Oldcastle APG University

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A CRH COMPANY

New Masonry Installation Technology

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New Masonry Installation Technology

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AIA 1 Learning Unit (LU/HSW)

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Learning Objectives:

Learning Objective #1:
Participants will understand how a design will go from a CAD file to installation and how this will ensure that the design intent and code standards will be implemented assuring a safe and healthy project.

Learning Objective #2:
Participants will understand how robotic technology can install CMUs on a project following construction best practices to ensure a save and healthy building.

Learning Objective #3:
Participants will understand that robotically installed CMU's will not sacrifice the quality control standards of traditional masonry

Learning Objective #4:
We will review the economic opportunities new technology can offer a project.

New Masonry Installation Technology

May 2022

About **FBR**

- **FBR** designs, develops, builds and operates dynamically stabilised robots.
- **FBR**'s flagship product, **Hadrian X®**, is the world's most advanced construction robot.
- **Hadrian X®** is designed to produce block structures safer, faster, cheaper, more accurately and with less waste than traditional construction methods.

About FBR

- **Hadrian X®** is enabled by **FBR**'s **Dynamic Stabilization Technology® (DST®)**

- **FBR** offers a new **Wall as a Service®** commercial model, where builders can order robotically erected walls with certainty on timing, cost, safety and waste.

- **Hadrian X®** is operating in the field already, delivering **Wall as a Service®** in Western Australia.

FBR Solution

- **Hadrian X®** is the only solution that is fully mobile without sacrificing utility, versatility, de-automation or speed of completion.

- Minimal mobilization and demobilization time – no gantry setup, minimal site footprint, can build from the road or any other side of a construction site.

- Uses existing building materials and produces walls that are visually the same as existing walls.

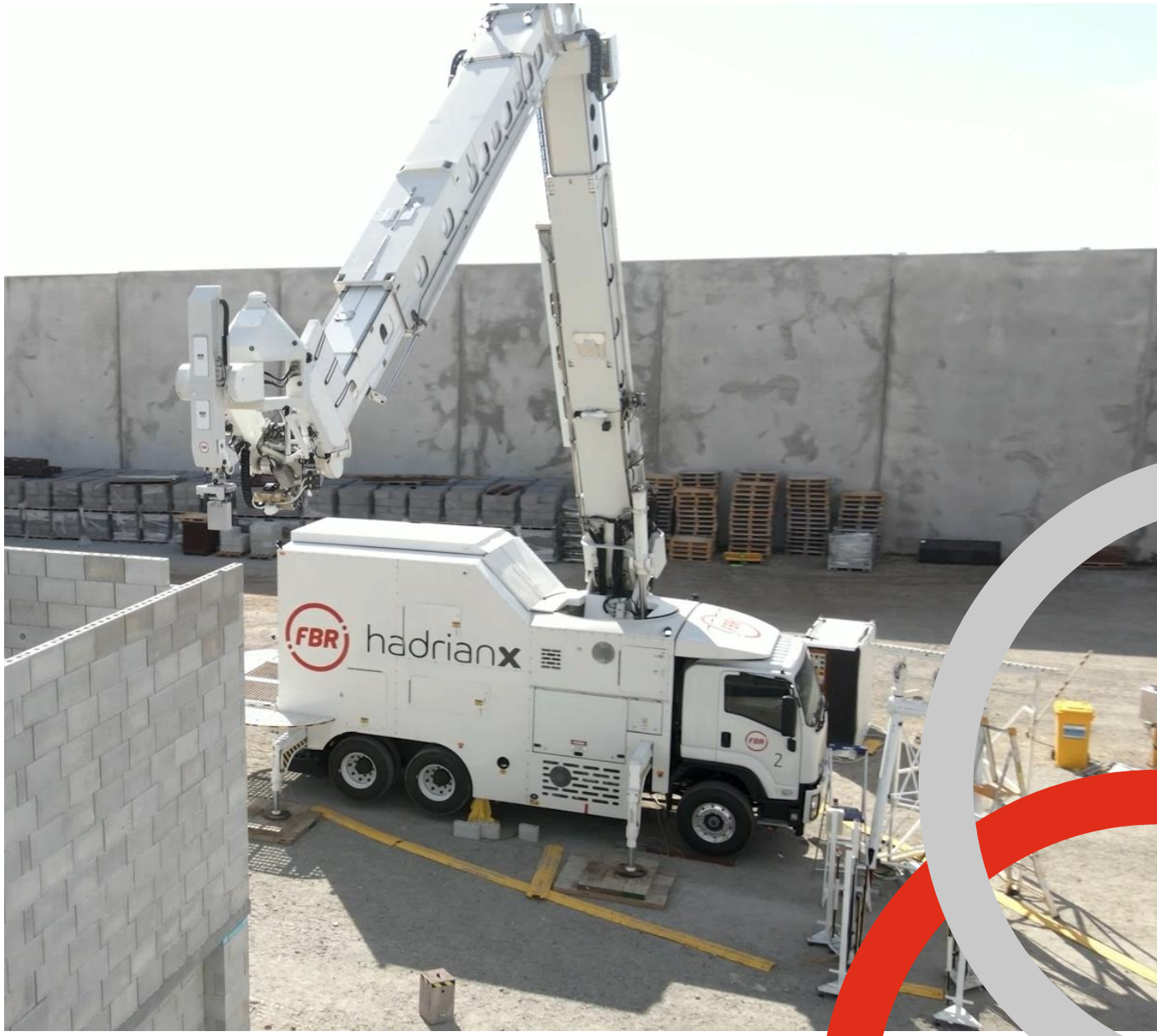
FBR Solution

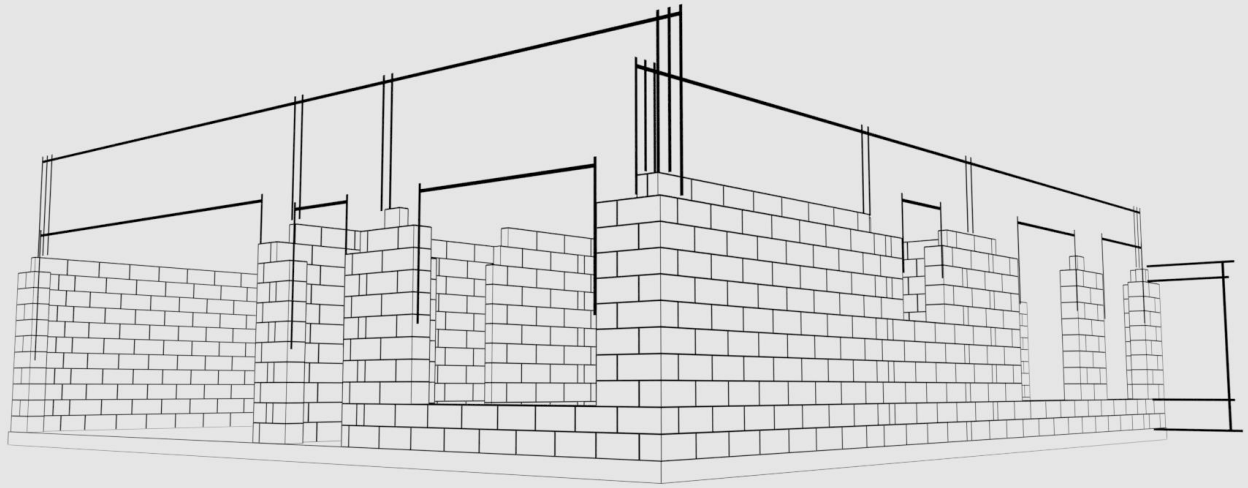
- Architectural software automatically populates CMU's from existing designs to generate **Hadrian** build file.
- Already compliant with building codes in some jurisdictions, working toward certification in others.
- Already in use in the Western Australian market in commercial application, delivering structures faster, more accurately, safer and with less waste than traditional construction methods.

