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How to Design a Structural Surface That Doubles as an Energy and Data Substrate

You have a wall, a slab, or a foundation that already carries structural load, and you want that same mass to also store energy, distribute power, carry data, and prove what it is. The hard part is not the physics of any one function; it is making all of them coexist, stay governable, and travel with the material. This guide describes an architecture for that, disclosed in U.S. Provisional Application No. 64/050,895 (not a shipping library), whose home inventive step is the Credentialed Surfaces inventive step.

What You Are Building

You are building a structural element, a wall, a slab, a foundation, a precast block, that is simultaneously credentialed to carry more than one function. Its primary job is still structural. On top of that, the same physical mass can hold an energy storage function, an electrical distribution function, a data networking function, a thermal coupling function, and a carbon sequestration record. The goal is not a battery bolted to a wall. The goal is a single piece of building material that carries these capabilities as declared, independently signed properties, and that carries proof of those properties with it from the factory through installation, service, and recycling.

This is a design problem faced by anyone who wants the built environment itself to do work that today requires separate installed equipment: battery rooms, distribution wiring, network cabling, cooling loops. If you are architecting long-duration storage, a data center power and cooling plant, or a distributed grid resource, and you are tired of paying for storage capital that scales only with dedicated devices, this is the approach to understand. The filed disclosure calls the inversion "substrate-mode storage": storage as a credentialed property of structural materials, aggregated by the building's own electrical system, rather than storage as a property of dedicated devices.

Why the Obvious Approaches Fall Short

The obvious approach is a structural battery: take a battery cell and embed it into a host material such as a carbon-fiber panel. This is real, demonstrated work, and the disclosure is explicit that cell-level structural batteries exist and ship in specialty electric-vehicle and aerospace applications. The limitation is architectural, not a straw man. In that approach the storage device is the architectural primary and the structure is a host shell. Each cell or pack remains a discrete connected device that needs its own power-electronics interface, and the design does not treat thermal, fire, distribution, or carbon behavior as independent, separately governed peers of the storage function.

The second obvious approach is to keep storage as installed equipment and wire it up conventionally. Here the gap is in the codes and management systems, not the hardware. Building codes today recognize load ratings, fire ratings, R-values, sound transmission, and vapor permeability as material properties. None of them recognize energy storage, electrical distribution, data networking, or carbon sequestration as material properties of a structural element. Electrical codes treat storage exclusively as installed equipment. Building energy management systems treat installed batteries as discrete connected loads or sources; there is no provision for one to discover storage distributed across structural elements, characterize who may access it, aggregate it into a coherent resource, and dispatch from it under evaluated permissions.

So the structural gap is this: there is no shared architectural primitive under which structural, thermal, energy, distribution, network, fire, and carbon properties are all independently credentialed but compositional surfaces of one substrate. That primitive is what you are building.

The Architecture

The architecture rests on one data object: the credentialed admissibility profile. Every mechanism below traces to the filed disclosure.

Property surfaces. A credentialed structural element carries an admissibility profile made of a plurality of admissibility surfaces. Each surface declares property-specific parameters and admission conditions for one property category: structural, thermal, energy storage, electrical distribution, data network, water-coupled, thermal-coupling, fire-performance, sound-transmission, vapor-permeability, environmental, and carbon-sequestration. A profile must carry at least two such surfaces to qualify as multi-property. Critically, each surface is independently credentialed by an authority with a declared scope. In the disclosed model a structural engineering authority signs the structural surface, a thermal-rating authority signs the thermal surface, a fire-marshal authority signs the fire-performance surface, a utility or building-code authority signs the storage surface, and an environmental-credit authority signs the carbon surface. No single authority owns the whole element.

Composition rules. Surfaces do not just coexist; they interact through a composition-rule architecture. A composition rule is itself a credentialed, signed, versioned data artifact held in a composition-rule registry. Each rule declares a scope of surfaces and conditions it applies to, a composition logic for how those surfaces interact, a version vector for deterministic conflict resolution, a conflict-resolution policy (the disclosed options are latest-signed-rule, declared-precedence-table, and authority-rank-resolution), and an authority signature. The disclosure gives representative rules you can model directly: a fire-event rule that drives storage admissibility to zero when the fire surface reports a fire event; a rule that constrains storage dispatch during high thermal-surface readings; a rule that derates storage as a function of cumulative freeze-thaw cycles or carbonation depth; and a rule that reduces storage admissibility when the structural surface reports fatigue above a threshold. The registry is consumed by the building energy management system at the moment it evaluates admissibility.

