1st Individual Assignment-Ontological Modeling

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Topic: Reinforced Concrete Retaining Wall (Gravity Type)

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1. **Reinforced Concrete Containment Retaining Wall (Gravity type) Background Research**

Purpose and Scope

Reinforced concrete retaining walls for chemical containment serve as safety structures around storage tanks or chemical facilities. Their purpose is to retain hazardous liquids in case of leaks or spills, preventing contamination of the surrounding environment(scribd.com)(concrete.org.uk). In chemical plants and fuel depots, regulations usually require that the bunded area hold at least 110% of the volume of the largest tank (to accommodate the full contents plus firefighting foam(concrete.org.uk). The scope of this system is secondary containment – it is not holding back soil for landscaping, but rather containing liquids (and possibly firefighting water) within a designated area. Essentially, it forms an impermeable perimeter (like a basin or trough) around storage units. Such walls are generally of robust concrete construction, since these materials provide adequate chemical resistance for most stored liquids(concrete.org.uk). In cases of very aggressive chemicals (e.g. strong acids), additional protective coatings on the concrete are applied to ensure durability(concrete.org.uk). This containment wall system addresses the engineering challenge of preventing uncontrolled chemical release – it must be liquid-tight, structurally stable against hydrostatic pressure from liquids, and resistant to any chemical attack.

Intended Users and Use

The intended users of this engineered system include civil/structural engineers (who design the wall), facility owners/operators (who incorporate it into the plant for safety compliance), and environmental safety regulators. Operators use the bunded enclosure in routine operations to passively contain any accidental spillage. The intended use of the wall is as a safety barrier: in normal conditions it simply stands around a tank, but in an accident, it holds leaked liquid, preventing spread. In practice, these walls are an essential secondary containment measure for hazardous liquids where large quantities are stored(concrete.org.uk).

System Components and Structure

The **physical components** of the RC containment wall system can be summarized as follows:

- **Vertical Wall body (Stem):** This is the upright concrete slab that contains the liquid. In our context, it is typically 4–5 meters high and quite thick (on the order of 0.5 to 0.65 m) to provide stability. Its inside face is exposed to the chemicals being contained (during a spill), and its outside may be in contact with soil or open air. The wall must withstand lateral hydrostatic pressure from liquid; hence it is heavily reinforced with steel bars to resist bending.

- **Matt Foundation:** A double layer matt foundation at the foot of the wall provides footing and stability. It typically extends on one or both sides of the wall (forming a "heel" under the liquid side and a "toe" on the opposite side, similar to a cantilever retaining wall)(asdipsoft.com). The base distributes the loads to the foundation soil and prevents overturning and sliding. The Matt Foundation in our example is about 0.50 - 0.60 m thick (e.g. a 5 m wall might have a 0.50 m thick foundation). It is usually cast separately from the wall or in keyed segments. RC walls of this type are generally effective for heights up to ~5 m(tensarinternational.com.)

- **Reinforcement:** Steel reinforcing bars (rebar) are embedded in both the wall and foundation to provide tensile strength. Typically, there are two layers of steel mesh (near the inner and outer faces of the wall) to handle tension on either face depending on loading. In a containment scenario where liquid exerts pressure on the inner face, the outer face of the wall near the base sees tension, so rebar is placed accordingly. For example, a common design might use vertical bars of 16–20 mm diameter at 150–200 mm spacing as the primary (flexural) steel, and horizontal bars of around 12–20 mm at ~200 mm spacing as secondary (distribution) steel(scribd.com). In our case, horizontal bars of 20 mm @200 mm and vertical bars of 16 mm @150 mm (both with ~25 mm concrete cover) would be a reasonable reinforcement layout, using steel of yield strength ≈ 400 MPa. Notably, concrete in such structures is often high quality (e.g. C40/50 concrete, meaning 40 MPa cylinder strength) to ensure low permeability and good chemical resistance(ejournals.eu).

