Seismic BMP Retrofit Checklist

This checklist outlines Best Management Practice (BMP) retrofits to improve seismic safety in warehouses storing flammable, hazardous, or corrosive materials. These measures prioritize preventing earthquake-induced chemical releases, fires, and environmental contamination. Each BMP includes a description, authoritative source, and implementation steps. Facility managers and compliance personnel can use this as a field checklist to enhance warehouse resilience.

1. Anchoring & Bracing of Racks, Shelves, and Equipment

Unanchored storage racks, shelving units, and heavy equipment can tip or collapse during earthquakes, spilling hazardous materials wbdg.org. Proper anchoring and bracing keeps these structures stable, reducing spill and fire risks. FEMA and Oregon codes emphasize that shelving for hazardous materials must be braced/anchored to resist seismic forces codes. For example, FEMA notes that earthquake shaking can overturn inadequately anchored pallet racks, causing contents to topple.

Source: FEMA E-74 (Nonstructural EQ Damage Prevention) and Oregon Structural Specialty Code §414.20. FEMA's field manual also recommends anchoring hazmat cabinets to floors or walls.

Implementation Checklist

☐ Anchor All Storage Racks/Shelves: Bolt racks and shelving units to the floor and/or structural walls. Use steel brackets or anchor bolts into concrete slabs or wall studs. Ensure anchors are rated for seismic loads and installed per manufacturer instructions.

☐ Brace Tall Shelving: Install steel angle brackets or cross-bracing on racks over 6 ft tall to prevent sway. Gang adjacent units together and to structural elements for stability.

☐ Secure Hazardous Material Cabinets: Fasten flammable liquid cabinets and chemical storage lockers to floors or walls (engage wall studs or concrete). Check that hazmat cabinets have factory-provided anchoring points used or retrofit with brackets.

☐ Restrain Equipment & Tanks: Anchor heavy equipment (generators, compressors) and chemical tanks to structural support. Use bolt-down framing or straps as needed. Ensure anchorage is designed for the equipment's weight plus contents.

☐ Double-Chain Gas Cylinders: Secure compressed gas cylinders (flammable or toxic gases) upright with upper and lower restraints (e.g. chains or straps) to a fixed rack or wall bracket. Single straps are insufficient. Use two-point restraints to prevent cylinders from breaking loose.

☐ Inspection: Mark each anchor/bracket installation and log it. Inspect anchors periodically (e.g. annually) to ensure they remain tight and corrosion-free.

2. Seismic Restraints for Stored Hazardous Contents

In addition to anchoring the fixtures themselves, the contents on shelves and racks must be restrained to prevent falling, mixing, or rupture of containers. This is crucial for hazardous materials, because broken containers can lead to fires or toxic releases. For example, Oregon State University EHS guidelines require that shelves with chemicals have seismic restraints (like lips or bars) to stop containers sliding off. Shelf lips of at least 2-inch height are recommended for hazardous material storage. Separating incompatible chemicals is also vital to prevent dangerous reactions if containers break.

Source: FEMA 74 Nonstructural Checklist and OSU Chemical Storage Guidelines. These sources emphasize securing shelf contents and proper chemical segregation as earthquake safety measures.

Implementation Checklist

☐ Install Shelf Lips or Fencing: Ensure each hazardous storage shelf has a raised lip (≥2" high) or wire/front barrier to keep containers from sliding off during shaking. If lips are missing or too low, retrofit metal or wood strips on shelf edges.

☐ Use Straps/Nets for Pallets: For palletized drums or IBC totes on racks, use seismic straps or netting to secure them. Pallet rack safety bars or pallet stop angles can prevent pallets from falling.

☐ Secure Small Containers: Store smaller chemical bottles in bin trays or "egg-crate" partitions inside cabinets. This prevents individual bottles from tipping and breaking.

☐ Segregate Incompatibles: Physically separate acids, bases, flammables, oxidizers, etc., by using dedicated cabinets or secondary bins. Do not store incompatible chemicals together on the same shelf, otherwise an earthquake could knock them together and cause a hazardous reaction. Use secondary containment trays (see next section) to keep different classes apart.

☐ Latch Cabinet Doors: Equip chemical cabinets with positive latching door hardware (e.g. barrel bolts or auto-latching catches) so doors stay closed in a quake. This keeps contents inside. Check that flammable cabinets' self-latching mechanisms work.

☐ Floor Storage Caution: Avoid floor storage of heavy glass carboys or barrels unless they are in secondary containment or cradles. Never store glass chemical containers directly on the floor without secondary containment.

