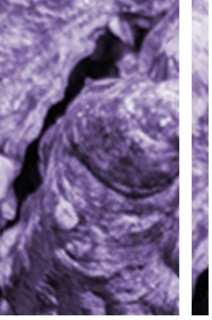
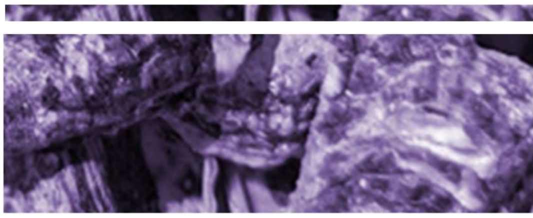
SHELL SHOCKED

RESURECTING AN OBSOLETE CONSTRUCTION MATERIAL TO COMBAT OUR INSATIABLE APPETITE



CONTENTS



INTRODUCTION

The high demand for oysters globally has led to an ironic existence: this saltwater mollusc praised for its ability to filter 200L of water a day[1] has become the pollutant itself with an estimated 10 million tonnes of shell waste discarded a year, most of which ends up in landfills.[2] Historically, shells have played a significant role in construction, but with oyster consumption at an all-time high the use of shells in the construction industry has almost vanished. Inspired by emerging organisation's hard work to divert shells from landfill, this submission explores the return of oyster shells to the construction industry offering a plethora of affordable, sustainable and low embodied-energy materials to Australia's construction industry and a system to ensure its effective specification amid rising waste from our ever-increasing appetite.

[1] Oyster Heaven (2022), Ocean's Clean-Up Crew: How Do Oysters Filter Water?

[2] Topic Popovic, N. et. al. (2023), Shell Waste Management and Utilization: Mitigating Organic Pollution and Enhancing Sustainability

THE OYSTER...

Oysters today are typically associated with fine dining and considered a delicacy in many cultures, however, this mollusc had formed an important part of the human diet for several thousand years. Found in marine and brackish environments, oysters are a mollusc with a fleshy edible interior surrounded by a highly calcified shell.

Nicknamed the "canaries of the estuaries"[3] it is suggested that oysters are amongst the most sustainable animal to farm[4] and are often an indicator of a body of water's overall health. In Australia the most common oysters consumed include Sydney Rock Oysters, Pacific Oysters and Flat Oysters[5] all of which are grown on shores and estuaries along Australia's coasts. After 3-4 years of growing, the oysters are ready for consumption and sold to restaurants. As the global population increases, as does the demand for oysters with consumption increasing fivefold since 1990[6]. The popularity of the mollusc has been pushed by both an interest in fine dining and health benefits associated with consumption of natural organic products.

Figure 1: Sydney Rock Oysters

[3] Nash C. et al (2024), Monitoring the canaries of our catchments
[4] GoodFish (2019), Oysters
[5] Fisheries Research & Development Corporation (2020), 2020-2025 Oysters Australia Strategic Plan
[6] Botta, R. et al, (2020), A review of global oyster aquaculture production and consumption

...AND THE PROBLEM

Despite the net positive effect of oysters on Australia's waterways, the massive increase in the number of oyster shells has become problematic. Proteins in the shells cause calcium carbonate to form calcite crystals making the shells tough to break and thus almost impossible to break down.[7] As such, mollusc shells do not decompose in landfills, which is unfortunately where the majority end up if not dumped into the ocean.[8] Evidence of shell middens in Australia dates back tens of thousands of years confirming the longevity of shells and strength of material.[9]

It is a biproduct that is frequently overlooked as it is considered a natural product, yet it is the part of the 350kt of seafood consumption in Australia per annum[10] growing by approximate 8% every year[11]. In 2018-2019 the oyster industry of New South Wales produced 76 million oysters across 280 oyster farming businesses throughout 32 coastal estuaries.[12]

By collecting discarded shell waste destined for landfill, organisations such as Shuck Don't Chuck and OzFish have recognised the growing issue and are partnering with restaurants to use mollusc shells in reef restoration projects. The process typically involves a six to twelve month curing process to eliminate any diseases[13] before placing the shells in hatchery tanks for juvenile oysters, and then relocation to the ocean floor. These companies aim to reinstate habitats from near the brink of extinction and make a substantial contribution to improving Australia's estuaries and oceans.[14]