- **Joints and Waterstops:** Large retaining walls are built in sections, so construction joints or expansion joints are provided at intervals (for a 22 m long wall, there might be joints every ~7–10 m, or at corners). A waterstop is typically a flexible strip (often made of PVC or Rubber, here a 400 mm wide rubber waterstop strip) placed in the middle of the concrete thickness at the joint(publicregister.naturalresources.wales). Half of its width is cast into the first pour, and the other half is cast into the adjacent pour, creating a continuous barrier that prevents liquid from seeping through the joint. According to manufacturer literature, *"Waterstops are used for the waterproof sealing of construction and expansion joints against water penetration ... and water under hydrostatic pressure."*aus.sika.com In chemical containment, special chemical-resistant waterstops (e.g. made of nitrile-modified PVC or even stainless steel) can be used to withstand aggressive liquids(usa.sika.comusa.sika.com). The floor-to-wall joint is another critical interface – typically a waterstop is installed at the wall base joint as well, to prevent any leakage at the wall-foundation connection.

- **Protective Coating:** To enhance impermeability and chemical resistance, the inner face of the wall (and floor) is often coated. In our example, a bituminous coating ~20 mm thick was applied on the inside surfaces. A bitumen-based waterproofing layer is a common, cost-effective choice for bunds containing hydrocarbons or mild chemicals. It acts as a membrane to prevent any spilled liquid from seeping into the concrete. Industry guidance on retaining walls also recommends using a waterproofing membrane on the side exposed to water or moisture (e.g. a rubberized asphalt or bituminous coating on the back of a retaining wall) to prevent water penetration(retainingwalllosangeles.com).
- **Chamfers and Fillets:** At sharp corners and edges of the concrete, chamfers or fillets are provided. All exposed external corners usually get a small chamfer (e.g. 20–25 mm) to prevent chipping(gysbi.gy). More importantly for containment, the internal corner where the wall meets the floor is often beveled with a 45° fillet (in our case, a sizable 40 cm by 40 cm chamfered fillet along the wall-floor junction). This serves multiple purposes: it eliminates the hard 90° corner (which is difficult to clean and to coat), it can act as a gutter or guide for liquids, and it reduces stress concentration at the base. Apart from the large internal chamfer, all vertical and top edges of the wall would have small chamfers (e.g. 25 mm) for protection and to allow uniform coating application(publicregister.naturalresources.wales).
- A containment wall usually has an impermeable floor slab connecting all walls, forming a "bathtub" to hold liquids. Because it must hold fluids, typically no penetrations or permanent weep holes are provided in the wall (unlike retaining walls for soil which have weep holes for groundwater. Any pipes that must pass through are carefully sealed or routed over the top of the wall(soilutions.co.uk) to maintain integrity.

Example Design and Parameters

- The wall encloses a rectangular tank farm area about 22–23 meters in length on each side. Two wall heights were used: one section is 5.0 m high (for full containment of a taller tank) and another is 4.0 m high in a different area. The 5 m wall was built 0.65 m thick, while the 4 m wall is 0.50 m thick, both of plain rectangular cross-section (gravity). The base slab and wall were cast in segments of a few meters, with 40 cm wide rubber waterstop strips installed at all vertical and horizontal construction joints to ensure a liquid-tight continuous structure(aus.sika.com). The concrete used was high-strength C40 (40 MPa) ready-mix, and steel reinforcement was grade St 400 (yield strength 400 MPa).
- Structurally, the 5 m high wall segment was reinforced with vertical bars 16 mm in diameter spaced 150 mm apart (center-to-center) on the side facing the liquid (these act as the main steel for bending tension). The horizontal reinforcement consisted of 20 mm bars at 200 mm spacing, placed near mid-height and distributed across both faces, to handle shrinkage and any minor bending effects(scribd.com). The 4 m high wall used a similar layout, slightly reduced for the lower moment demands. All rebar had a clear concrete cover of 25 mm on inner and outer faces (since an additional coating provides environmental protection, a 25 mm cover was deemed acceptable for these internal elements – though for external faces exposed to soil, often 35–50 mm cover is used(gysbi.gy). At the wall-foundation junction, a large 45° chamfer fillet 0.4 m × 0.4 m was integrated, creating a smooth transition from floor to wall. This chamfer was included to avoid sharp corners.
- The inside surfaces (up to the design liquid level) were coated with an ordinary bituminous waterproofing layer ~20 mm thick. This black bitumen layer was applied over a primer to form a continuous membrane across the floor and wall up to the top. Bitumen was chosen here because the contained substances were hydrocarbon-based (for which bitumen has good resistance) and the coating is relatively easy to reapply or repair if needed.

