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OPUS
Challenges relating to the seismic performance of NSE

Implications of failure of NSE

In most cases the damage sustained to non-structural elements in recent NZ earthquakes could have been significantly reduced if they had been installed with appropriate clearances and seismic restraint.

Air conditioning ducts collapsed

Electrical cable ladders and lighting collapsed

Pipes broke loose

Ceilings collapsed

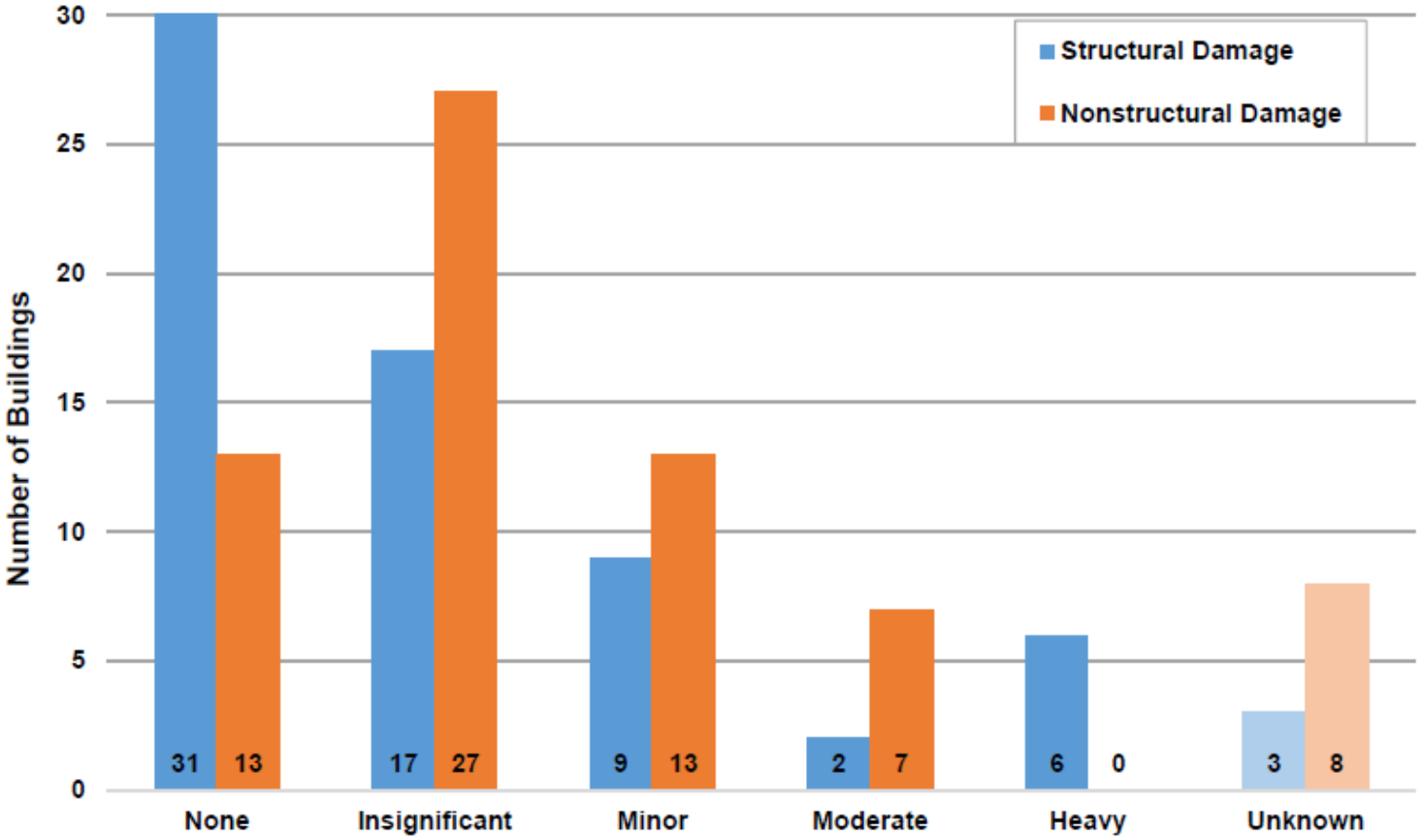
Partitions and glazing damaged

Sprinkler pipes broke and soaked carpets, electrical wiring and office equipment

No severe injuries (but could have been).