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[7] Woods Hole Oceanographic Institution (2024), How are seashells made?
[8] Topic Popovic, N. et. al. (2023), Shell Waste Management and Utilization: Mitigating Organic Pollution and Enhancing Sustainability
[9] Tasmanian Government, Aboriginal Heritage Tasmania Department of Natural Resources and Environment Tasmania (date unknown), Aboriginal Middens
[10] Australian Government Department of Agriculture, Fisheries and Forestry (2022), Seafood consumption in Australia
[11] Fisheries Research & Development Corporation (2020), 2020-2025 Oysters Australia Strategic Plan
[12] Ocean Watch Australia (2024), NSW Oysters
[13] The Nature Conservancy Australia (2024), Shuck Don't Chuck: shell recycling project
[14] Cottingham, A. (2022), Quantifying the Potential Water Filtration Capacity of a Constructed Shellfish Reef in a Temperate Hypereutrophic Estuary

Figure 2: Shells Curing at TNC'S Curing Site

Figure 3: Shells Curing in SA

A SOLUTION

Oyster and mollusc shells are no stranger to the built environment and have deep roots in Australian history. Archaeological evidence such as shell middens scattered around the coasts of Australia has proven the importance of shellfish to First Nations people as a source of food, trade and culture.[15] Some studies suggest shellfish consumption by Indigenous Australians date back over 8000 years with species including mussels, pipis, snails, abalone and oysters[16]. The current presence of midden in amongst today's coastal landscapes suggests the longevity of shells and strength of material.[17]

European colonisers in Australia turned to shell waste to produce quicklime as limestone was not discovered in mainland New South Wales until 27 years after the founding of the convict colony,[18] destroying Aboriginal coastal middens in the process.

"I have not yet discovered anything lime limestone, but the quantity of oyster shells on the beaches inland is beyond conception; they are in some places for miles. These are four foot deep without either sand or earth" [19]

The burning of shells to make lime "*provided excellent lime to make mortar*"[20] though the collecting of shells was time consuming for such little yield in primitive kilns. As the colony grew in numbers, the oyster population dramatically fell and the burning of oyster shells for lime was banned by the government in 1868[21] prompting oyster farming in the years following.

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[15] Reeder-Myers, L., et al. (2022) Indigenous oyster fisheries persisted for millennia and should inform future management
[16] Gibbs, M. C., et al (2006), Recognising the importance of shellfish to First Nations peoples, Indigenous and Traditional Ecological Knowledge in aquaculture and coastal management in Australia
[17] Tasmanian Government, Aboriginal Heritage Tasmania Department of Natural Resources and Environment Tasmania (date unknown), Aboriginal Middens
[18] Mayer, W. (2007), Four Centuries of Geological Travel
[19] Mayer, W. (2007), ibid
[20] Mayer, W. (2007), ibid
[21] Government of New South Wales (1867), Oyster Beds Acto of 1868 No 3a (NSW)

Physical evidence of tabby, a type of concrete constituted of shell, lime and sand, dates to the 1670s, with some sources indicating an earlier presence.[22] Tabby was desired prior to the development of Portland cement for its low cost, easy to access materials, strength, durability and resistance to fire with many tabby buildings still standing today. However, limits on wild caught oysters amongst a growing population and the production of Portland cement stunted the continuation of tabby and shells in the construction industry in general.

We are unable to satisfy our global craving for oysters, and thus the mass abundance of shell waste. A resurgence oyster shells in construction can have a positive impact on the building industry and pave the way for a more sustainable built environment offering a material from a renewable source to replace those that aren't.

But how can architects control and communicate quality and performance of the use of oyster shells in the construction industry to ensure materials can achieve the highest practicality but the required aesthetic desired by designers. And how can this be done with ease to ensure our increasing appetite for the mollusc can be sustainably and financially beneficial to the built environment.

Figure 4: Lime kilns near Coogee Beach, 1910s

[22] Gritzner, Janet Bigbee (1978). Tabby in the Coastal Southeast: the Culture History of an American Building Material

REINTRODUCTION

USAGE 01: SHELLS

Rather than a resurgence of oyster shells used in a single material, this proposal seeks to explore how oyster shells can be used across the breadth of the built environment and how architects and building designers can effectively specify shells to ensure quality across their reintroduction into Australia's construction industry.

A FOUR-PRONGED APPROACH TO EFFECTIVELY EXPLAIN THE DESIRED QUALITY OF SHELLS

To do this effectively, it is important for architects to be able to efficiently explain the quality of material that is to be achieved to clients, builders and contractors. The variance of a naturally occurring material can have vastly different aesthetic outcomes and structural qualities. By using the following four-tiered approach, architects can have more control over the finished product by being able to directly specify a materials desired outcome through a shell grading system when whole shells or shell fragments are used within a project.