Introducing **Hadrian X®**

- **Hadrian X®** builds block structures from a 3D CAD model, producing far less waste than traditional construction methods while dramatically improving site safety.

- **Hadrian X®** is capable of building the walls of a house in situ in as little as a day, with no human hand touching a brick.





3D CAD Model

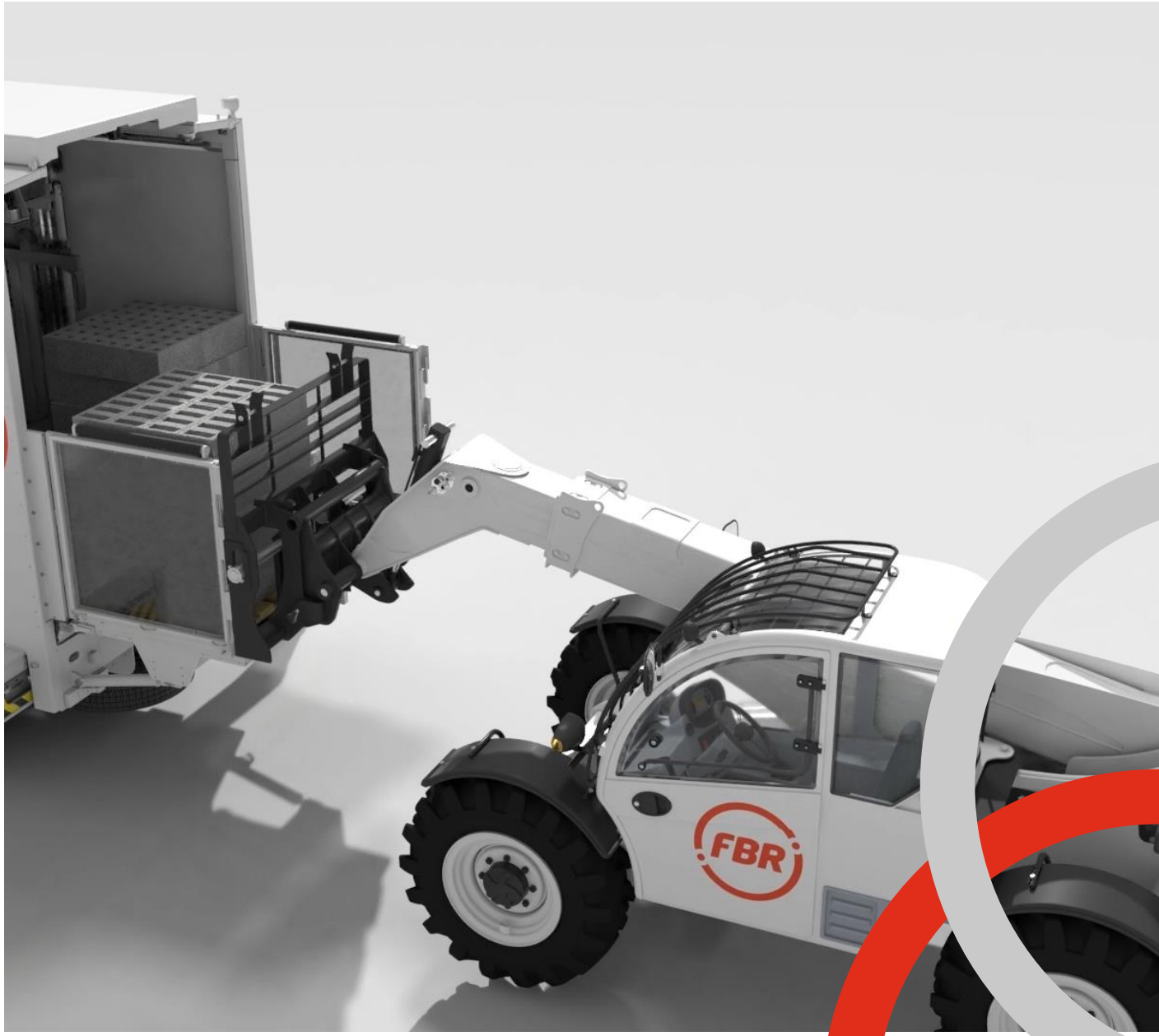
- Unique optimization software converts wall sketches into block positions, and minimizes handling and waste of block products to improve efficiency of residential construction.

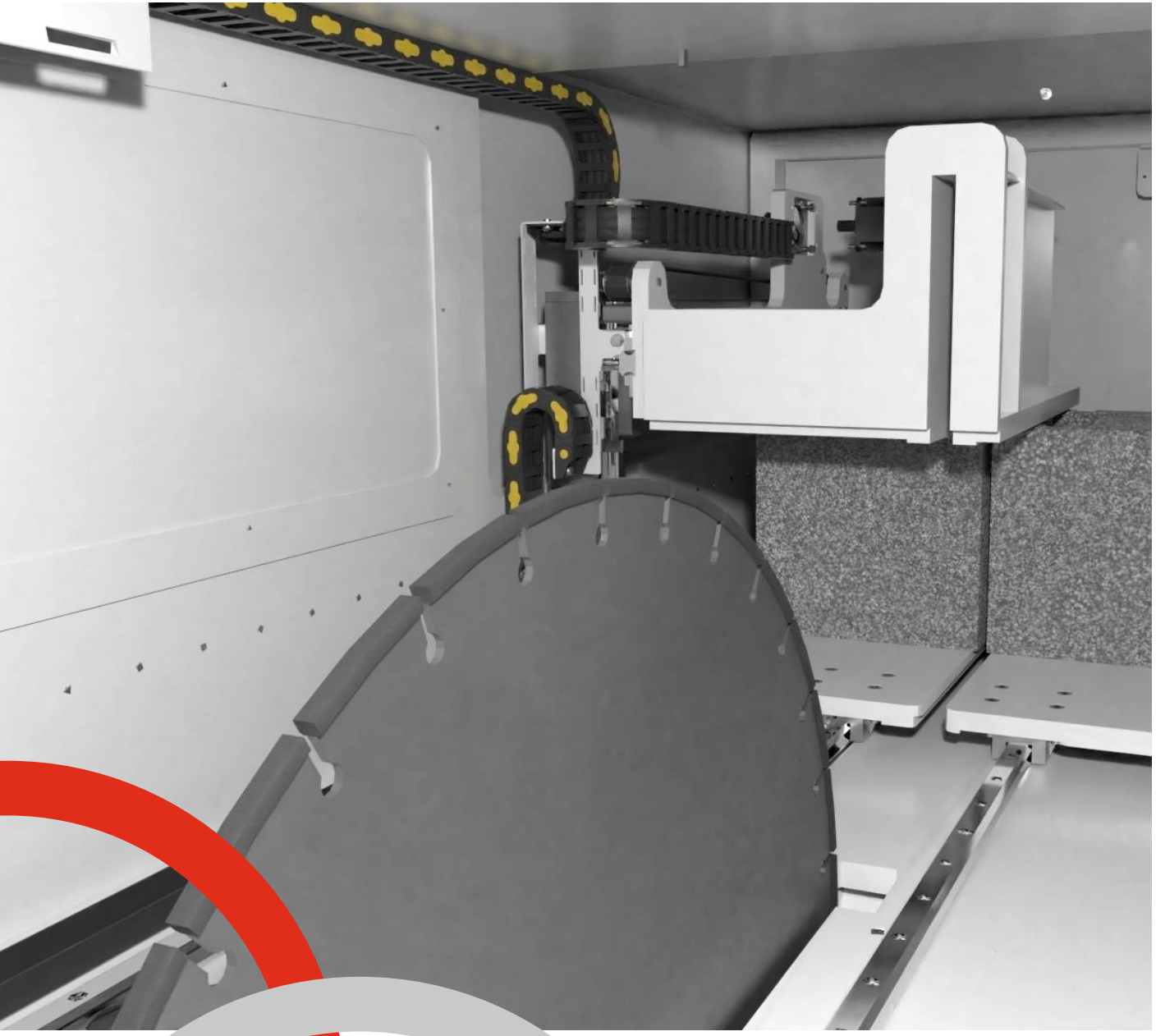
- Every supplier throughout the homebuilding process from the architect to the final trades will work from a single source of data, enabling parallel manufacture of materials.