Major issue – Business Interruption

Implications of failure of NSE



Source: FEMA P-1024 “Performance of Buildings and Non-structural Elements in the 2014 South Napa Earthquake”, dated February 2015.

Challenges to achieving good performance of NSE in earthquakes

1. Coordinated Construction Documentation
   - Fragmented requirements in NZ Standards
   - Specimen design for façade, glazing, building services. Contractor DB
   - Seismic restraint of NSE usually covered by Performance Spec
2. Contractor and Sub-Contractor installation
   - Multiple sub trades not well coordinated – result - lack of clearance
   - Responsible for coordinating NSE and their restraints within completed documentation
3. Enforcement
   - Independent body inspects & certifies sprinkler system to Code Compliance Cert
   - Lack of follow up and inspection for façade, glazing, partitions, ceilings and building services are installed in accordance with relevant standards.

What is causing damage to NSE?

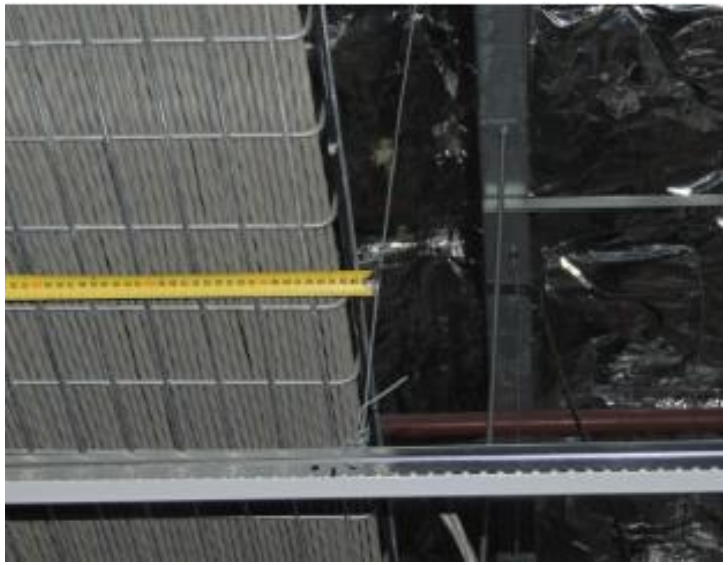
1. Elements with no seismic restraint

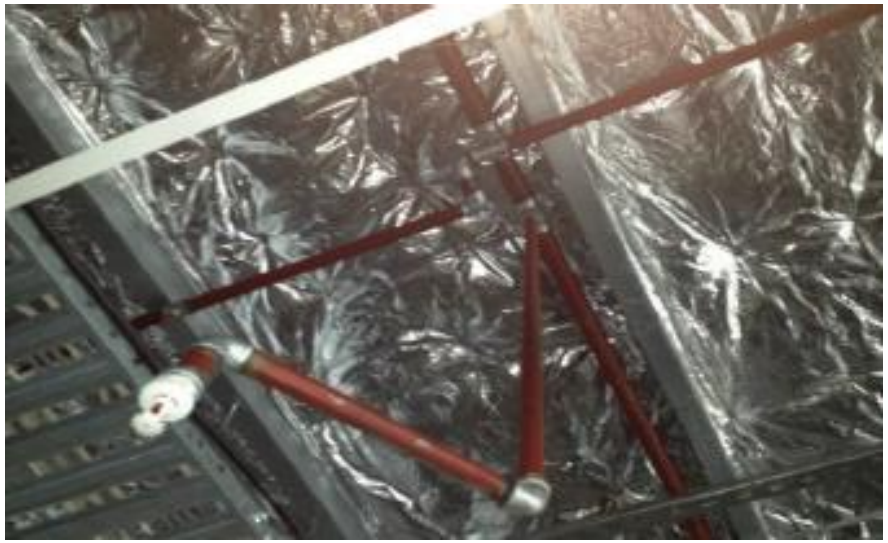
What is causing damage to NSE?