CATEGORY 01: GRADING BY SPECIES

Along with allowing architects to achieve a desired aesthetic potential, grading by species is critical when considering the embodied energy of a product. While Australia is capable of farming oysters, the type and species of oysters is exceptionally reliant on the temperature of the water of which it is grown in. This means a Victorian architect specifying the use of a tropical oyster can dramatically increase the embodied energy of a project in shipping of materials. Similarly, incorrectly specifying an oyster that is solely cultivated internationally – while still saving oyster shells from landfills – may be a less sustainable than a locally grown oyster.

As oyster shells are exported Australia wide for consumption, exceptions can be made for locally sourced oyster shells that have already been transported to local restaurants and serveries. However, as a general rule the following table shall apply to ensure shells from the north of Australia are not specifically transported to the south of Australia for use in a building product in an effort to reduce the overall emissions associated with the shells.

SPECIES	TAS	VIC	SA	ACT	NSW	QLD	WA	NT
Magallana gigas *Pacific Oyster*	X	X	X	X	X	SOUTH ONLY	SOUTH ONLY	
Saccostrea glomerata *Sydney/Albany Rock Oyster*				X	X	SOUTH ONLY	SOUTH ONLY	
Ostrea angasi *Angasi Oyster*	X	X	X					
Saccostrea cucullate *Hooded Oyster*								
Pinctada maxima South Sea Pearl Oyster							NORTH ONLY	X
Pinctada fucata *Akoya Pearl Oyster*					NORTH ONLY	SOUTH ONLY	X	X
Pinctada margaritifera *Black Lip Pearl Oyster*						NORTH ONLY	NORTH ONLY	X

* Table above generally refers to the coastal regions of each state. Architects should specify species closest to the location of construction

* *North NSW* refers to the coasts of Woolongong and above

* *South WA* refers to the southern coasts of Western Australia including Esperance, Albany and Perth

**North WA* refers to the Kimberlys and Broome

* *South QLD* refers to K'gari and south

CATEGORY 02:
GRADING BY SHELL

Oyster shells are made up of two parts: the cupped left shell and the flat right shell. Oysters are typically served in the left shell due to the natural cupping of the shell forming a natural serving platter. While both shells have a hard calcium carbonate makeup, they differ slightly which will affect the usage in the built environment.

The hinge of the left outer shell is significantly thicker than the rest of the shell and takes on a different shape, causing it to differ slightly in thickness between the centre of the shell and the edges of the shell. The right shell is much flatter in shape yet has an almost feathery and organic lip. Being able to effectively communicate the part of the shell for usage and even the orientation when used in full shell applications will have implications for the outcome.

NAMING CONVENSION	DESCRIPTION	EXEMPLAR
LSE (left shell exterior)	- Cupped oyster shell in which typically the flesh is served - Coloured exterior facing externally	
RSE (right shell exterior)	- Flat oyster shell which is typically discarded - Coloured exterior facing externally	
LSI (left shell interior)	- Cupped oyster shell in which typically the flesh is served - White interior facing externally	
RSI (right shell interior)	- Flat oyster shell which is typically discarded - White interior facing externally	
RSX or LSX	- Right shell or left shell as notated without a preference of external face	Any of the above shall apply

APPLICATION

Exemplar 01: the left oyster shell rain chain would be classified as **LSE**, as it is comprised of the left shell with it's exterior face facing externally.

Exemplar 02: the left oyster shell rain chain would be classified as **LSI**, as it is comprised of the left shell with its interior face facing externally.

Exemplar 03: the left oyster shell pergola would be classified as **RSE**, as it is comprised of the right shell with it's exterior face facing externally.

Exemplar 04: the left oyster shell pergola would be classified as **RSI**, as it is comprised of the right shell with it's interior face facing externally.

Exemplar 05: any aggregate or gravel application of oysters shells would be classified as RSX and/or LSX due to the inability to control the direction of shell. This concrete tile sample is classified as **LSX** as it solely uses the left shell and has no control over exterior facing orientation.

CATEGORY 03:
GRADING BY COLOUR

There is a natural variance in the colour of oyster shells depending on the species. These can range from cream to purple, brown to black or with a green hue. These can be present through stripes, patches or full colours.

