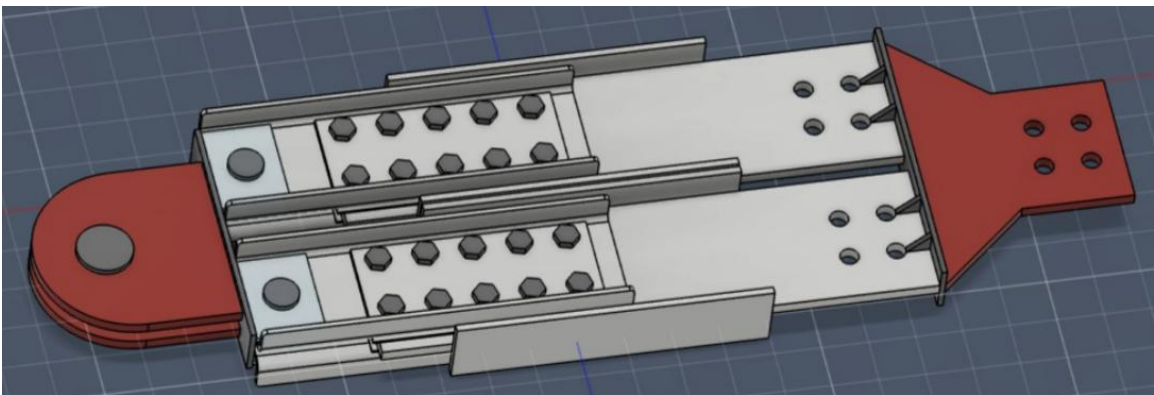
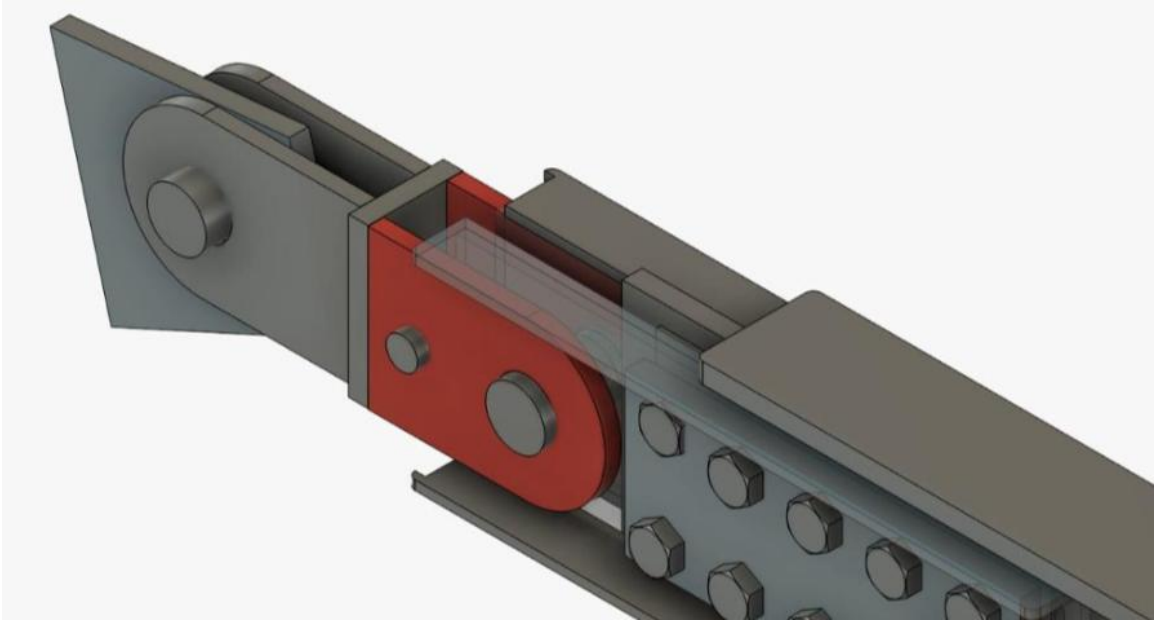


Richter Resilience (P) Ltd

3B4, R&I Park, IIT Delhi

Quality Assurance & Test Plan – 75/45/105/120 Ton Friction Damper



This quality plan is prepared based on the observed load–displacement response displayed during laboratory testing of the 75 Ton damper system.