Questions??

Loading Hadrian X®

- Pallets of blocks are loaded into the back of **Hadrian X®** using a telehandler and automatically dehacked for further processing inside the machine.



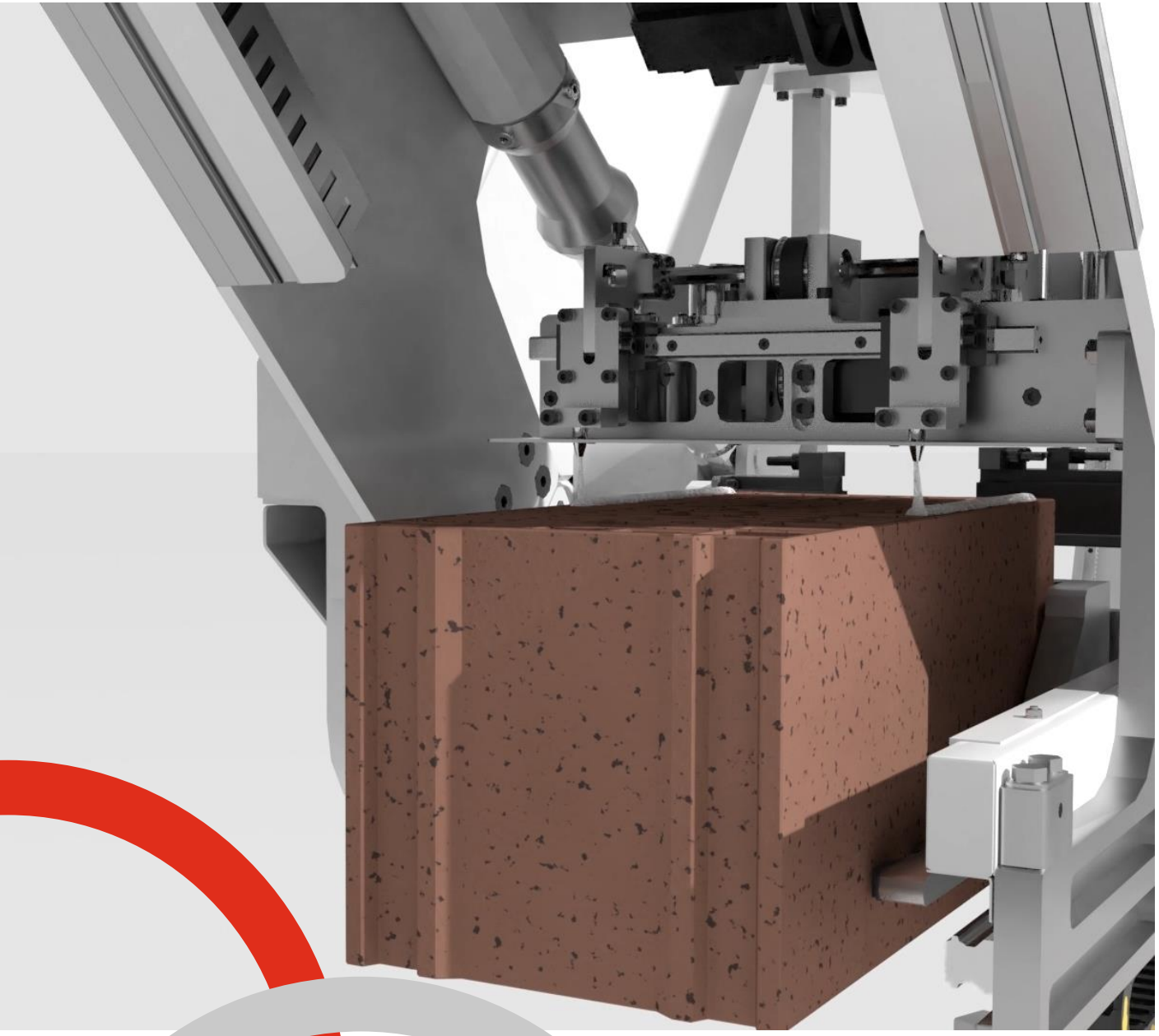


Internal Saw Module

- As required by the CAD model, blocks can be automatically cut using the internal saw module into a range of sizes. Block offcuts are stored in internal storage bays for use later in the build, to reduce masonry construction cost and waste.

Telescopic **Boom**

- Blocks are transported through a dynamically stabilized telescopic boom that allows **Hadrian X®** to build a full house structure from a single position on site.