While having minimal effect in the quality of its usage, establishing the desired colour outcome can have a dramatic impact on the aesthetic outcome of the material. Embedding a schedule within the specification of the colour variation and colour acceptance for a specific outcome can help architects effectively communicate the desired outcome of the material.

After selecting the suitable oyster species, the following grading system can be used to specify the desired colour outcome.

PHOTO	COLOUR GRADE	INDENTIFIABLE BY:	SPECIES PRESENT IN
	C1	Majority cream, minimal to no purple variation	- *Pacific Oyster* - *Sydney/Albany Rock Oyster* - South Sea Pearl Oyster - *Akoya Pearl Oyster*
	S1	Majority cream, thin purple stripes visible	- *Pacific Oyster* - *Sydney/Albany Rock Oyster* - *Akoya Pearl Oyster*
	S2	Striped with even distribution of cream and purple	- *Pacific Oyster* - *Sydney/Albany Rock Oyster* - *Akoya Pearl Oyster*
	S3	Majority purple, cream stripes visible	- *Pacific Oyster* - *Sydney/Albany Rock Oyster* - *Akoya Pearl Oyster*

	S4	Majority purple, cream pin stripes visible	- *Pacific Oyster* - *Sydney/Albany Rock Oyster* - *Akoya Pearl Oyster*
	B1	Blotched colours, approximately even distribution of purple and white	- *Pacific Oyster* - *Sydney/Albany Rock Oyster* - *Akoya Pearl Oyster*
	B2	Blotched, larger variation of purple colouring	- *Pacific Oyster* - *Sydney/Albany Rock Oyster* - *Akoya Pearl Oyster*
	B3	Majority purple, minimal cream blotches	- *Pacific Oyster* - *Sydney/Albany Rock Oyster* - *Akoya Pearl Oyster*
	P1	Majority purple, minimal to no cream blotches.	- *Pacific Oyster* - *Sydney/Albany Rock Oyster* - *Akoya Pearl Oyster*
	G1	Any formation of greening on the surface of the shell, regardless of under shell colour.	- *Pacific Oyster* - *Sydney/Albany Rock Oyster* - *Akoya Pearl Oyster*
	T1	Tan, striped, sometimes a sludgy green. This is largely reserved for *ostrea angasi* which has minimal colour variation	- Angasi Oyster

	L1	Majority black in colour with high presence of white dotted stripes. Base of shell may be lighter in colour.	-	Black Lip Pearl Oyster
	L2	Majority black in colour, presence of white dotted stripes	-	Black Lip Pearl Oyster
	L3	Largely black in colour with minimal to no white dotted stripes	-	Black Lip Pearl Oyster

APPLICATION

Exemplar 01: the tolerance of shell aggregate used is to be within a strict B2, B3 & P1. The below shells would be accepted for the product.

Exemplar 02: the tolerance of shell aggregate used is to be within a lenient C1 & S1. The below shells would be accepted for the product.

Exemplar 03: the tolerance of shell aggregate used is to be within a strict G1. The below shells would be accepted for the product.

CATEGORY 04:
GRADING BY SIZING

In lieu of course stones, crushed oyster shells are a suitable candidate for aggregate in the production of concrete. Similarly, crushed shells are appropriate for substitution in landscape such as pathways and free draining backfills. However, an oyster aggregate grading system needs to be established to successfully control and communicate the coarseness of aggregate.

By crushing oyster shells to different sizes, differences in material strength and material aesthetics can be achieved. By applying the following sizing chart, architects can effectively specify the sizing of crushed shells that can be used across a variety of projects. The chart can help to effectively communicate the intended patterns across concrete applications or in landscaping applications.

Naming convention	**Shell fragment sizing**	**Photo of desired effect**
Superfine shell	0.5-1cm fragments	
Fine shell	1-2cm fragments	
Coarse shell	2-4cm fragments	

Super coarse shell	4cm+ fragments	
Full shell application	Whole shells, unfragmented	

APPLICATION

- 0242 Landscape Fences and Barriers
  - Gabion walls
  - This could be a good part of the curing process for oyster shells to support shell recycling facilities. Similarly for protecting shorelines, riverbanks and slopes form erosion, to suit their traditional use
- 0271 Pavement Base and Subbase
  - Finely crushed oyster shells as a substitute for compacting sand in pavement applications
- 0310 Concrete
  - Aggregate replacement in loadbearing and non-load bearing concrete structures
- 0331 Brick and Block Construction
  - For aggregates in brick and blocks
- 0431 Cladding
  - In conjunction with 0310 Concrete, precast concrete panels with oyster shell aggregate
- 0551 Joinery
  - Use of aggregate in benchtops
- 611 Rendering and Plastering
  - Use of aggregate in renders
- 0631 Tiling
  - Use of aggregate in terrazzo style tiles