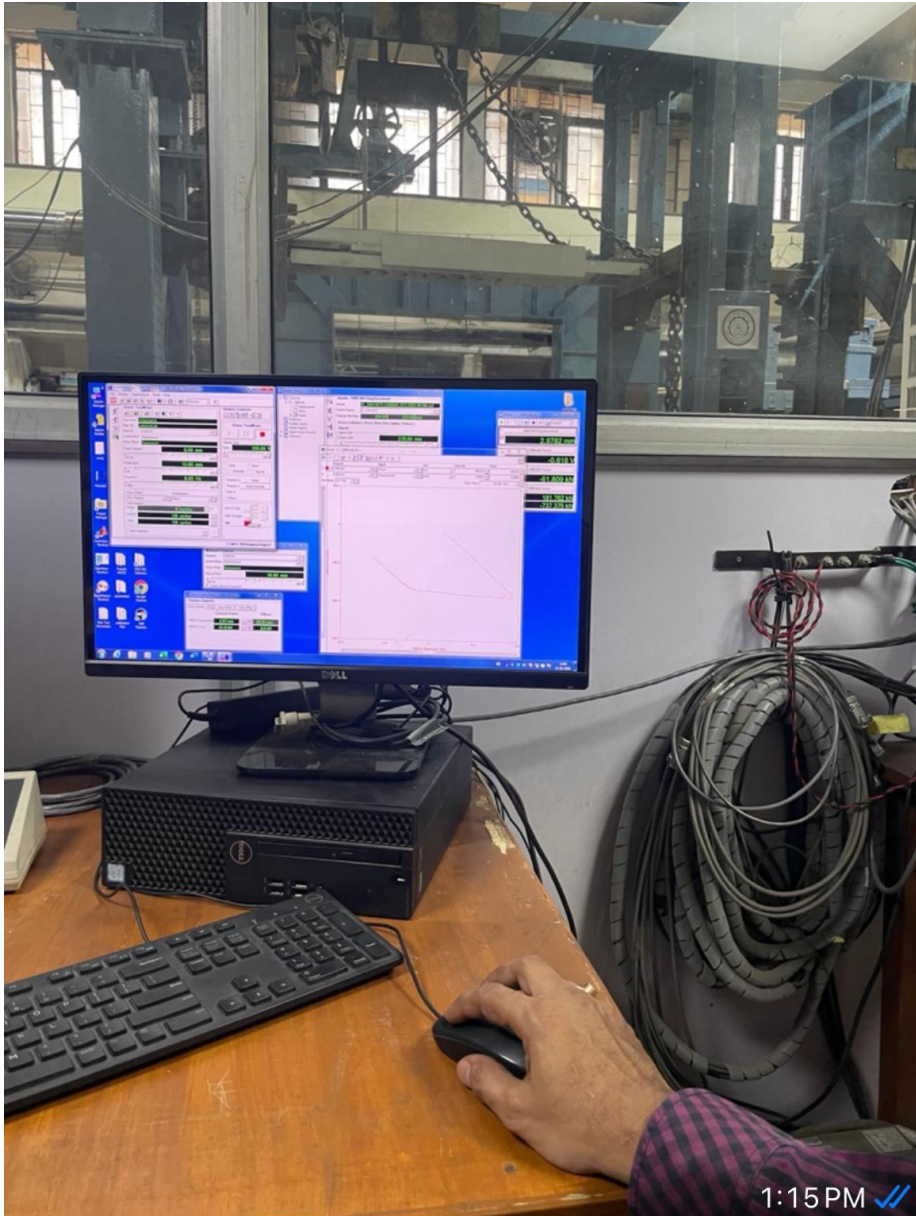


Figure 1: Test setup and representative force–displacement response.

1. Scope

This Quality Assurance & Test Plan establishes the comprehensive procedures, inspection requirements, verification protocols, documentation standards, acceptance parameters, calibration controls, traceability measures, and final release criteria applicable to the manufacturing and testing of 75 Ton friction dampers intended for structural seismic applications. The plan is intended to ensure consistency in fabrication quality, dimensional accuracy, assembly integrity, slip-load performance, and overall operational reliability of the damper system prior to installation and commissioning.

2. Design Basis

Nominal Capacity: 75 Ton (approximately 735 kN)

Damper Type: Friction Damper

Performance Objective: To provide stable and reliable hysteretic energy dissipation under structural loading conditions through controlled frictional sliding.