The lineage chain. The profile is bound to the element's identity by cryptographic signature and travels with the element through manufacturing, installation, operation, and end-of-life. Every lifecycle transition, pre-installation credentialing, in-service dispatch, state-of-health attestation, end-of-storage-life, decommissioning, recycling-grade re-credentialing, is a signed event recorded in a lineage chain. This is what makes the material cradle-to-cradle: end-of-storage-life updates the storage surface to reduced capacity while the structural surface keeps carrying load, and a recycler authority can later re-credential recovered material at a recycled grade. The disclosure also describes continuous re-credentialing, where in-service material flows (mortar repointing, coating refresh, cavity-fill replacement) are themselves credentialed events, so the element's identity persists across material turnover.

The management system as aggregation primitive. The building energy management system, not per-element power electronics, is the aggregation primitive. It runs a discovery module, a characterization module, an attestation module, an aggregation module, an access-evaluation module, and a dispatch module. It discovers credentialed elements, characterizes their profiles against the building's operational spec, signs state-of-health attestations, sums capacity weighted by state-of-health, evaluates access requests against the composite profile (admit, deny, or partial-admit), and dispatches, recording each dispatch in lineage.

The physical storage layer is deliberately held at arm's length by this architecture, and the disclosure is careful about what it is. The storage medium is biomass-derived carbonaceous material, in the primary embodiment turbostratic graphene produced by flash Joule heating, distributed in a cementitious matrix, storing energy in an electric double layer at the graphene-electrolyte interface. The underlying materials science and physical effects here are pre-existing and treated as prior art in the disclosure. The disclosed novelty is the combination and the credentialing architecture, a new category of building material, not a newly discovered basic science of carbon or cement. Because chemistry is declared in the profile and governed by composition rules, the architecture is chemistry-invariant: capacitive, asymmetric pseudocapacitive, Faradaic, and air-cathode classes all admit through the same framework.

How to Approach the Build

You implement this yourself. The following ordered steps mirror the disclosed architecture.

1. Define your property surfaces first, not your storage cell. Decide which of the surfaces your element will carry. Every one of them needs its own parameter schema and admission conditions. An illustrative, spec-faithful sketch of what a profile looks like:

```
CredentialedAdmissibilityProfile {
  elementIdentity:   <bound identity>
  surfaces: [
    { type: "structural",  params, admissionConditions, authoritySig },
    { type: "storage",     params, admissionConditions, authoritySig },
    { type: "thermal",     params, admissionConditions, authoritySig },
    { type: "fire",        params, admissionConditions, authoritySig },
    { type: "carbon",      params, admissionConditions, authoritySig }
  ]
  compositionRuleRefs: [ ... ]
  lineageChainRef:     <ref>
}
```

Treat this as illustrative only; the disclosure describes the object, not a wire format you can copy.

2. Assign an authority per surface. The design principle is separation: the party competent to attest a property signs only that property. Model authorities as distinct signers with declared scope. Do not let one signer vouch for everything, because your composition and lifecycle logic depends on being able to trust or revoke surfaces independently.

3. Build the composition-rule registry before you build dispatch. Author each rule as a signed, versioned artifact with an explicit conflict-resolution policy. Start with the safety-critical rules from the disclosure (fire-event zeroing storage, thermal constraint on dispatch) because those are the rules that make the composite governable. Your admissibility evaluator reads the registry at evaluation time, so the registry, not hardcoded logic, is where behavior lives.

4. Choose an identity binding. The disclosure describes three identity classes you can implement: a tag-bonded identity (RFID, NFC, or optical tag bonded at manufacture), a physical-fingerprint identity (a signed hash of observable characteristics such as an impedance signature or fiber-distribution pattern), and a per-batch-with-subdivision identity (a batch identity subdivided into per-element identities by the installer authority). Pick per your manufacturing reality.