APPLICATION: APPLYING THE GRADING SYSTEM

EXEMPLAR	GRADING	SUB CATEGORY 02:	OUTCOME:
EXEMPLAR 01: Concrete paving slab application	**CATEGORY 01:** Pacific Oyster & Sydney Rock **CATEGORY 02:** LSX & RSX **CATEGORY 03:** all grades **CATEGORY 04:** Equal parts superfine, fine, coarse and supercoarse	Ratio 1:3:5 1 part concrete 3 parts sand 5 parts aggregate	
EXEMPLAR 02: Concrete terrazzo tile application	**CATEGORY 01:** Pacific Oyster & Sydney Rock **CATEGORY 02:** LSX & RSX **CATEGORY 03:** B2, B3, P1 **CATEGORY 04:** **CATEGORY 04:** fine, coarse	Ratio 1:3:2 1 part concrete 3 parts sand 2 parts aggregate	
EXEMPLAR 03: Concrete terrazzo tile application	**CATEGORY 01:** Pacific Oyster & Sydney Rock **CATEGORY 02:** LSX & RSX **CATEGORY 03:** S1, S2, S3, S4, B1 **CATEGORY 04:** superfine & fine	Ratio 1:3:5 1 part concrete 3 parts sand 5 parts aggregate	
EXEMPLAR 04: oyster shell rain chain application	**CATEGORY 01:** Pacific Oyster **CATEGORY 02:** LSE **CATEGORY 03:** All: no two grades to be used in immediate succession **CATEGORY 04:** whole shell	N/A	

EXEMPLAR 05: oyster shell gravel	**CATEGORY 01:** Pacific Oyster & Sydney Rock **CATEGORY 02:** N/A **CATEGORY 03:** All **CATEGORY 04:** superfine	N/A	

USAGE 02: OYSTER LIME & QUICKLIME

Lime is a common building material and is used across a variety of products including bricks, mortar, paints and plastering. The calcification of oyster shells produces quicklime which can be used in lieu of lime in the built environment. Given lime has little impact on the aesthetic appeal of materials, the creation and processing of quicklime becomes very important to the specification of the project, making it suitable for oyster shells unused in the above grading process, or shells that are fused or disfigured due to growth disabilities or barnacle growth or shells otherwise unused in the process.

To produce quicklime, oyster shells must be heated to approximately 900C for several hours to undergo calcification. In this process, the oysters go from their initial form to grey white and powdery[23]. Quicklime is highly reactive and will react exothermically with water and moisture to form a more stable and usable product (a process known as slaking). The two following products can be an outcome of the slaking of quicklime.

METHOD 01: HYDRATED LIME POWDER

A small amount of water is added to the quicklime to cause a reaction (slaking) in an approximately 1:1 water to quicklime ratio. The hydrated lime must then be strained and dried to form a fine powder. Hydrated lime powder has a faster set time, is easier to store and is more cost effective for larger projects given its ability to be stored. However, it has less plasticity than lime putty (see method 02) making it harder to work with and a shorter working time as it dries faster.

[23] SkillCult (2011), Lime Squad

METHOD 02: LIME PUTTY

By gradually adding a 2:1 ratio of water to quicklime, a thick and smooth putty will form. It is stored under a few centimetres of water and it’s recommended to allow to mature underwater for several days before use. Lime putty is more applicable to more plastic applications as it is easier to work and shape. It also offers less shrinkage and more breathability than hydrated lime powder but is more difficult to store (as it must be stored under a layer of water) and takes a longer time to set.

Backyard limemaking could only achieve a temperature to produce a small amount of lime