Expected Behaviour: The damper shall exhibit controlled slip behaviour with a stable load plateau and consistent force response during reloading, with permissible variation limited to $\pm 15\%$ of the specified performance parameters.

3. Raw Material Inspection

- Verify and review mill test certificates for all steel plates, bolts, shims, friction plates, and associated interface materials to ensure compliance with approved material specifications and design requirements.
- Confirm material grade, plate thickness, mechanical properties, hardness, dimensional conformity, and surface condition prior to fabrication and assembly.
- Inspect all components for visible defects including excessive warping, surface corrosion, edge cracking, lamination defects, or mechanical damage, and reject any material not conforming to the specified quality requirements.

-

4. Dimensional Inspection

- Verify plate thickness, flatness, and dimensional tolerances in accordance with approved fabrication drawings, with allowable plate thickness tolerance limited to ± 0.5 mm.
- Confirm hole diameter, spacing, and alignment tolerances to ensure proper assembly fit-up and uniform load transfer, with permissible hole alignment deviation limited to ± 0.1 mm.
- Inspect pin diameters, bush clearances, and mating interface dimensions to ensure conformity with approved engineering drawings and specified assembly tolerances.
- Verify weld size, weld continuity, edge distances, and overall fabrication quality in accordance with approved shop drawings and applicable welding standards.

5. Bolt Tightening & Pretension Control

- All bolts associated with the friction interface assembly shall be tightened using calibrated torque wrenches having valid calibration certification and traceable calibration records.
- Tightening torque values for each bolt and friction interface shall be measured, recorded, and maintained as part of the quality assurance documentation and inspection records.
- Random verification of bolt preload and tightening consistency shall be conducted during assembly to confirm compliance with specified torque requirements and intended clamping force.
- A documented bolt tightening sequence shall be maintained to ensure uniform load distribution, consistent preload application, and proper assembly integrity across all friction interfaces.

6. Functional Testing

Preloading:

- Prior to commencement of slip-load testing, a seating or preloading force equal to approximately 10–15% of the rated damper capacity shall be applied to ensure proper seating of all contact surfaces, stabilization of the assembly, and uniform engagement of the friction interfaces.
- The preload stage shall also be used to verify alignment, actuator response, fixture stability, and proper functioning of the test setup prior to application of the full test load.

Slip Load Test:

- The applied load shall be increased gradually and in a controlled manner until the onset of initial slip is observed within the friction damper assembly.
- The load corresponding to the first stable slip event shall be recorded as the measured slip load of the damper system.
- The measured slip load shall remain within $\pm 15\%$ of the specified design slip-load value and shall demonstrate stable and repeatable sliding behaviour without abrupt instability, excessive force fluctuation, or mechanical distress.

7. Acceptance Criteria

- The damper system shall exhibit a stable and repeatable hysteresis response without abrupt force drop, excessive instability, or irregular sliding behaviour during loading and reloading conditions.
- Variation in measured energy dissipation characteristics between successive loading cycles shall not exceed $\pm 15\%$ of the reference performance values established during testing.
- Residual deformation of the damper assembly, pins, plates, and associated components after completion of testing shall remain within approved and acceptable engineering limits.
- No evidence of fracture, weld cracking, plate buckling, excessive pin deformation, mechanical distress, or permanent damage to any structural component shall be permitted during or after testing.
- Slip-load behaviour shall demonstrate acceptable repeatability and consistency within the specified tolerance limits established for the damper system.

8 Documentation

- All inspection records, dimensional verification reports, testing observations, and quality control documents shall be properly maintained, reviewed, and retained as part of the project quality assurance documentation.
- Calibration certificates for torque wrenches, load cells, actuators, measuring instruments, and other relevant testing equipment shall be preserved with full traceability and validity records.
- A comprehensive final Quality Assurance dossier containing inspection reports, material certificates, calibration records, test data, observations, acceptance documentation, and relevant traceability records shall be compiled and submitted to the client for review and final approval.

9 Recommended Additional Monitoring.

- Following completion of testing, all friction interfaces and contact surfaces shall be visually inspected for evidence of excessive wear, scoring, surface degradation, localized damage, uneven contact patterns, or abnormal material deterioration that may affect damper performance.
- Periodic bolt retightening audits and inspection checks shall be conducted after transportation, handling, and final installation to verify retention of the specified preload condition and overall assembly integrity prior to commissioning.

