected by OSHPD may be considered to satisfy the nonstructural safety and functional recovery requirements for a 4 star rating. However, because this would introduce new evaluation criteria not intended by ASCE 31 itself, this idea might be outside the limits we have set for the EPRS. We expect more questions like this to arise as we develop translation rules for other evaluation methodologies.

Structural Performance[2]	Nonstructural Performance	Geotechnical Performance[3]	Safety Rating Definition	Rating
Rating Not Achievable	IO selection	IO	**No entrapment.** Building performance would not lead to conditions commonly associated with earthquake-related *entrapment.*	★★★★★
IO	LS	LS[4]	**No injuries.** Building performance would not lead to conditions commonly associated with earthquake-related *injuries.*	★★★★
LS	LS selection S3	LS[4]	**No death.** Building performance would not lead to conditions commonly associated with earthquake-related *death.*	★★★
LS selection S2	LS selection S2	LS selection S2	**Death in isolated locations.** Building performance in select locations within or adjacent to the building leads to conditions known to be associated with earthquake-related *death.*	★★
Less than LS selection S2			**Death in multiple or widespread locations.** Performance of the building as a whole leads to conditions known to be associated with earthquake-related *death.*	★

[1] Structural, Nonstructural, and Geotechnical levels of performance must be satisfied to achieve rating. "Selection" indicates that some of the ASCE 31 criteria need not be met; the selection will be defined in the SEAONC rating instructions. Selection "S3," for example, indicates the particular selection of ASCE 31 issues required for a 3-star safety rating.

[2] Includes performance of foundations

[3] Refers to items from the Geologic Site Hazards Checklist (i.e. liquefaction, slope failure, and surface fault rupture)

[4] Need not comply with liquefaction evaluation statement

Table 2: Mapping of ASCE 31-03 Performance to SEAONC Safety Rating for Areas of High Seismicity[1]

Structural Performance[2]	Nonstructural Performance	Geotechnical Performance[3]	Repair Cost Rating Definition	Rating
Rating Not Achievable			**Within Typical Operating Budget.** Building performance would lead to conditions requiring earthquake-related repairs commonly costing less than 5% of building replacement value.	★★★★★
Rating Not Achievable	IO	Rating Not Achievable	**Within Typical Insurance Deductible.** Building performance would lead to conditions requiring earthquake-related repairs commonly costing less than 10% of building replacement value.	★★★★
IO	IO	IO	**Within Industry SEL limit.** Building performance would lead to conditions requiring earthquake-related repairs commonly costing less than 20% of building replacement value.	★★★
LS	LS	LS	**Repairable Damage.** Building performance would lead to conditions requiring earthquake-related repairs commonly costing less than 50% of building replacement value.	★★
Less than LS			**Substantial Damage.** Building performance would lead to conditions requiring earthquake-related repairs costing more than 50% of building replacement value.	★

[1] Structural, Nonstructural, and Geotechnical levels of performance must be satisfied to achieve rating.

[2] Includes performance of foundations

[3] Refers to items from the Geologic Site Hazards Checklist (i.e. liquefaction, slope failure, and surface fault rupture)

Table 3: Mapping of ASCE 31-03 Performance to SEAONC Repair Cost Rating for Areas of High Seismicity[1]

Structural Performance[2]	Nonstructural Performance	Geotechnical Performance[3]	Time to Regain Function Rating Definition	Rating
Rating Not Achievable			**Within Hours.** Building performance would support the building's basic intended functions within *hours* following the earthquake.	★★★★★
IO	IO selection F4	IO	**Within Days.** Building performance would support the building's basic intended functions within *days* following the earthquake.	★★★★
IO selection F3	IO selection F3	LS	**Within Weeks.** Building performance would support the building's basic intended functions within *weeks* following the earthquake.	★★★
LS selection F2	LS	LS	**Within Months.** Building performance would support the building's basic intended functions within *months* following the earthquake.	★★
Less than LS selection F2	Less than LS	Less than LS	**Within Years.** Building performance would support the building's basic intended functions within *years* following the earthquake.	★

[1] Structural, Nonstructural, and Geotechnical levels of performance must be satisfied to achieve rating. "Selection" indicates that some of the ASCE 31 criteria need not be met; the selection will be defined in the SEAONC rating instructions. Selection "F3," for example, indicates the particular selection of ASCE 31 issues required for a 3-star functionality rating.