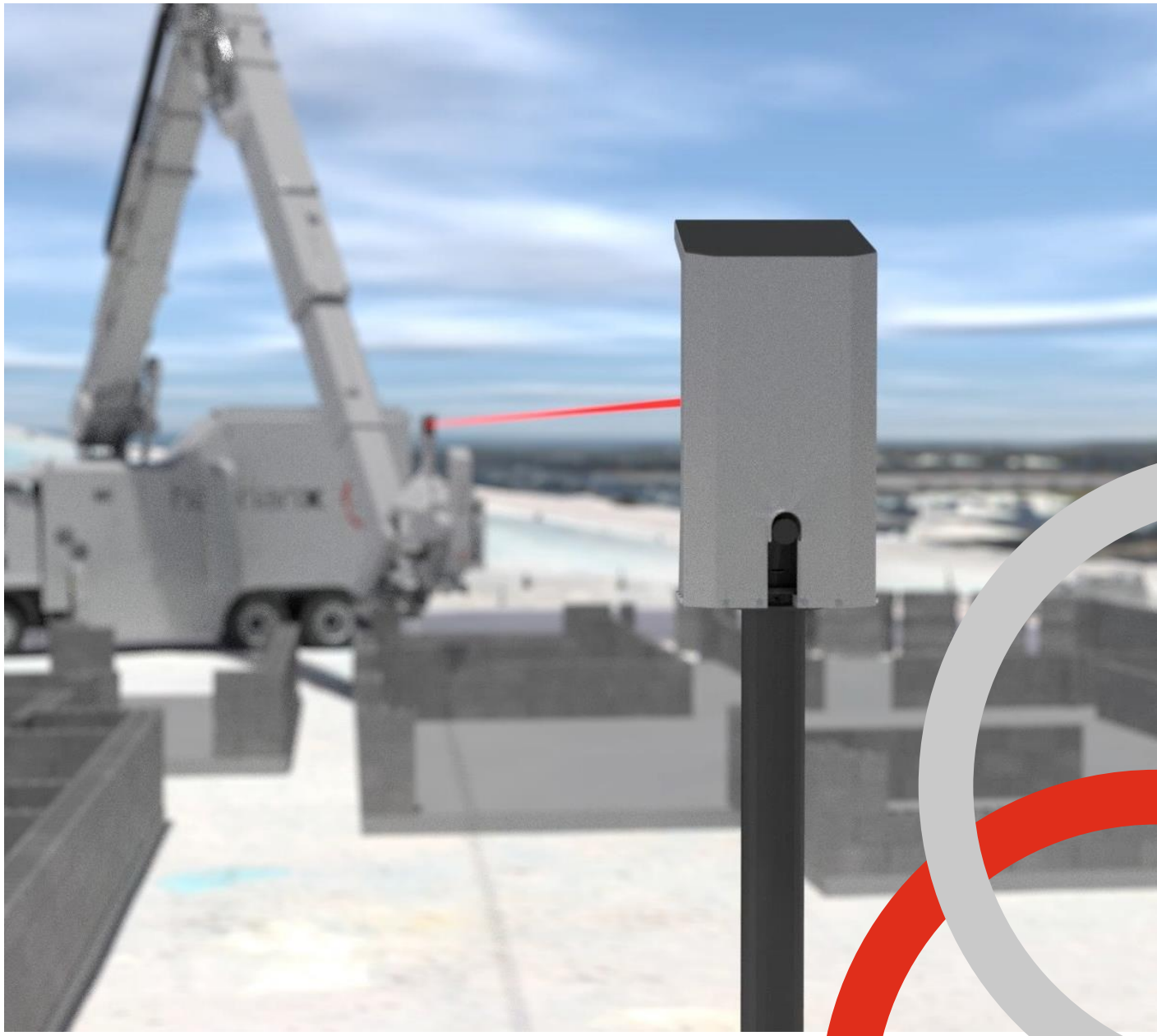
Construction **Adhesive**

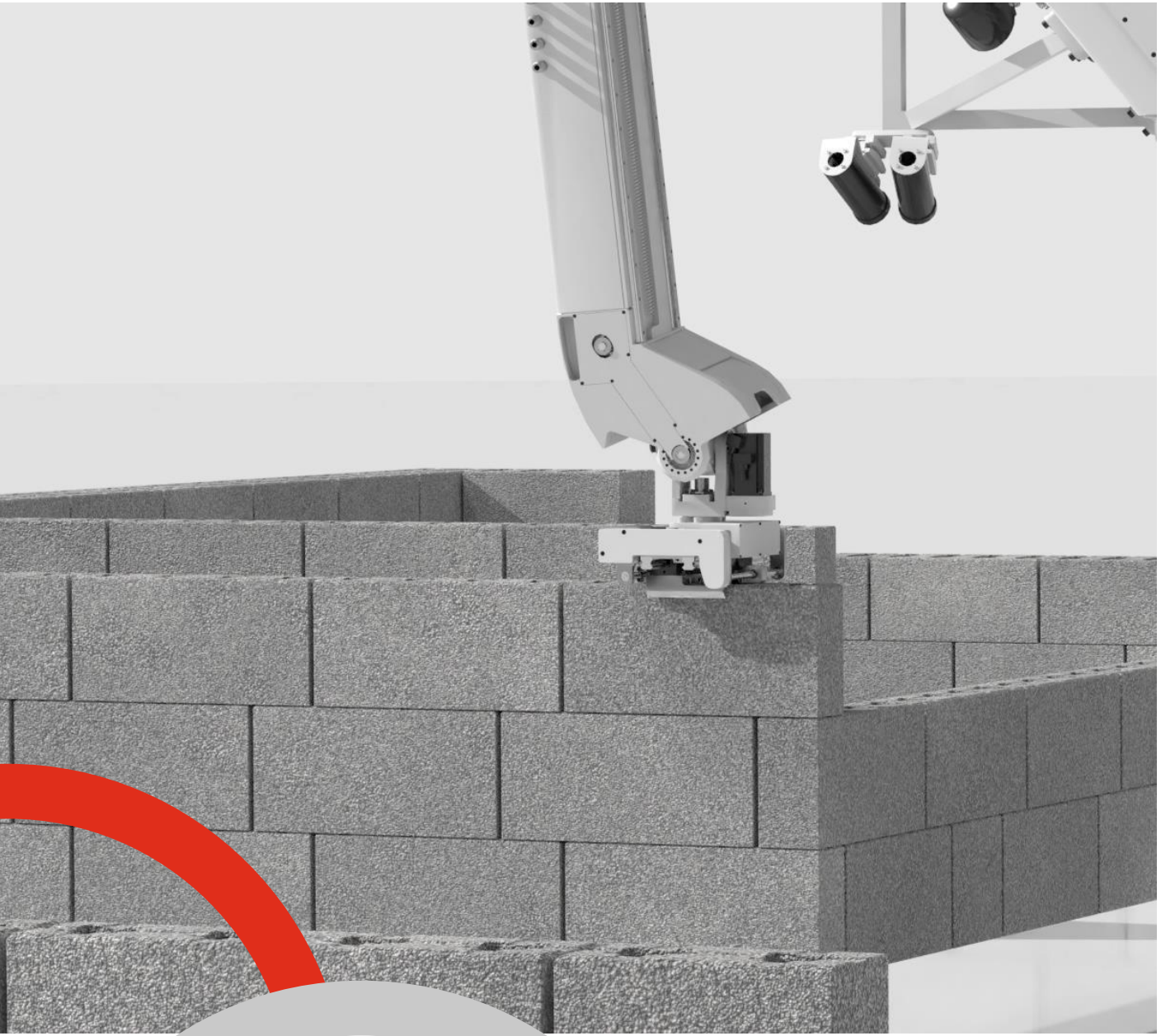
- After transportation through the boom, the block arrives at an adhesive applicator, where an advanced construction adhesive is applied instead of traditional mortar.
- Using adhesive allows **Hadrian X®** to build continuously, rather than having to wait for mortar to dry.
- The adhesive also bonds much stronger than mortar, produces less mess on site and eliminates the on-site water requirement in the wall building process.

DST®

- **Hadrian X®** uses **FBR®**'s **Dynamic Stabilization Technology™**, or **DST™**, to work with precision in outdoor environments.

- **DST™** corrects for dynamic interference and vibration in the boom and layhead in real time, and places blocks with precision.





