Seismic Qualification Test Protocols, Standards and Methodology

Chris Stone, TRaC Global Limited
TRaC Global Limited

Environmental Testing
Seismic Qualification
Finite Element Analysis
EMC Testing
Telecoms & Radio Testing
CE Marking
Safety Testing
ATEX / DSEAR

www.tracglobal.com
Who Needs Seismic Qualification?

**Nuclear Industry:**
Power stations, Processing Plants and Submarine bases

**Telecoms Industry:**
Equipment (cabinets and contents) 99999s Requirement for installation in Europe / USA / Japan / Taiwan etc.

**Oil, Gas and Power Generation Industries**
Control and Containment

**Engineering Consultancies:**
Validation of FE analysis e.g. non-linear dynamic contact elements

**Engineering Contractors:**
Testing of new materials / construction techniques
Seismic Qualification

Seismic Testing
- Functionality,
- Physical Limits

Modelling
- FEA

Experience

www.tracglobal.com
Where to Start?
Preparation and Planning

Work through the Seismic Test Process detailing each stage – testing is not cheap and needs to be right first time!

Seek input from Design Authority (End Customer), Commercial Depts, Design/Development, Test House and Relevant Quality Depts

Outcome – Detailed Test Plan
Typical Qualification Process

- Preliminary meetings to agree test specification including
  - Equipment requirements
  - Main test spectra
  - Number and amplitude of shakes
  - Exploratory test requirements
  - Details of function testing

- Preparation of test documentation – Detailed Test Plan, Inspection Plan, Functional Test Plan

- Generate shakes ready for testing
- Arrival of specimen, examination for transport damage
- Mount specimen on shaking table
- Install instrumentation
- *Functional tests*
- Exploratory tests
- *Functional tests*
- Main seismic tests including basic data processing
- *Functional tests*
- Remove specimen from shaking table and return to client
- Final data processing and produce test report
Test Specifications

IEEE 344 – IEEE Recommended Practice for the Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations

BELCORE – NEBS
   Telcordia North America and Generic Requirements
   GR-63-CORE Issue 2, April 2002
   European Telecom ETSI EN 300 019-2-3 V2.2.2

IEC 60068-2-57
   International Test Standard Environmental testing –

IEEE 693 – IEEE Recommended Practice for the Design of Substations

Sellafield ET372

British Energy, BNG, Site Specific etc

www.tracglobal.com
Zones and Regions

Figure 3.
National Seismic Hazard Map

www.tracglobal.com
Required Response Spectra - Generic
Required Response Spectra - Specific

11020 Seismic Test RRS

- E-W Spectrum
- N-S Spectrum
- Vertical Spectrum

Frequency (Hz)

Acceleration (g)
Damping

Typically Specified 2, 5, 10%
May be measured during Exploratory Testing
Time Histories
Test Durations

Ramping
Strong Motion
Test Sequences

Uni-, Bi- and Tri-axial Shakes:

25%, 50%, 75%, 100%, 140% *(and back down)*

5 at 25%, 1 at 100%, 1 at 140%

5 at OBE, 1 DBE, 1 SSE (SME)

Other combinations are possible

Shakes more than 100% are used to check for “cliff edge” effects
Ageing

Dynamic Testing
- Vibration
- Shock and bump
- Bench handling
- Transportation bounce
- Acceleration

Radiation

Thermal Cycling

www.tracglobal.com
Ageing

Climatic Testing

- Temperature, humidity, altitude, icing
- Driving sand & dust
- Ingress protection (IP)
- Salt corrosion
- Solar heating
- Fluid Contamination

www.tracglobal.com
Specimen Mounting

Representative of In-Service Conditions or Rigidly Mounted

Orientation wrt gravity

Test Fixturing
  – cabling/pipework

Mounting Bolts

Tightening Torques

www.tracglobal.com
Functional Testing

Safety Critical

Continuity
CAP708E7R1

Change of State
Camera shake-table-y-axis

Containment

Data Transfer
Start time 2008-07-11T11:32:45.102Z

Acceptable Limits
BEELAB

Seismic Test of a Valve Actuation System
Response Measurements

Dynamic Characteristics acceleration and displacement
Pass/Fail Criteria

Safety

Structural

Functional

- **Category S1**
  This category only permits qualification by demonstration of a specified functional performance during an appropriate full-scale shake table routine on the item itself or a representative sample. Some degree of operability will be maintained after the seismic event, which is given by the pre-defined functional test, which is an integral part of the test. The physical state of the item after the shake test is immaterial provided it passes the functional tests. If shake table testing is used as part of the repair/replacement philosophy then it will have to be shown that suitable repairs can be performed, and/or suitable replacement items are available, and can be fitted, both within an acceptable period of time.

- **Category S2**
  Plant items in category S2 will be able to operate after the event without any repair or maintenance, although the function may be different after the event to that prior to the earthquake. It must be noted that the ability to contain a fluid or maintain pressure is the requirement for category S3 and additional requirements are needed to raise the items to category S2.

- **Category S3**
  Category S3 items retain fluids, maintain pressure and have no section breaks. Depending on its function the item may not be able to operate without maintenance or repair. Gross deformation and loss of dimensional stability are possible for items in this category provided the basic requirements are maintained.

  Category S4 is for plant items, which, in themselves have no requirements for seismic qualification, but whose failure could lead them to cause an accident or loss of safety related function. For these items leakage is acceptable but total or partial collapse is not.

All equipment is to be designed to their designated category taking into account the Seismic damping values stated for them (Ref 4)
Reporting (1)

- purchase order or contract number
- equipment identification – bom
- colour photographs of the test set-up
- identification of the test facility, including location and test equipment
- a brief description of the purpose of the test programme
- a listing of all instrumentation used to collect data including model number, serial number and calibration information. Calibrations and certificates of accuracy should be traceable to British National Standards
Reporting (2)

all test data obtained to fulfil the requirements of the Test Plan including the following plots: acceleration transmissibility from the exploratory tests, identifying any significant frequencies, magnifications, and damping values

time histories and test response spectra for the control accelerometers, analysed at 5% damping, superimposed on the required spectra, for all test runs

detailed information on any modification required of the equipment and remedial action taken if malfunctions occurred during testing

record of compliance with the applicable acceptance criteria or specific deviations; demonstration that the TRS exceeds the RRS (including the required margin)

a colour video recording of the seismic testing will be provided in DVD format

signed copies of the test record sheets

www.tracglobal.com
Test Plan and Approval

INTRODUCTION
SPECIMEN
SPECIFICATION
SPECIMEN MOUNTING
TEST ASSEMBLY RESPONSE MEASUREMENTS
TEST SPECIMEN AGEING
TEST SPECIMEN FUNCTIONAL TEST PROGRAMME
TEST PROGRAMME
REPORTING
QUALITY ASSURANCE

APPROVAL BY MANUFACTURER AND DESIGN AUTHORITY