5. Implement the lineage chain as append-only signed events. Every transition, from pre-installation credentialing to recycling re-credentialing, is one signed event. Design it so the structural surface can outlive the storage surface: end-of-storage-life is a state change, not a demolition trigger.

6. Build the management system as six modules. Discovery, characterization, attestation, aggregation, access-evaluation, dispatch. Keep aggregation at the system level so you never require per-element inverters just to participate.

7. Only then choose your physical implementation class. The disclosure gives you a ladder: a passive substrate using cement pore solution alone with perimeter terminals (simplest, low-power reserve, good for retrofit coatings); an open-cell ambient-water-coupled class for marine and hydraulic works; and an engineered closed-cell cavity-bath class with sealed engineered electrolyte, refillable through a fill-and-drain manifold, for the highest performance envelope. Select the class through the electrolyte-architecture-selection composition rule rather than hardwiring it.

What This Does Not Give You

This is an architecture, not a drop-in library. There is no package to install, no SDK, and nothing here "just works" out of the box. You implement the profile object, the authorities, the registry, the lineage chain, and the management-system modules yourself, and you engineer the physical substrate to your codes and climate.

It is a provisional disclosure of an architecture. Nothing described here is claimed to be built, validated, benchmarked, or production-proven. Where the disclosure states parameter ranges, energy density, cycle life, round-trip efficiency, cavity dimensions, conductivities, they are the disclosure's own projected or as-disclosed figures, not measured results, and you should treat them as design targets to verify, not guarantees. The materials science underneath (turbostratic graphene, double-layer storage, cementitious chemistry) is pre-existing prior art; the architecture is the contribution, so do not expect it to advance the physics.

It also does not relieve you of code compliance. Real deployments must satisfy structural, electrical, and fire codes, grounding and bonding, arc-flash and shock protection, fault isolation independent of the management system, and inspection provisions. The architecture gives you a way to declare and govern those; it does not certify them for you. And it does not apply everywhere: where high per-mass energy density is the dominant requirement, the carbon-only capacitive class may be the wrong choice, and the disclosure itself points to Faradaic and air-cathode classes with their own tradeoffs.

Disclosure Scope

The architecture described in this guide is disclosed in U.S. Provisional Application No. 64/050,895. This guide is educational. It explains an architectural approach so a skilled developer can understand and build it; it is not a warranty, a performance guarantee, or an offer of software, and it does not describe a shipping product. All parameters, ranges, and behaviors attributed here to the disclosed approach are drawn from that filing and are presented as disclosed or projected, not as measured or certified results. The home inventive step is the Credentialed Surfaces inventive step.

Credentialed Surfaces (/credentialed-materials)

All 40 steps → (/inventive-steps)

Building surfaces as credentialed agents that participate in the structure's networking and electrical systems.

Provisional application

PRIMARY TECHNICAL DISCLOSURE

- Credentialed Building Materials: Cryptographic Admissibility for Structural Surfaces (/articles/credentialed-building-materials-cryptographic-admissibility-for-structural-surfaces)

SECONDARY TECHNICAL

- Carbon-Sequestration Admissibility Surface (/articles/credentialed-materials/carbon-sequestration-property-surface)
- Composition Rules Governing Surface Interactions (/articles/credentialed-materials/composition-rules)
- Decommissioning And Re-Credentialing Attestation (/articles/credentialed-materials/decommissioning-and-recredentialing)