10 Suggested Graph Interpretation

“The displayed force–displacement response indicates controlled force reduction and stable sliding behaviour, which are characteristic performance features of a properly functioning friction damper system. The observed response demonstrates effective frictional energy dissipation with a relatively stable load plateau during sliding. Accordingly, the quality assurance and testing program shall place particular emphasis on repeatability of slip-load performance, consistency of bolt pretension and clamping force, stability of hysteretic behaviour, and reliability of energy dissipation characteristics throughout the testing and inspection process.”

Test Rig



Damper Mounted on Rig



Damper Head



Damper Tail



Actuator: Servo Controlled. Make MTS



Actuator Shaft



Bridge between Damper and Moment Resisting Frame



Moment Resisting Frame

Test Rig Description and Theoretical Relation between Torque and Slip Load

The test rig tests the slip load of the Damper. The force is applied by the hydraulic actuator-the hydraulic actuator builds pressure according to the response force in the system-the weakest link being the Damper and the response force having a maximum of “Maximum force of static friction.”

The maximum force of static friction is controlled by the torque applied on the Bolts in the Damper. The relation between Torque applied and Normal force is governed by the equation:

For a friction damper, the torque applied to the bolt creates a preload (clamping force) in the bolt, and that preload becomes the normal force acting on the friction plates.

The standard relationship is:

$$T = K \cdot F \cdot d$$

Where:

- T = tightening torque on the bolt
- K = nut factor / torque coefficient (depends on lubrication, threads, washers, surface condition)
- F = bolt preload = normal force
- d = nominal bolt diameter

Rearranging:

$$F = T / (K d)$$

For friction dampers, the slip load is then approximately:

$$F_{\text{slip}} = \mu \cdot n \cdot F$$

Where:

- μ = friction coefficient

- n = number of friction interfaces
- F = normal force from bolt preload

So combining both equations:

$$F_{slip} = \mu n T / (K d)$$

$$F_{slip,total} = \mu \sum (n_i F_i)$$

This means:

- Higher bolt torque → higher clamping force → higher slip load.
- But the relationship is often not perfectly accurate in practice because K varies significantly due to:
 - lubrication,
 - washer hardness,
 - thread condition,
 - galling,
 - surface roughness.

In real friction dampers, torque-based preload estimation can easily vary by $\pm 20\text{--}30\%$, which is why critical dampers often use:

- calibrated bolt tensioning,
- direct tension indicators,
- load cells,
- or slip-load testing.

Typical values of K :


- Dry steel: 0.18–0.25
- Lubricated bolts: 0.10–0.18

In our case, $n=1$, $K= 0.1465$ (through experimentation-in our case), Coefficient of Static Friction: 0.3, $n_i = 16$

Therefore, the torque per bolt was Mean: 710.6 N-m and with a SD: ± 20.34

****The LVDT is not attached to the Damper but to the Actuator. Therefore, all motions of Damper, Frame and Connecting elements are captured in the graph***

Appendix – Damper Inspection Check List

| | |
|---|-------------------------------------|
|  | <h1>RICHTER RESILIENCE (P) LTD</h1> |
| <h2>DAMPER INSPECTION CHECK LIST</h2> | |
| Project: _____ | Job No.: _____ |
| Damper Type: _____ | Slip Load: _____ |
| MCE Stroke: _____ | Maximum Stroke: _____ |

| ASSEMBLY: | REMARKS |
|------------------------|-------------|
| WASHER PLATE | |
| BOLTS / NUTS / WASHERS | |
| ALUMINIUM STRIP | |
| CHANNELS | |
| STAINLESS STEEL PLATES | |
| CENTER PLATE, WELD | |
| LUBRICANT | |
| INITIAL PRIMER | |
| W-40 LUBRICATION | |
| TOTAL LENGTH | |
| BY: _____ | DATE: _____ |
| TESTING: | |
| SLIP LOAD | |
| TOTAL LENGTH | |
| SERIAL NUMBER | |
| LOGO | |
| BY: _____ | DATE: _____ |
| INSPECTION: | |
| CHECKLIST | |
| FINAL LENGTHS | |
| PAINTING | |
| BY: _____ | DATE: _____ |

Appendix - Bolt Torque Recording Table

| Bolt No. | Location | Specified Torque (N-m) | Recorded Torque (N-m) | Remarks |
|----------|----------|------------------------|-----------------------|---------|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |

Inspector Signature: _____ Date: _____