2. Elements that are unable to withstand building deformations

What is causing damage to NSE?

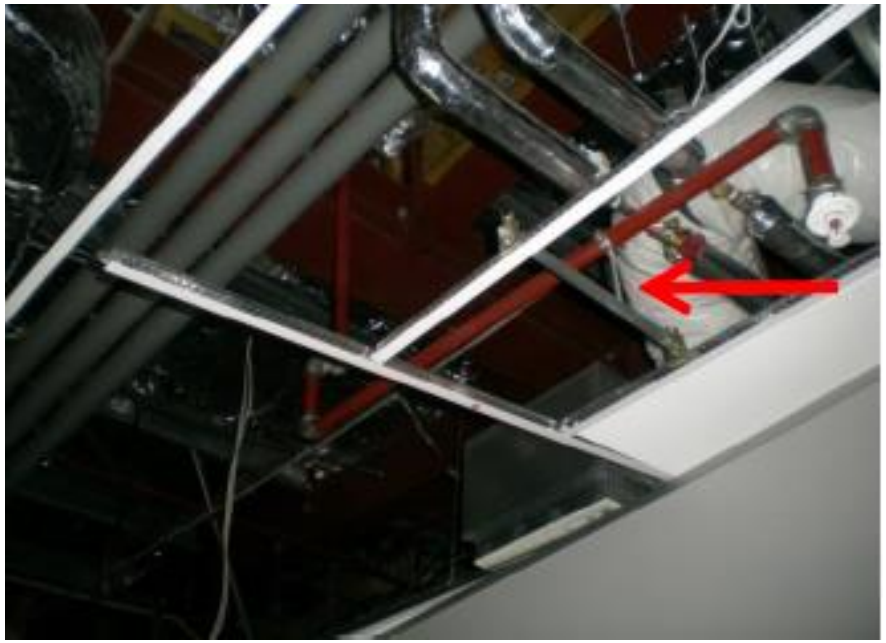
3. Elements without sufficient clearances





What is causing damage to NSE?

