15
Clerkenwell Close

22004098
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15 Clerkenwell Close is a load bearing limestone framed building in Islington, London, accomodating 8 apartments and an archtect's studio.

Streetscape photo, Google Earth

Streetscape photo, Google Earth

Location map, GROUPWORK
Site conditions diagram, drawn by author

Streetscape photo, Google Earth

Streetscape photo, Google Earth

15 Clerkenwell Close (15CC) occupies a small plot of land within the enclosed Clerkenwell Green, just a few minutes' walk from the hectic Farringdon Road and the exposed underground tracks that sit beneath it.

Farringdon Road has the highest levels of toxic pollution in London (Aron, 2016). This, along with multiple other environmental factors, as shown on the diagram to the left, may have influenced the design of the project. For example, 15CC provides a biodiverse roof and a glazed solar chimney which both contribute to reducing the building's overall carbon footprint (Wilson, 2019).

Most surrounding buildings of the site are from the post-war era, and are constructed in brick with concrete and steel frames. 15CC refuses to conform with this architectural language - its facade not only rejects the predominant material of the location, but it also possesses structural qualities that are not seen in Clerkenwell Green. These decisions pertain to the historical context of the site.

1. Clerkenwell Close
2. Clerkenwell Green
3. Farringdon Lane
4. Farringdon Road
5. Clerkenwell Road
6. St. James' Church

- sunrise to sunset in June
- sunrise to sunset in January
- south-west winds
- noise pollution from underground tracks
- air pollution from Farringdon Road

site context +

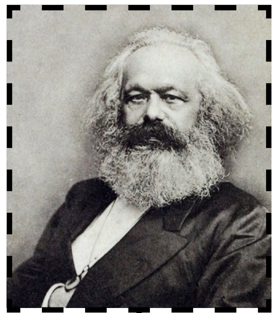
history of site


Abbey of Cerisy, Norman Connections

11th century following the Norman invasion, a limetone Norman Abbey occupied the site (Groupwork, n.d.).


Painting of Oliver Cromwell, Historic UK

17th century Oliver Cromwell replaced the site with a new home during his republican revolution (Groupwork, n.d.).


Karl Marx, Encyclopedia Britannica

20th century a socialist printing press was opened in Clerkenwell Green by poet William Morris (Silverman, n.d.). The press published books written by radical figures such as Karl Marx.


The Peabody Estate, A London Inheritance

1940s The Clerkenwell Estate was built by the Peabody Trust (A London Inheritance, 2017).


May Day Rally in Clerkenwell Green, Catherine Davison

21st century protestors and campaigners anually gather at Clerkenwell Green for the May Day rally (Morris, 2017).

2017 completion of 15 Clerkenwell Close.

15CC was informed by the rich history of its site. The use of limestone is a strong reminder of the original 11th century Norman abbey that once stood there.

It is evident that Clerkenwell Green has always maintained a tradition of radicalism. 15 CC's use of a fully load-bearing limestone exoskeleton is undoubtedly radical way of building in the context of its site.

Architecture from the post-war era is "mostly made up of half-brick stretcher bond, psuedo pastiche facades", the architect, Amin Taha said (Griffiths, 2018). I view 15CC as a way for the architect to challenge the mundane architectural language that we see across the country.

Limestone quarry in France, GROUPWORK

Photographs during construction of 15CC, GROUPWORK

The initial brief was to provide a loose fit building with column-free floors to accomodate both apartments and offices. Thus, the idea of a fully load-bearing external structure has always been at the centre of the project.

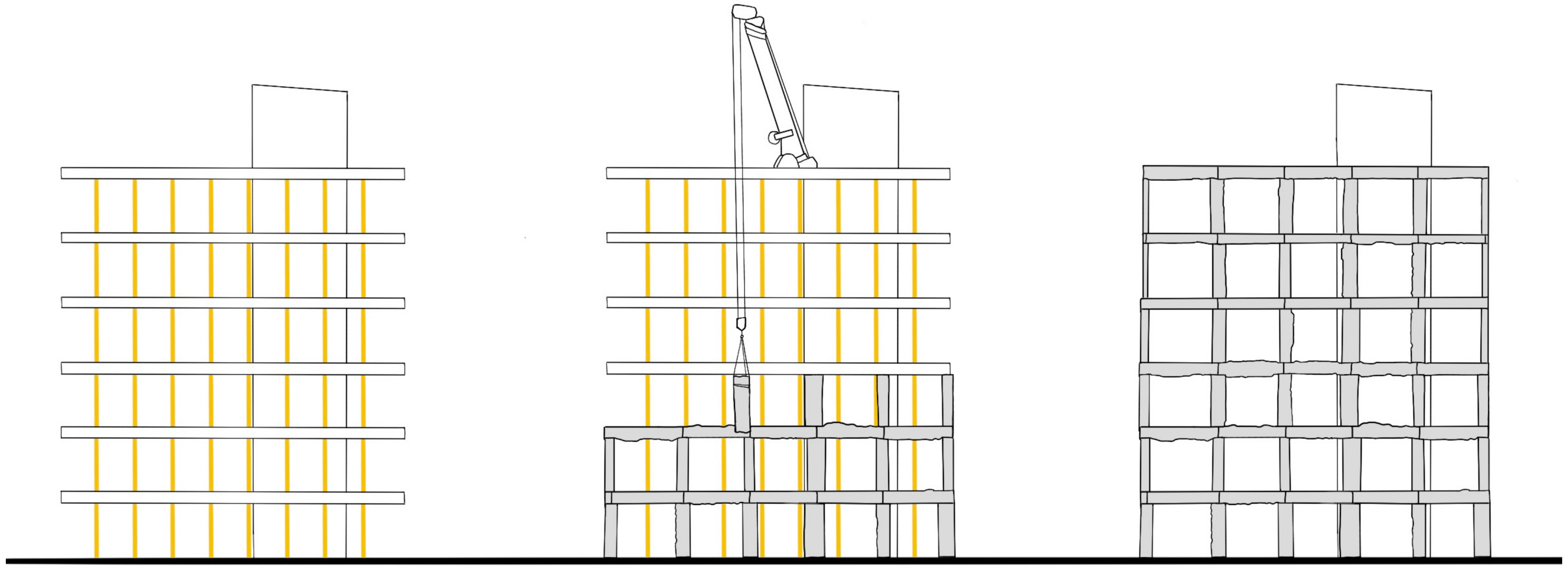
The six-storey building comprises of apartments, a double-height architect's studio at basement and ground level, and a roof-terrace level. Each reinforced concrete floor slab sits in a glazed envelop and meets the structural limestone exoskeleton through steel I-beams.