Fastbrick Wall System®

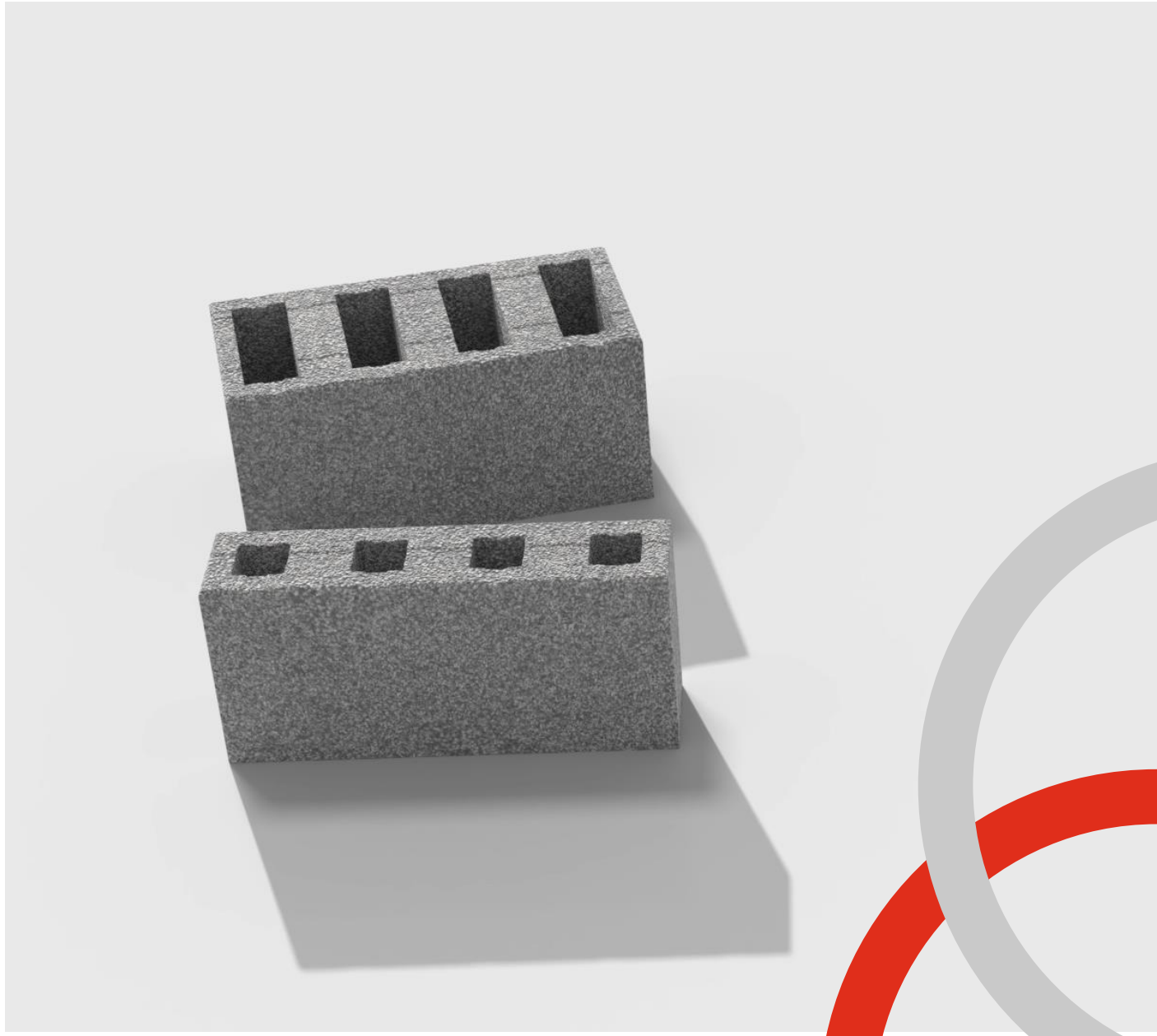
- **FBR®**'s **Fastbrick Wall System™** is a combination of **Hadrian**-optimized blocks and adhesive, together with a cladding material like acrylic render/Stucco
- **Hadrian X®** uses modularly designed blocks with aligned cores, enabling easy installation of cabling and services through the cavities.
- Standard 8" x 8" x 16" CMU

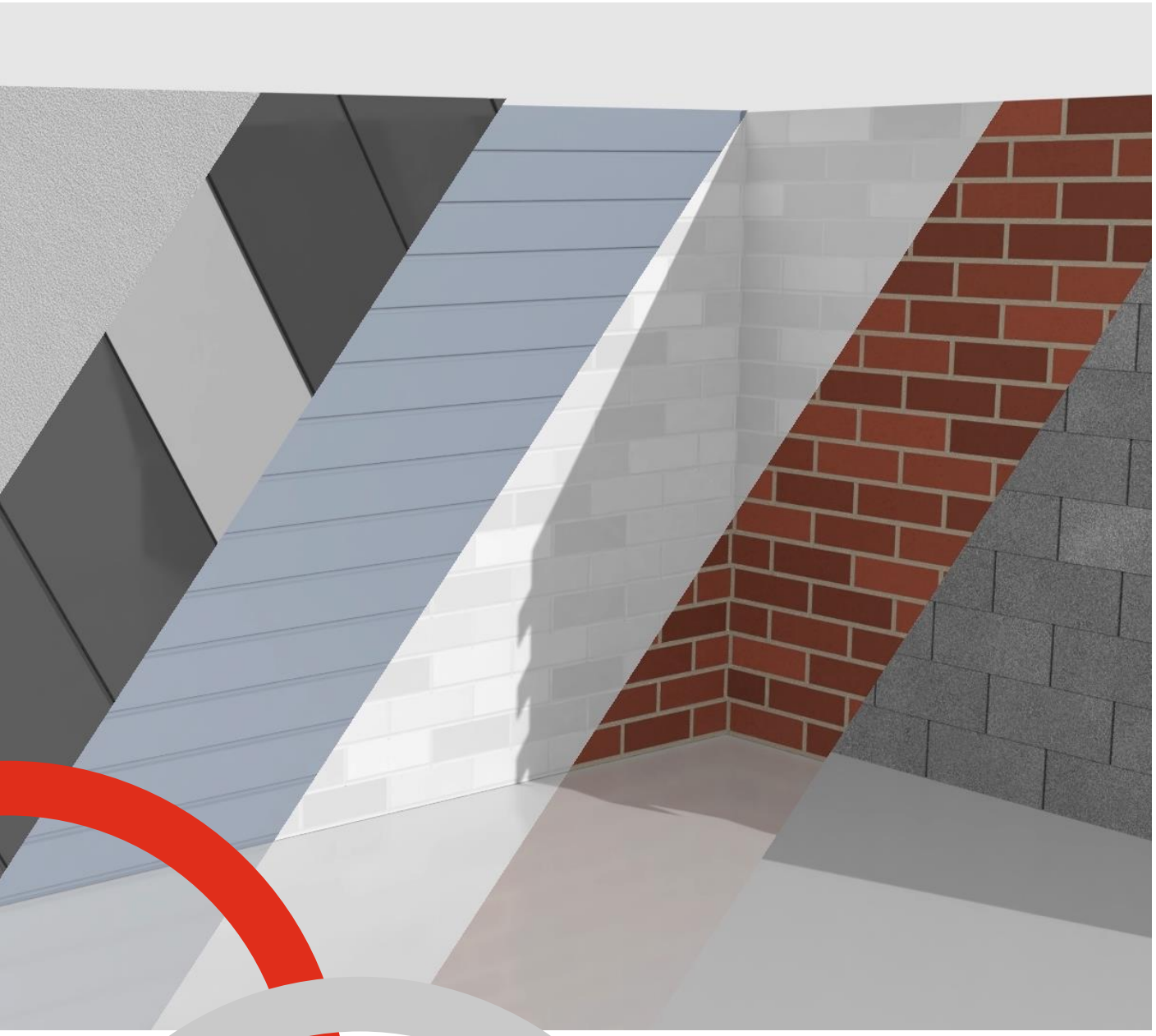
Optimized **Blocks**

Hadrian X® can work with a wide variety of block designs, and **FBR®** works collaboratively with block manufacturers and builders to design the ideal block

Hadrian X® can handle a range of block sizes, depending on the requirements of the customer.

Hadrian X® is designed to carry much heavier blocks than a human would usually work with, which allows it to build walls much faster on a square foot basis.





Finishings

- Once the structural wall has been built by **Hadrian X®**, the builder will apply their customer's preferred style of cladding to the exterior walls.