4. Coordination/Construction/Inspection

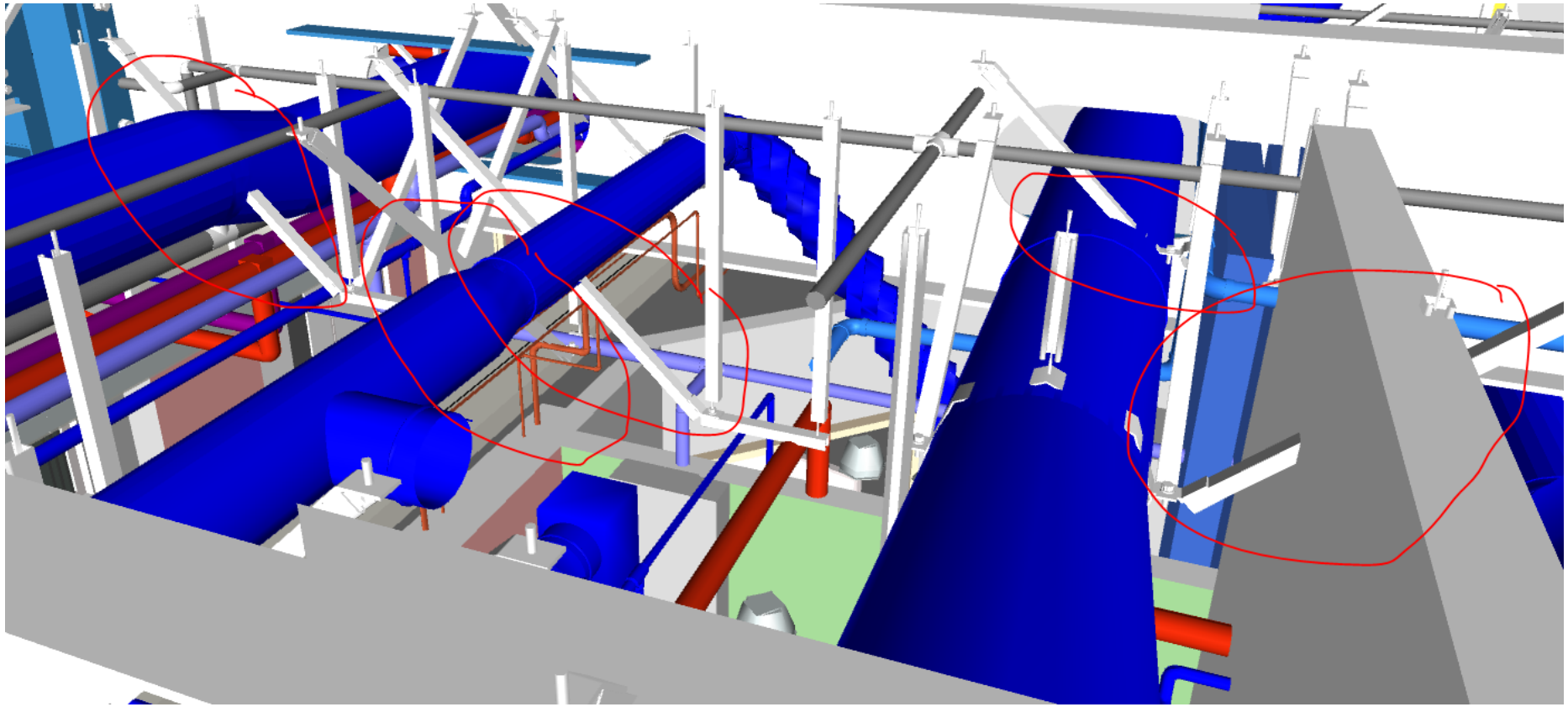


Comparison of Building Standards

Standard	ASCE-7	NZS 4219	NZS 4541	NZS 2785	Partitions
Peformance Requirements	Reduce risk to occupants and improve likelihood that essential facilities remain functional	P1, P2, P3 – do not collapse, rupture or lose support after ULS earthquake	All sprinkler system components shall be designed and installed so as to remain operational at ULS earthquake loads specified in NZS 1170.5	ULS Performance – ceiling shall have adequate strength if the probability of failure of failure of the system (system becomes unstable or loses equilibrium) is acceptably low throughout its intended life	Objective B1.1 - *"Safeguard people from injury caused by structural failure,* and to *safeguard people from loss of amenity caused by structural behaviour"*
	Minor earthquake - minimal damage, not likely to affect functionality	P4 – do not collapse, rupture or lose support after ULS earthquake for IL4 structure	The sprinkler system shall not be able to be damaged or impaired by the movement or failure of other features or components of the building	SLS Performance – Probability of loss of serviceability of the system is acceptably low and the ceiling maintains its intended performance level throughout its intended life	Performance B1.3.1 – *"Buildings, building elements and site work shall have a low probability of rupturing, becoming unstable, losing equilibrium, or collapsing during construction or alteration and throughout their lives."*
	Moderate earthquake - some damage that may affect functionality	P5 – operational continuity for IL4 buildings. Restrained so that system is able to continue to perform function after SLS2 earthquake		Ceiling hangers shall be proportioned such that the failure or removal of a single hanger does not trigger a progressive collapse of the ceiling system	Performance B1.3.2. – *"Buildings, building elements and site work shall have a low probability of causing loss of amenity through undue deformation, vibratory response, degradation, or other physical characteristics throughout their lives or during construction or alteration when the building is in use."*
	Design earthquake - major damage but significant fall hazards avoided, likely loss of functionality	All components to be restrained so that system retains structural and operational integrity without requiring repairs after SLS1 earthquake			
Design Requirements	+ Specific design of design forces ASCE-7 + NSE to accommodate drift, deflections and relative displacements in accordance with ASCE-7 + Most NSE lack ductility, toughness and redundancy - therefore low ductility factors are provided for various types of NSE	Specific design using NZS 1170.5 and non-specific design (prescriptive method to determine earthquake loads along with 2.5% drifts and prescriptive capacity of braces for given bolt fixings)	+ Piping support system based on an assessment using earthquake loadings of NZS 1170.5 (parts category P4), or piping support system to comply with prescriptive requirements + All pipework to be designed to resist 1g seismic actions in any direction in addition to gravity load	+ Gravity loads defined by AS 1170.1, wind loads by As 1170.2 and earthquake loads by NZS 4203 + ULS Load combinations similar to NZS 1170.0 except gravity which is more onerous 1.4G & 1.7U	Damage to internal partition linings does not typically impact the amenity of a building - depending on the use of the lining (e.g. damage to fire separation or operating theatres is important)