Figure 5: Lime putty: not by author

Hydrated lime powder, by author

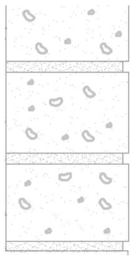
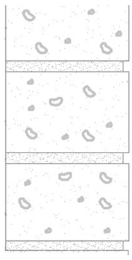
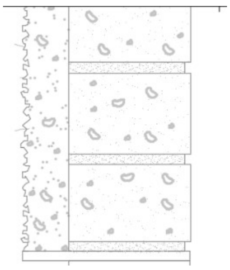
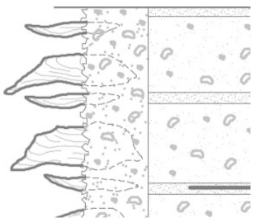
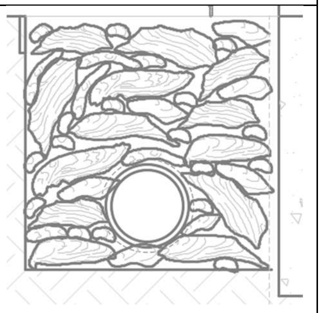
ARCHITECTS SPECIFYING THE CORRECT LIME APPLICATION FOR THE PROJECT

Allowing architects to be well informed about the lime application process allows for the best method for each project. While both methods can be used equally across the breadth of the built environment, both can have an impact on the quality and strength of the material, but also an impact on the cost and time implications of the projects given the difference in workability, setting time and ease of storage

SUITABILITY

APPLICATION	SPEED	COST	STRENGTH	WORKABILITY	LONGEVITY	SUGGESTED (GENERALLY)
Brickmaking	HLP	HLP	LP	HLP	LP	**HLP** Due to the high number of bricks required in typical projects, hydrated lime powder will improve the cost effectiveness through a reduction in onsite labour and more difficult lime storage requirements. In smaller scale projects or for double skin loadbearing brickwork, **LP** may be more applicable.
Binders including mortar and grout	LP	HLP	LP	LP	LP	**LP** Due to the plasticity required in mortar, lime putty is more easily workable and will reduce onsite labour requirements due to the speed of application through workability. However, in larger scale projects HLP may be considered due to the ease of storage, especially on large construction sites.
Plastering & rendering	LP	HLP	LP	LP	LP	**LP** Due to the plasticity required in plastering, lime putty is more easily workable and will reduce onsite labour requirements due to the speed of application through workability especially for more detailed applications.
Limewash & lime paint	LP	LP	LP	LP	LP	**LP** Only lime putty is recommended for lime washing due to the plasticity and wetness of the product.
Repointing	LP	LP	LP	LP	LP	**LP** Only lime putty is recommended for use in repointing due to the plasticity of the product.

MATERIAL EXEMPLARS

EXEMPLAR	GRADING	LIME	NOTES	OUTCOME:
EXEMPLAR 01: General bricks	**CATEGORY 01:** Pacific Oyster, Sydney Rock Oyster, Angasi Oyster **CATEGORY 02:** N/A **CATEGORY 03:** all **CATEGORY 04:** superfine	Hydrated lime powder	Ratio: 1 part lime, 3 parts aggregate, 1 part sand, water to form clay consistancy	
EXEMPLAR 02: General brickwork mortar	**CATEGORY 01:** Pacific Oyster, Sydney Rock Oyster, Angasi Oyster **CATEGORY 02:** N/A **CATEGORY 03:** all **CATEGORY 04:** superfine	Hydrated lime powder	Ratio: 1 part lime, 3 parts aggregate & sand, water as required	
EXEMPLAR 03: General lime render	**CATEGORY 01:** Pacific Oyster, Sydney Rock Oyster, Angasi Oyster **CATEGORY 02:** RSX & LSX **CATEGORY 03:** all **CATEGORY 04:** superfine, fine, coarse	Hydrated lime powder	Ratio: 1 part lime, 3 parts aggregate & sand, water as required	
EXEMPLAR 04: Wall type 02: refer to working drawing set	**CATEGORY 01:** Pacific Oyster, **CATEGORY 02:** LSE & RSI **CATEGORY 03:** C1 only **CATEGORY 04:** Whole shell	Hydrated lime powder	Grading dictates whole shell usage in wall type. Refer to above for general lime render.	
EXEMPLAR 05: Agricultural drain: refer to working drawing set	**CATEGORY 01:** Pacific Oyster, Sydney Rock Oyster, Angasi Oyster **CATEGORY 02:** RSX & LSX **CATEGORY 03:** all **CATEGORY 04:** Super coarse, whole shell	N/A	Shells as free draining backfill for slotted agricultural drain	

CONCLUSION

Although oyster shells were once a key material in construction, their use was made obsolete from the built environment due to their scarcity. With dramatic increases in oyster consumption - and thus oyster shell wastage – the return of oyster shells to the construction industry can divert kilotons of shells destined for landfill offering Australia an affordable, sustainable and renewable material, providing a practical solution to the growing waste problem and promoting effective utilisation within Australia's construction sector.

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