Current **Specifications**

ENVIRONMENTAL
Operating temperature: 32°F to 113°F
Rain: Light Rains
Wind (peak gust): 37 mph

BRICK DATA (adaptive on request)
Block width: $4^{17/32}$ in to $19^{11/16}$ in
Block width: $2^{23/64}$ in to $9^{27/32}$ in
Block height: $2^{23/64}$ in to $9^{27/32}$ in
Block mass (max): 48.5 lb.
Block material: concrete or clay

LAY GEOMETRY AND PERFORMANCE
Boom reach: 16”4ft to 82ft
Vertical lay reach: 0 to 19”8ft
Nominal laying rate: 240 blocks per hour

**Specifications are current as of March 2022 and subject to change without notice.*

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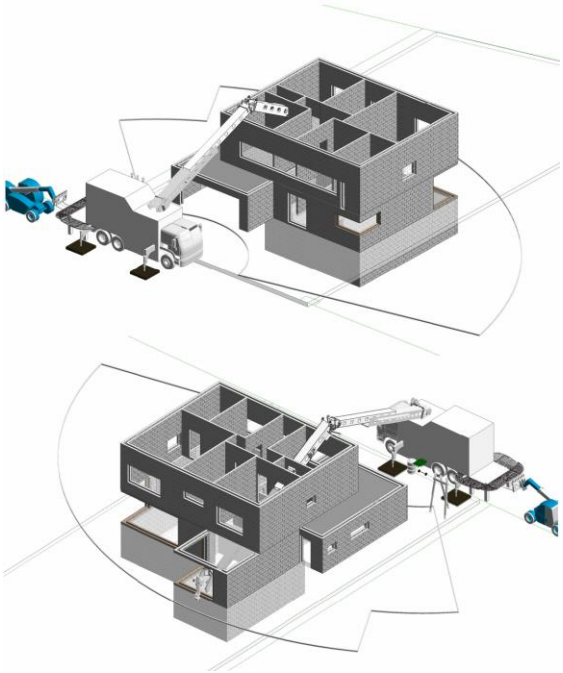
Current **Specifications**

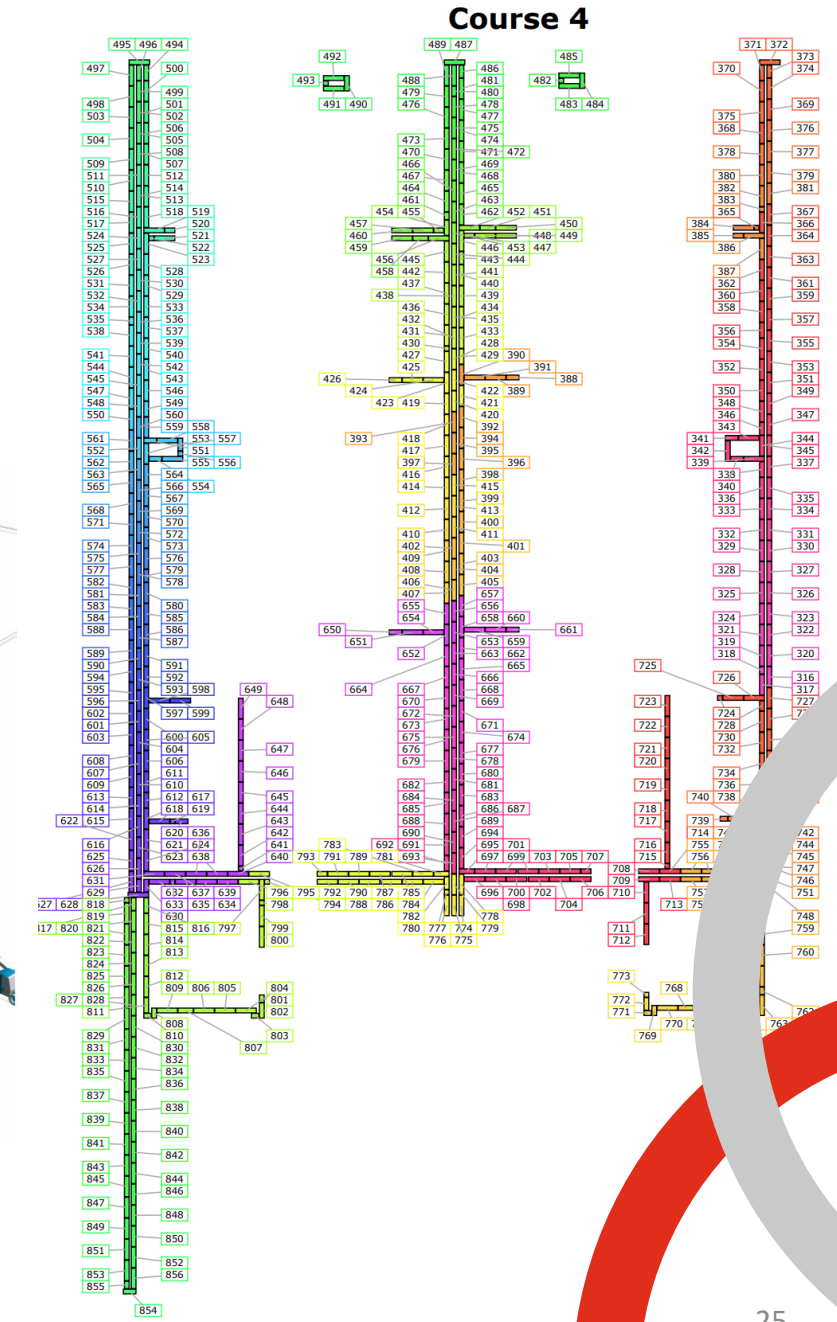
TECHNICAL REQUIREMENTS

- Sufficient access to rear of **Hadrian X®** is required to load blocks via a telehandler.
- Quality control of wall will be undertaken by **FBR** during the process of build.
- **Hadrian X®** may be restricted from use during heavy rain events and storms.
- **Hadrian X®** will be able to operate 24/7 if building permits or other approvals allow.
- **Hadrian X®** can be moved to different locations on site to shift the building envelope as required.

Generating a build file

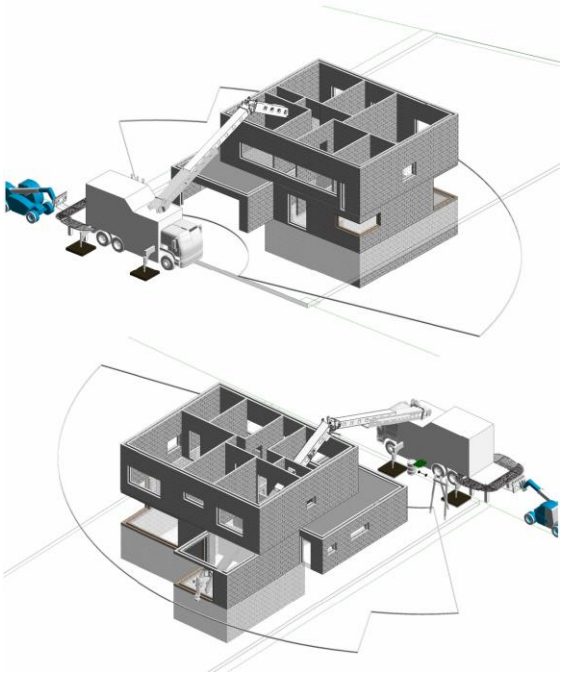
- Sequenced build files are generated from a proprietary architectural design plugin based on the Unity platform.
- Build files contain sequenced block data, giving each block used in a build a position in 3D space.
- Build strategies will vary between builds depending on the height of the build, proximity to existing structures and the volume of cut blocks in the structure.
- Taller builds will use the retreat method to assist with maintaining line of sight with laser trackers.