- Electrical-Distribution Admissibility Surface (/articles/credentialed-materials/distribution-property-surface)
- End-Of-Storage-Life Attestation (/articles/credentialed-materials/end-of-storage-life-attestation)
- Energy-Storage Admissibility Surface (/articles/credentialed-materials/energy-storage-property-surface)
- Lineage Chain Across Material Lifecycle (/articles/credentialed-materials/lineage-chain-across-lifecycle)
- Authority Signatures Block Binding Property Surfaces To Material Identity (/articles/credentialed-materials/master-credential-binding)
- Multi-Authority Signature Block (/articles/credentialed-materials/multi-authority-signature-block)
- Data Network Admissibility Surface (/articles/credentialed-materials/network-property-surface)
- Profile Versioning Continuity (/articles/credentialed-materials/profile-versioning-continuity)
- Structural Admissibility Surface (/articles/credentialed-materials/structural-property-surface)
- Thermal-Property Admissibility Surface (/articles/credentialed-materials/thermal-property-surface)
- Versioned Admissibility Profiles With Lineage Chain (/articles/credentialed-materials/versioned-profiles-with-lineage)
- Water-Coupled Admissibility Surface (/articles/credentialed-materials/water-coupled-property-surface)

APPLICATIONS · GENERAL

- Credentialed Structural Materials for Construction and Civil Infrastructure: Carrying Strength, Mix, and Provenance as Multi-Authority Attestations (/articles/credentialed-materials/construction-and-infrastructure)
- Carbon-Credit-Bearing Building Materials: Sequestration Attestations That Survive Incorporation, Transfer, and Decommissioning (/articles/credentialed-materials/carbon-credit-materials)
- Building-Product Compliance and Code Approval: Property-Surface Profiles as Machine-Evaluable Admissibility Evidence (/articles/credentialed-materials/building-product-compliance)
- Credentialed Building Materials for Real Estate Valuation, Insurance, and Disclosure: A Property History That Binds to the Asset (/articles/credentialed-materials/real-estate-and-asset-lifecycle)
- Recredentialing Recovered Materials: Verifiable Lineage for Reuse and Decommissioning in the Circular Economy (/articles/credentialed-materials/circular-economy-and-decommissioning)
- Energy and Grid-Coupled Surfaces: Crediting Stationary Storage in Structural Mass Without Trusting the Cell (/articles/credentialed-materials/energy-and-grid-surfaces)

- Credentialed Surfaces for Water and Environmental Infrastructure: Signed Performance and Compliance Attestations on Water-Coupled Concrete (/articles/credentialed-materials/water-and-environmental-infrastructure)
- Data-Center Infrastructure Substrate: Collapsing UPS Rooms, Cooling Distribution, and Raised-Floor Wiring Into One Credentialed Structural Surface (/articles/credentialed-materials/data-center-infrastructure)
- Turning EV-Charging Sites Into Structure: Credentialed Substrate That Stores, Distributes, and Settles Power in the Slab (/articles/credentialed-materials/ev-charging-infrastructure)

APPLICATIONS · SPECIFIC

- Circularise, a blockchain-based supply-chain traceability and digital-product-passport platform for materials vs credentialed material surfaces: attestations bound to the physical material (/articles/credentialed-materials/circularise)
- EC3 (Embodied Carbon in Construction Calculator) by Building Transparency vs a credentialed carbon-sequestration surface bound to the material (/articles/credentialed-materials/ec3-building-transparency)
- CarbonCure Technologies, which injects and mineralizes CO2 into concrete during mixing vs a credentialed carbon-sequestration attestation architecture (/articles/credentialed-materials/carboncure)
- Sublime Systems, maker of low-carbon cement via an electrochemical (ambient) process vs a credentialed carbon-sequestration surface bound to the material (/articles/credentialed-materials/sublime-systems)
- Brimstone carbon-negative portland cement vs credentialed material attestations: process decarbonization or per-element carbon accounting? (/articles/credentialed-materials/brimstone)
- The EU Digital Product Passport (DPP) under the Ecodesign for Sustainable Products Regulation (ESPR) vs credentialed surfaces: a data-carrier standard next to a material-bound attestation architecture (/articles/credentialed-materials/eu-digital-product-passport)
- One Click LCA, a life-cycle-assessment and EPD software platform for construction vs a credentialed carbon-sequestration property surface bound to the material (/articles/credentialed-materials/one-click-lca)
- Concrete.ai vs credentialed carbon-sequestration surfaces on structural materials (/articles/credentialed-materials/concrete-ai)
- Madaster alternative: material passports as a building registry vs credentialed surfaces bound to the physical material (/articles/credentialed-materials/madaster)

Credentialed Surfaces overview → (/credentialed-materials)