Interaction between components	+ Each non-structural component's seismic interaction with all other connected components and with the supporting structure shall be accounted for in the design. +Sprinkler system and ceiling grid are permitted to be designed and tied together as an integral unit. + Flexible droppers can be used as an alternative.	+ Prescriptive clearances provided. + Equipment supported independently of suspended ceiling shall have a clearance of 25mm all round	Minimum clearances to building elements (walls, floors, beams, platforms and foundations) are provided. Gaps may be sealed with flexible or frangible material (it is noted that gypsum board is considered frangible)	+ Partitions shall be fixed to the primary framing members of the grid and not to the tiles or infill panels. Partitions shall be fixed in accordance with the ceiling manufacturer's requirements. + Mechanical and electrical services shall be completed before installation of the suspension systems + Basic guidance for mech air grilles and downlights, all other services incorporated into suspended ceiling shall be in accordance with AS 2946 or NZS 4219	Some guidance is provided in NZS 2785 regarding fixing the partitions to the ceiling grid – noting that this is guidance only as in located in the Appendix as 'Informative' only. Although important for controlling damage due to storey drift, there are no code requirements governing the detailing at the head of the wall
Enforcement	Enforcement through jursidiction not through standard	No enforcement provisions	Building Warrant of Fitness requires a listed contractor to issue a certificate of compliance confirming that they are satisfied that the system is performing in accordance with the design requirements to which the system was installed	No enforcement provisions	No enforcement provisions

Design & Construction Coordination

Opportunities to coordinate multiple services, partitions, ceilings, structure



Possible Solutions

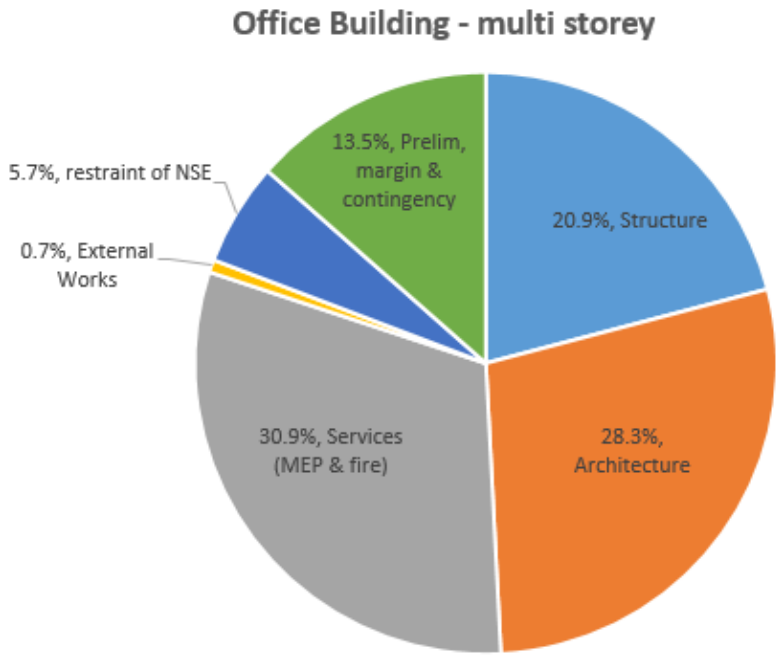
- Introduce design and coordination for the seismic restraint of non-structural elements during the design phase.
- Allowance for both building owner and tenant requirements
- Consider coordination of seismic restraints for multiple services in congested areas. This is likely to result in reduced costs, reduced construction timeframes and improved buildability.
- ECI – to ensure primary and secondary services are taken into account and installation experience is incorporated into the design.
- Larger ceiling spaces. Insufficient ceiling space can lead to conflicts between services, seismic supports, structure and partitions.
- Independent inspections of the installation to confirm that it meets the requirements of the relevant standards.