2. Logical axiom Table

This ontology was developed following the methodology of Noy and McGuinness. The domain is RC Retaining Wall Design, with key classes such as RC_RetainingWall, FoundationInteraction, and StructuralComponent. A top-down approach was used to define the class hierarchy, starting from general structures down to specific components. Core properties like hasComponent and hasMaterial were added with proper domains, ranges, and characteristics (e.g., inverse, transitive). Restrictions such as someValuesFrom, allValuesFrom, and cardinalities were applied to ensure logical completeness. Existing vocabularies were considered but extended where domain-specific details were needed.

Axiom Type	DL Syntax	Protégé Syntax	Ontology Example
SubClassOf (Class Subsumption)	C ⊑ D	Subclass Of	BitumenContainmentUse ⊑ RC_RetainingwallUse
EquivalentClasses (Class Equivalence)	C ≡ D	Equivalent To	ConcreteMaterial ≡ {ConcreteMix_C40}
DisjointClasses (Disjointness)	Disjoint(C_1,…,C⍰)	Disjoint Classes	BitumenContainmentUse ⊥ ChemicalContainmentUse
Existential Restriction	∃R.C	some	hasFoundationInteraction some FoundationInteraction
Has-Value Restriction	∃R.{a}	value	hasChamfers value ChamferVerticalEdges_0.40x0.40
Nominal (One-of Class)	{a}	One Of	Chamfers ≡ {ChamferVerticalEdges_0.40x0.40}
Inverse Object Properties	R ≡ S^{-1}	Inverse Of	hasComponent ≡ isComponentOf^{-1}
SubObjectProperty Of	R ⊑ S	Sub Property Of	hasChamfers ⊑ hasStructuralComponents
SubDataPropertyOf	r ⊑ s	Sub Property Of	hasLocation ⊑ hasOrientation
Transitive Object Property	Transitive R	Transitive	hasComponent is Transitive
Domain (Object Property)	Domain(R) = C	Domain	Domain(hasFoundationInteraction) = RC_RetainingWallGravityType
Range (Object Property)	Range(R) = D	Range	Range(hasFoundationInteraction) = FoundationInteraction
Class Assertion	C(a)	Type	BituminousCoating : ProtectiveCoating

3. Engineering Examples:

A. Design of a Retaining Wall System for a New Chemical Storage Facility

Scenario: A new industrial plant requires the design of reinforced concrete containment walls to store more than 2,000,0000 L of chemicals under varying temperature conditions. The walls must resist hydrostatic pressure, prevent leakage, and maintain long-term durability.

Use Case: Using the ontology, designers can explore predefined structural configurations of retaining walls, including wall body, mat foundation, reinforcement layout, and protective coatings. The ontology helps in selecting appropriate material combinations (e.g., C35 concrete, rubber waterstop) and in defining the logical relationships between them. These relationships are then implemented in a digital model, enabling consistent design verification, parametric optimization, and integration with structural analysis tools.

B. Retaining Wall Design with Limited Foundation Depth

Scenario: A containment facility is being constructed on a site where deep excavation is restricted due to nearby utility corridors. The design must incorporate a gravity retaining wall with a foundation depth limited to 80 cm, while still resisting significant hydrostatic pressure from stored bitumen.

Use Case: With the ontology, designers can evaluate structural configurations suited to shallow foundations by exploring combinations of wider base widths, optimized wall geometry, and enhanced reinforcement patterns. The ontology supports reasoning through relationships such as foundation width-to-height ratios and pressure distribution over limited soil bearing area. By adjusting parameters in a digital model, engineers can balance stability, material usage, and footprint constraints while maintaining safety margins against sliding and overturning.

C. Reinforcement Optimization for a Durable Retaining Wall in Bitumen Storage

Scenario: An outdoor bitumen storage facility requires a reinforced concrete gravity retaining wall that can withstand long-term hydrostatic pressure without cracking or structural degradation. The design must ensure a durable wall section by properly configuring the vertical and horizontal reinforcement within the stem to control bending, shear, and crack width under sustained loads.

Use Case: Using the ontology, engineers can define and compare reinforcement schemes by adjusting properties such as bar diameter, spacing, and layer configuration. Logical relationships link reinforcement layout to wall height, thickness, and loading conditions. The ontology enables selection of appropriate steel grades, spacing limits, and detailing rules (e.g., minimum cover) in compliance with design codes. By creating parametric wall models with varying reinforcement arrangements, engineers can analyze structural performance under hydrostatic loads and optimize for both safety and material efficiency.

References

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