[2] Includes performance of foundations

[3] Refers to items from the Geologic Site Hazards Checklist (i.e. liquefaction, slope failure, and surface fault rupture)

Table 4: Mapping of ASCE 31-03 Performance SEAONC Time to Regain Function Rating for Areas of High Seismicity[1]

Benchmark Buildings Structural Safety Ratings				
	Model Building Seismic Design Provisions[5]			
Building Type[1, 2]	UBC 1976	UBC 1994	UBC 1997	IBC 2000
Wood Frame, Wood Shear Panels (Type W1 & W2)	★★★	★★★	★★★	★★★
Wood Frame, Wood Shear Panels (Type W1A)	—	—	★★★	★★★
Steel Moment-Resisting Frame (Type S1 & S1A)	—	—	★★★	★★★
Steel Braced Frame (Type S2 & S2A)	—	—	★★★	★★★
Light Metal Frame (Type S3)	—	—	★★★[4]	★★★
Steel Frame w/ Concrete Shear Walls (Type S4)	—	★★★	★★★	★★★
Reinforced Concrete Moment-Resisting Frame (Type C1)[3]	—	★★★	★★★	★★★
Reinforced Concrete Shear Walls (Type C2 & C2A)	—	★★★	★★★	★★★
Tilt-up Concrete (Type PC1 & PC1A)	—	—	★★★	★★★
Precast Concrete Frame (Type PC2 & PC2A)	—	—	★★★	★★★
Reinforced Masonry (Type RM1)	—	—	★★★	★★★
Reinforced Masonry (Type RM2)	—	★★★	★★★	★★★

[1] "Building Type" refers to one of the Common Building Types defined in ASCE-31 Table 2-2.

[2] Buildings on hillside sites shall not be considered Benchmark Buildings.

[3] Flat slab concrete moment frames shall not be considered Benchmark Buildings.

[4] Differs with ASCE 31 Benchmark Table based on superior seismic performance of these structures when not damaged by falling contents

[5] Adopting jurisdiction must have enforced code and provided construction inspection

Table 5: ASCE 31-03 Star Ratings[1]

Rating Validation

The committee realizes the critical importance of maintaining a high level of technical credibility within the rating system to improve its use among all stakeholders. The committee envisions that independent non-profit organizations would be established by others to provide peer review and technical consistency in the use of the rating system. For example, an organization may choose to adopt the SEAONC rating system as the technical basis for its own categorization of building performance, similar to the LEED system adopted by the US Green Buildings Council. That organization would then accredit engineers who wish to market and use its application of the SEAONC system and provide peer review of the engineer generated ratings.

SEAONC itself would not participate in the reviews or in the accreditation. However, it may choose to review an application developed by a non-profit to ensure that it is applying the SEAONC rating system properly. In this way SEAONC assures that an independent organization does not inappropriately claim to be using the SEAONC rating system if it does not adhere to the evaluation process established by the committee. As part of a future effort, the committee may also establish accreditation requirements for engineers and may develop minimum peer review standards.

Implementation Issues

There are many ways for the proposed SEAONC EPRS to be implemented. One is for it to be adopted by an organization (other than SEAONC) that is able to address many of the issues that are beyond the capabilities of the SEAONC Committee. This would be a somewhat similar path to the private sector endeavor of the US Green Building Council setting up the LEED Rating system for sustainable design of buildings. The implementation effort will take time. The environmental and energy efficiency rating system LEED is only now hitting its stride after 13 years of use.

The implementation phase will face the challenge that most property owners do not want a seismic rating and definitely do not want to pay for it. However the market forces outlined in Table 5 will drive demand, depending on the range of building quality being reviewed as the implementation process begins. From the start, the subcommittee has envisioned a rating system that will be adopted first by building owners, or "sellers," who would benefit from it, and only later by "buyers" who request ratings in order to make comparisons between buildings.

Top End Ratings	**Developers:** Owners of new buildings will want a rating for marketing purposes. They just spent millions to meet current seismic standards and they are leasing against older buildings that do not measure up. **Major Tenants:** Major tenants want information on down-time as well as risks to life and contents. **Governments and Institutions:** If ratings gain acceptance in the private sector, the public sector will follow suit to reassure the electorate that funds are being well spent and that new buildings are safe.
Mid Range Ratings	**Lenders and Tenants:** Lenders and tenants will welcome this information as they make go/no go decisions: Do I lend on or lease in this building or not?
Low End Ratings	**Cities and States:** Governing bodies could mandate ratings be obtained and disclosed for known classes of vulnerable or dangerous buildings. (A rating system designed for voluntary private use might need to be modified for application in these mandatory public contexts.)

Table 6: Demand for Seismic Ratings

Rating programs that are funded by those being rated are subject to forces that can lead to real and/or perceived corruption and manipulation. Abuses crop up in most buyer-pay rating systems, for example collateralized bond ratings (Moody's, S&P, and Fitch), and the current PML system for seismic vulnerability. Sarbanes–Oxley has pushed the accounting industry to meet this credibility challenge by having "an audit of the audits process." A similar review process will be necessary for the ongoing credibility of a seismic rating program.

Conclusion

A methodology to obtain earthquake performance ratings utilizing ASCE 31 has been completed. A near term future committee product will be the publication of the select evaluation statements necessary for particular ratings plus application examples. Longer term efforts are likely to include the mapping of other existing evaluation standards to ratings.

Important progress has also been made regarding future implementation, including incorporation of feedback from expected users into the rating system.

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