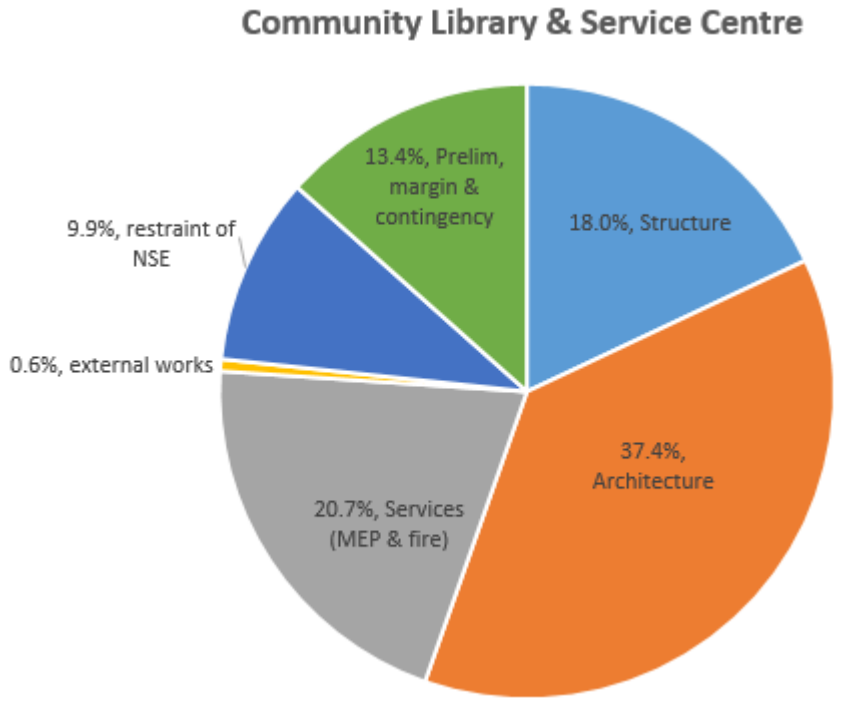
Design cost to provide compliant NSE

- The professional fees to design and undertake full 3D coordination of the seismic restraints for non-structural elements is around 0.5 – 1% of the construction value for new-build.
- Fletcher Construction have advised that they allow 2.5% of the new-build construction value to design and coordinate non-structural elements if it has not been done during the design phase
- The reason the cost is greater when done by the Contractor during the construction phase is because there is a greater amount of coordination required to work in around already completed design.
- Retrofit costs and programme can be substantially more.

Construction costs

Construction costs to install code compliant seismic bracing to ceilings, partitions and building services elements is relatively small





Summary

- In most cases the damage sustained to non-structural elements in recent earthquakes could have been significantly reduced if they had been installed with appropriate clearances and seismic restraint.
- Challenge is to move toward:
  - Fully integrated design
  - Elements that are designed by the Contractor are integrated into the design documentation
  - Sub-trades construct in accordance with the integrated design
  - Ensure appropriate inspection occurs to confirm that the non-structural elements have been constructed to meet the requirements of the relevant standards