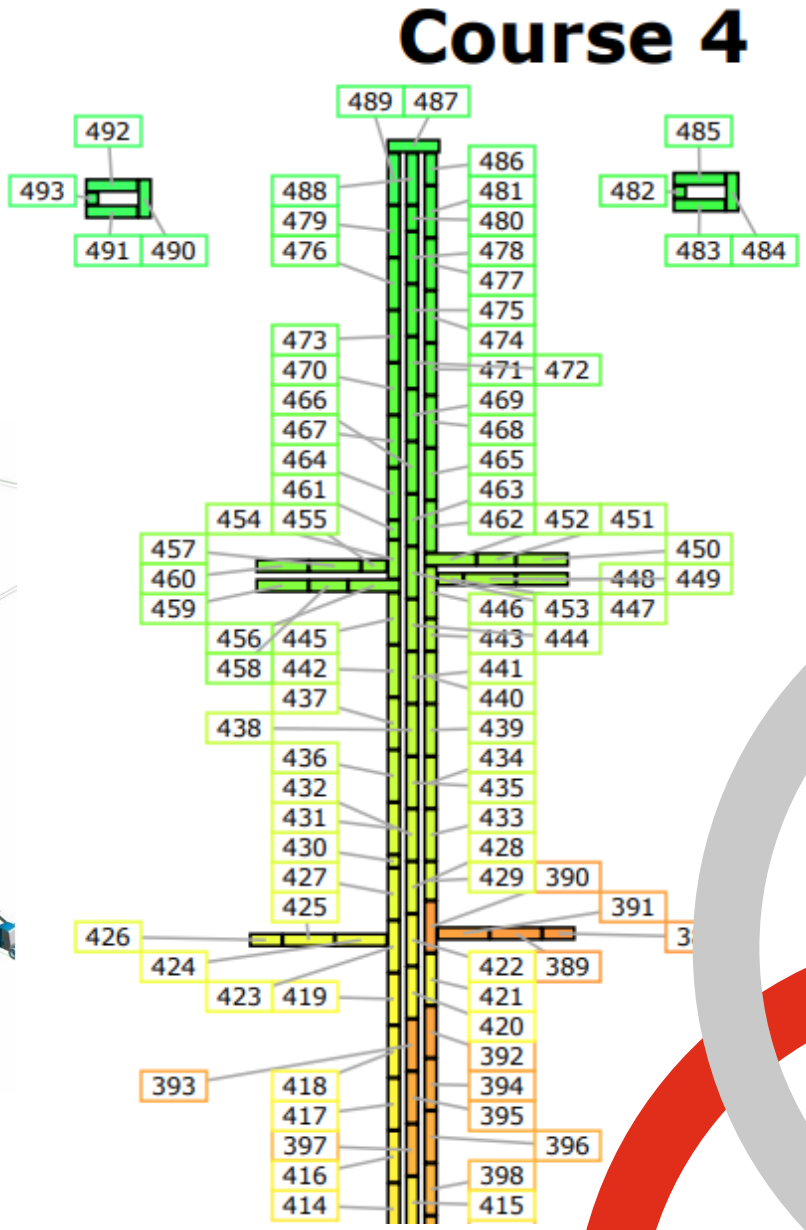




Generating a build file

- Standard size single story builds use the fastest lay path sequence.
- Slew limits of construction robot are tested in build file creation phase to confirm suitability of solution to the job.
- The build file acts as the single source of truth from which other trades can commence parallel fabrication of finishing materials like roof trusses, window frames, door frames, lining materials and cabinetry.



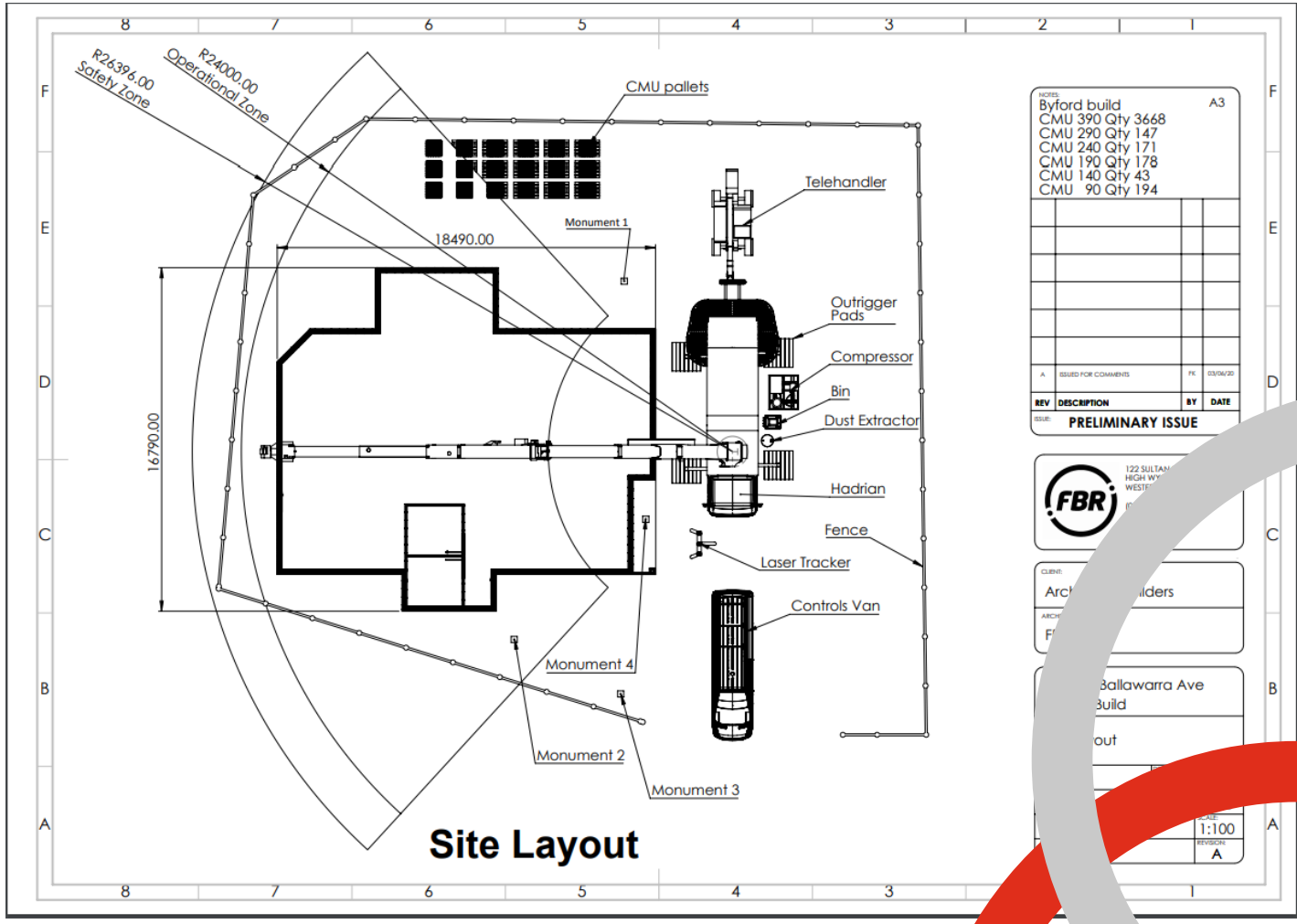


Questions??