3. Secondary Containment and Spill Control Upgrades

Secondary containment provides a backup barrier to hold hazardous liquids if primary containers fail. In earthquakes, containers or tanks can rupture – containment prevents spreading chemicals that could ignite or contaminate soil/water. Facilities should have containment sized to hold at least the volume of the largest container (as per EPA/Oregon DEQ guidelines). Spill control infrastructure like dikes, berms, or sump systems should be evaluated for seismic stability (so they remain intact and don't leak when shaken). This BMP limits environmental release, aligning with spill prevention regulations.

Source: EPA Hazardous Waste & Oregon DEQ guidelines for secondary containment. OSHA and fire codes also require secondary containment for flammables and corrosives storage. The Oregon State University chemical storage fact sheet specifically urges using polyethylene or steel secondary containment trays under chemicals and for all floor-stored hazmat.

Implementation Checklist

☐ Containment Pallets/Trays: Use spill pallets, tubs, or trays under drums and liquid totes. These should hold 110% of the largest container's volume. Check that these trays are chemical-resistant (poly for corrosives, steel for fuels) and in good condition (no cracks).

☐ Fixed Containment Berms: Install curbs or berms around large storage areas or tank farms. For example, a concrete berm around a pallet storage zone can contain leaks. Ensure berms are structurally reinforced and anchored so they won't crack or separate during an earthquake.

☐ Floor Drain Controls: If floor drains are present, consider an automatic drain shutoff valve or manual shut valve that can be closed in an emergency. This keeps spilled chemicals from flowing into the sewer/outside. Regularly train staff to shut drains if a spill occurs.

☐ Sealant and Slope: Apply chemical-resistant sealant to concrete floors to prevent seepage. Slope floors gently toward a sump or low point within the building, so spilled liquids pool where they can be controlled (and not at exits). Check that door thresholds or ramps can hold back liquids (install door berms or raise door lips if necessary).

☐ Separate Containment for Incompatibles: Store acids, bases, flammables each in their own containment system. For instance, use separate plastic tubs for acids vs. bases to prevent mixing if both spill.

☐ Spill Cleanup Kits: While not a structural retrofit, equip each storage area with earthquake-accessible spill response kits (absorbents, neutralizers, PPE). Mount them in known locations that will be reachable even if shelving shifts.

4. Flexible Connections and Automatic Shutoff Valves for Utilities

Rigid utility lines (gas, water, electric conduits) can break during seismic shaking or building movement. Broken gas lines can ignite fires, and ruptured water or chemical feed lines can cause uncontrolled leaks. To mitigate this, flexible connectors and couplings should be installed at critical connection points, allowing movement without breaking. Additionally, seismic shutoff valves can automatically cut off gas flow when strong shaking is detected, reducing fire risk. Sprinkler and fire suppression piping should also have flexibility and bracing so that firefighting capability is retained post-earthquake. These upgrades directly target fire prevention and spill control following a quake.

Source: FEMA P-74 and FEMA P-417 guidelines recommend flexible utility hookups (e.g. flexible gas appliance connectors) to accommodate earthquake motion. The Oregon Resilience Plan highlights that post-earthquake fires are a major threat and utilities should be secured (consistent with USGS and FEMA

findings). Many local codes (e.g. California) even mandate automatic gas shut-off valves for seismic safety.

Implementation Checklist

☐ **Flexible Gas Connections:** Replace any rigid gas pipes to appliances (heaters, boilers, generators) with flexible corrugated stainless steel connectors. Ensure they are CSA-approved for seismic use. This prevents gas leaks if equipment shifts.

☐ **Seismic Gas Shutoff Valve:** Install an automatic earthquake-actuated gas shutoff on the main gas line entering the facility. Set to trip at ~5.2+ magnitude shaking. Test and reset per manufacturer schedule.

☐ **Flexible Couplings on Water/Chemical Lines:** Use grooved flexible couplings or expansion joints on fire sprinkler mains, process chemical lines, and other pipelines. These allow pipes to move a few inches without cracking. Verify sprinkler drop pipes have seismic flexible loops or sway bracing per NFPA 13 to reduce breakage.

☐ **Cable Slack for Power/Controls:** Provide slack or flexible conduit for critical electrical lines (emergency power, control systems for pumps). This helps maintain power to safety systems by preventing conduit rupture.

☐ **Backup Power for Monitors:** Ensure leak detection systems or emergency ventilation have backup battery or generator power and earthquake triggers if applicable (e.g. shut off HVAC to prevent spreading fumes after a big quake).

☐ **Valve Audit:** Identify manual shutoff valves for water, chemical feeds, etc. Label them clearly and make sure they are accessible (not blocked) and operable after an earthquake. Train staff to quickly shut them if automatic systems fail.