Flow of Work

Pre-Build

- Build file is generated in architectural software
- Site is levelled and compacted ready for footings and slab
- Builder supplies 3 phase power to site
- Subcontractors dig footings and slab
- Plumbers lay pipes and drains
- Termite protection applied
- Concrete footings and slab are poured
- Waterproofing applied to slab edge
- Surveyors survey slab



Build

- Blocklaying component
  - Telehandler positions the blocks on site by stacking pallets
  - Safety systems deployed – light curtain, physical fencing, any other appropriate measure
  - Laser system placed in appropriate location depending on build type
  - Bin, monuments and outrigger gluts placed on site
  - Slab reference carried out to confirm exactly where slab is located on site

Build

- Blocklaying component
  - Unpack sequence commences
    - Outriggers extend out and self level
    - Pack conveyors fold down
    - Roof opens, boom raises up, turns to desired location and begins to unfold
    - Adhesive cartridge is loaded
  - Optimized lay path commences to complete structure as fast as practicable – includes consideration of where the cut blocks are in a build
  - Blocklaying is completed

Post-Build

- Concrete or timber lintels, brick ties, insulation and door and window frames are installed
- Roof trusses and roof tie downs are installed
- Walls are finished with cosmetic finish, such as render or brick façade

Benefits of Robotic Construction

Environmental

- A much cleaner site with no materials dispersed across the build zone
- Reduced waste and exposure to environmental incidents.
- No sand, cement or water required on site, eliminating the impact of extraction, soil screening, removal and management of leftover waste
- No hazardous dust from the use of cement and sand (both containing silica) with the potential exposure to the local environment, workers and public within vicinity

Environmental

- TAD software heavily reduces off cuts & waste from block.
- Site cleanliness maintained reducing waste to landfill and the high cost associated with this
- Up to 10% of brick/blocks are wasted in manual bricklaying from overordering, logistics and handling, and cutting bricks onsite

Health and Safety

- Removes the repetitive work, stress and injury including sprains and strains from the industry that many bricklayers suffer from due to years of hard labour

- Removes all manual labour from construction site during structure build (except minimal quality control interactions)

- No working at elevated heights during blocklaying process. Removes the need for scaffolding, trestles or boards to reach the top courses and second story

Health and Safety

- Due to the use of construction adhesive, there is no exposure exposure and inhalation of cement and sand dust while mixing mortar.
- No inhalation of dust through dry dry cutting bricks manually (when a brick saw is used)
- Less people required at work site site during construction and less less trips to site required by workers
- **Hadrian X®** completes all necessary brick cuts

Operational

- Block laying speed significantly faster than manual labour
- Greater accuracy and repeatability than human bricklaying
- Build cost significantly reduced through faster build, greater accuracy and reduced waste
- Digitalizes the construction process and helps stakeholders to better understand the structure from inception to delivery to recycle use

Operational

- Streamed lined specification manufacturing and construction process.
- Machine can run 24/7 when required with no onsite human constraints during build cycle
- Solving genuine global skill shortage that will affect future business growth, while improving working conditions for existing and future bricklayers

Hadrian X® Economics in Australia

The larger the block used, the more economical the **Hadrian X®** becomes and the greater the benefit passed on to **WaaS®** customers. The costs below are direct laying costs and exclude all the other ancillary benefits enjoyed by the customer derived from the **Hadrian X®** from its improvements to safety, speed, accuracy and waste.

Iteration of Bricklayer	Block Type	Laying Speed (blocks p/hr.)	Times faster than single manual bricklayer	Cost of laying wall ($/sqm)	Standard double brick houses built per year
Manual Bricklayer	**Standard Clay Maxibrick** 305 x 162 x 90mm	42	1x	$57	10
H109 (Hadrian X®) – current performance	**Concrete Masonry Unit** 390 x 230 x 90mm	**174**	**7x**	**$35**	**59**
H109+	Concrete Masonry Unit	250	10x	$25	119
H110	Concrete Masonry Unit	500	20x	$14	237

Key Assumptions: Hadrian X® manufacturing cost at scale: $1 million. Hadrian X® crew: 2 people per 12 hour shift. Hadrian X® useful life: 12 years. Number of 12 hour shifts per year for Hadrian X®: 252. Hadrian X® maintenance and fuel cost per year: $175,000. Hadrian X® laying cost excludes corporate overheads. Standard double brick house has 351 vertical sqm of wall (237m^2 internal facing and 114m^2 external facing). Manual bricklayers work in a crew of three (two bricklayers and one laborer). Crew lays 1,000 maxibricks per eight-hour day. Equivalent to 108 standard bricks per hour per person. Manual maxibrick laying cost, taking one to two weeks (laying only) would be currently $2.50 per maxibrick laid in Perth, WA, plus allowing for mortar and sundries and cut bricks this equates to approximately $57/sqm wall laid. Hadrian X® laying speeds are averages ignoring planned and unplanned maintenance.

Case Study
Display Home Build

- The first display home built by an end-to-end autonomous bricklaying robot anywhere in the world completed in Dayton, a residential suburb in Western Australia.

- Site was bordered by seven occupied homes 3 bed x 2 bath – 2,991 Blocks measuring 390mm x 230mm x 90mm (13,759 Standard Brick equivalents (SBE)). (~ 15.35” x 9.06” x 3.54”)

- Average lay speed (during up time) was 146 blocks per hour or 671 SBEs per hour.

Case Study
Display Home Build

- Repeated peak lay speed during Dayton display home build was 192 blocks per hour or 882 SBEs per hour.

- Block wastage was less than 1/5 of a house built using traditional bricklaying methods.

- Operated in light rain and in dark/low light conditions.

"One of the most significant and historic achievements in the field of construction robotics."

Commercial Builds

- **Hadrian X®**'s first non-residential structure (a commercial and community center) was built in Byford, Western Australia.
- First time the **Hadrian X®** had built both the internal and external leaf of a double brick cavity wall with a slab step-down.
- **Hadrian X®** achieved an average laying speed during uptime of approximately 174 blocks per hour, or approximately 800 SBEs per hour, improving upon the results achieved during the display home build in Dayton, Western Australia.

Commercial Builds

- A peak laying speed of 228 blocks per hour, or 1,049 SBEs per hour was demonstrated during the build.
- **Hadrian X®** worked in hail for the first time, as well as high winds and heavy rain.
- The completed structure is 15 courses high including slab step-down, or approximately one and a half story's, with brick ties manually installed.

Multi-Story Builds

- **Hadrian X®**'s first two story structure was built on **FBR**'s premises for international clients.
- Built in a style commonly found around the world in developed and developing markets.
- This is the first time **FBR** has demonstrated **Hadrian X®**'s ability to build two story structures, as well as working with design elements like steel reinforced concrete columns, suspended concrete slabs and rebar.

Multi-Story Builds

- Starter bars were inserted into the concrete slab, with threaded couplers used to install rebar through the aligned cores of the blocks and concrete manually poured into the cores.

- Steel cages were inserted into the block columns built by **Hadrian X®**, with a concrete pump used to fill the columns.

- **FBR** crane-lifted a precast concrete slab onto the structure the day after the first story was completed

Multi-Story Builds

- In large Greenfields developments it is likely **Hadrian X®** would continue building the first levels of the adjacent buildings in the development while the second story slabs are formed and poured, before returning to build the second story of each structure once the slabs have cured.

- Demonstrates **FBR**'s ability to work with a range of design elements like steel reinforced concrete columns, which may be required in certain geographies due to factors such as seismic activity, weather patterns or custom.

Video Resources

Built by Hadrian X® | FBR Builds to Date

https://youtu.be/P-D3adT1MVY

https://youtu.be/1asfa4lua60

https://youtu.be/U00wfsI_7ic

https://youtu.be/kcwFjLqS-K8

https://youtu.be/z3UVc4nSxko

https://youtu.be/S0-4OZp8fmg

Technology Series | FBR Innovation

https://youtu.be/dFbVqT3a_6w

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Thank You!!