5. Structural Strengthening of Building Elements

The building structure must withstand seismic forces to protect both personnel and hazardous contents. Structural failures (wall collapses, roof cave-ins) can release all stored chemicals at once and compromise containment and sprinklers. Many older warehouses in Oregon (including Clackamas County) were built before modern seismic codes and may have vulnerabilities like unreinforced masonry (URM) walls, unbraced tilt-up concrete panels, or weak connections. Strengthening the structure, through retrofits like wall bracing, roof-to-wall anchors, column reinforcement, or frame bracing, greatly reduces the chance of collapse and subsequent chemical spills.

Source: Oregon Resilience Plan & FEMA 547 (Techniques for Seismic Rehab). The City of Portland URM program notes that unreinforced masonry buildings are extremely vulnerable to earthquake damage, often collapsing or shedding walls. FEMA and USGS studies have shown seismic retrofits (e.g. adding plywood shear walls, steel braced frames, or moment connections) significantly improve building performance in earthquakes. Clackamas County's hazard plan identifies hazardous material facilities as "critical facilities" that should remain intact to avoid secondary impacts.

Implementation Checklist

☐ **Engineering Evaluation:** Have a structural engineer assess the building's seismic weaknesses (per ASCE 41 seismic evaluation standards). Focus on elements like: wall-to-roof connections, foundation anchorage, bracing of masonry or concrete walls, and overall lateral force resistance.

☐ **Roof-to-Wall Anchors:** If the building has masonry or precast concrete walls, install anchorage tying walls to the roof diaphragm. Use steel angle clips or tie-rods at regular intervals to prevent walls from pulling away or collapsing. Brace or remove heavy parapets or chimneys that could fall.

☐ **Add Lateral Bracing:** Strengthen the lateral system (which resists horizontal shaking). Options include adding steel braced frames, moment-resisting frames, or plywood/OSB shear wall panels inside the structure. For URM walls, adding a reinforced concrete or shotcrete overlay can increase strength.

☐ **Strengthen Support Columns:** Many warehouses are open-floor, with tall columns supporting the roof. Retrofit steel jackets or fiber wrapping on concrete columns to improve ductility. Ensure any mezzanines or platforms are braced.

☐ **Ceiling and Lighting Safety:** Secure heavy ceiling fixtures, HVAC units, or lighting racks to the structure so they don't fall onto hazardous material containers. Use seismic clips for suspended ceilings in offices or labs attached to the warehouse.

☐ **Fire Sprinkler Bracing:** (Structural/Nonstructural crossover) Make sure sprinkler risers are braced to structure and the system has seismic separation gaps where it passes through walls or floors, so the sprinkler system remains operational to fight fires post-quake.

6. Spill Response Infrastructure & Preparedness

Even after physical retrofits, facilities must be prepared to respond to any spills or leaks that do occur. Robust spill response infrastructure ensures that if containment is breached, the consequences are minimized. This includes on-site systems and equipment ready for use right after an earthquake: fire suppression, ventilation, and spill cleanup resources. Being prepared also aligns with the Oregon community hazard planning emphasis on hazardous materials. While this category is more about readiness than a "retrofit," it involves tangible infrastructure and equipment installations that complement the above BMPs.

Source: Oregon Fire Code and OSHA regulations for hazardous material handling require emergency response plans and equipment. The Oregon NHMP (2025) notes a lack of full understanding of risks at hazmat sites and implicitly the need for better preparedness measures. FEMA and EPA guidance for chemical facilities also emphasize having containment and cleanup equipment accessible post-disaster.

Implementation Checklist

☐ **Fire Suppression Upgrades:** Ensure the warehouse has an automatic sprinkler or fire suppression system appropriate for the materials (foam sprinkler for flammables, etc.). Install seismic valves to shut off

product flow and simultaneously allow sprinklers to operate. Consider fireproofing critical structural elements to delay collapse in a fire.

☐ Emergency Ventilation & Scrubbers: If toxic gases or fumes could be released, have explosion-proof exhaust fans and scrubbers on standby power. Use seismic sensors to trigger ventilation if flammable vapors are detected post-earthquake (once fire risk is controlled) to prevent buildup.

☐ Spill Containment Kits & Stations: Deploy spill response stations throughout the facility: absorbent booms, neutralizers (lime for acids, etc.), and overpack drums for quick containment of leaks. These should be in robust cabinets or boxes secured to walls, clearly marked, and checked regularly.

☐ Personal Protective Equipment (PPE): Stock emergency PPE (chemical-resistant suits, respirators, gloves) in accessible locations so staff can safely respond to spills after an earthquake.

☐ Alarm and Communication Systems: Equip the facility with alarms (audible/visual) that can be triggered by earthquake sensors or manually to evacuate personnel and alert them to hazmat spill response protocols. Maintain battery-backed communication (two-way radios, etc.) in case power and phones fail.

☐ Training & Drills: Train employees in earthquake response: how to shut off utilities, activate spill response, and use equipment. Conduct periodic drills simulating an earthquake with a spill scenario.