The use of limestone for the exoskeleton was a highy economical decision - coming in at 25% of the cost of a similar steel or concrete structure. The overall cost of the shell and core equated to approximately 50% of the equivalent using concrete or steel (Buxton, 2018).

The construction process of 15CC was relatively unique. The enclosed nature of Clerkenwell Green meant that there was limited access to the site. This small working space was exacerbated by the close proximity of adjoining buildings. Thus, it was not safe for the concrete slabs and stone columns to be installed simultaneously (Webb Yates Engineers, n.d.).

A construction arrangement was therefore developed - the concrete frame was to be fully constructed first on temporary props, followed by the installation of load-bearing stone facade with the use of cranes (Webb Yates Engineers, n,d.).

The Chomerac limestone columns and lintels were quarried near Lyon, France and transported to the site.



Construction process diagram of 15CC, drawn by author

Start on site June 2016
Completion Nov 2017

Gross internal floor area 2,045 m^2

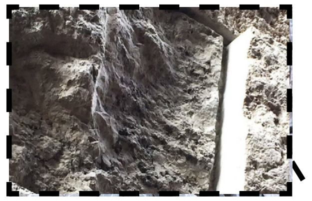
Construction cost £4.6m
Construction cost per m^2 £2,250

Airtightness 4.44 m^3/hr m^2 @ 50Pa
Annual CO_2 emissions 7.8kg/m^2/annum (not all flats fully occupied)

Architect Groupwork + Amin Taha
Client 15CC
Structural engineer Webb Yate
M&E consultant MLM
Quantity surveyor Cumming Corporation
Project manager Cumming Corporation
CDM co-ordinator Cumming Corporation
Approved building inspector MLM
Main contractor JB Structures
Acoustic consultant RB Acoustics
Fire engineering consultant Optimise
Sustainability consultant MLM
Landscape consultant Longstaffe-Gowan

+ vital statistics + construction

+ material analysis



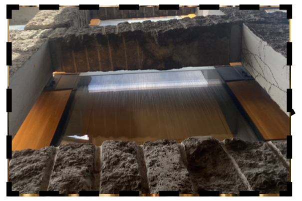
The load-bearing exoskeleton is constructed with **limestone** columns and lintels, each roughly measuring 3m x 0.5m x 0.5m. In depth analysis of limestone as a material on the following page.

Reinforced **concrete** was used for the core and 20cm thick floor slabs. With limited access to the site, concrete being able to be casted on site to the desired strength meant that it was an ideal material. Concrete's high durability meant that 15CC's inner frame could resist weathering and abrasion whist maintaining desired structural properties, including the core's function of combatting lateral loads.

On the contrary, concrete's tensile strenght is 1/10th of its compresive strength (Civil Engineering Tutor, 2016), meaning the ratio of weight to strength of precast concrete is very high. This may suggest an unnecessary increase in the amount of dead load transferred onto the exoskeleton. A composite floor deck could be an alternative solution as it is much lighter in weight.

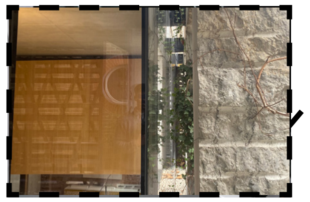
Manufacturing concrete also produces significant carbon emissions.

The floor slabs are attached to the exoskeleton via bolted, galvanised, **mild steel** connections. The most notable properties of mild steel include its high tensile and impact strength. It also meets strict wind requirements. Its low carbon content allows it to be cut, machined and formed intricately without adding proportional stresses (Velling, 2020). As the connections at 15CC are intricate components which bear much of the structural functions, these are most likely the reason why this material was chosen.



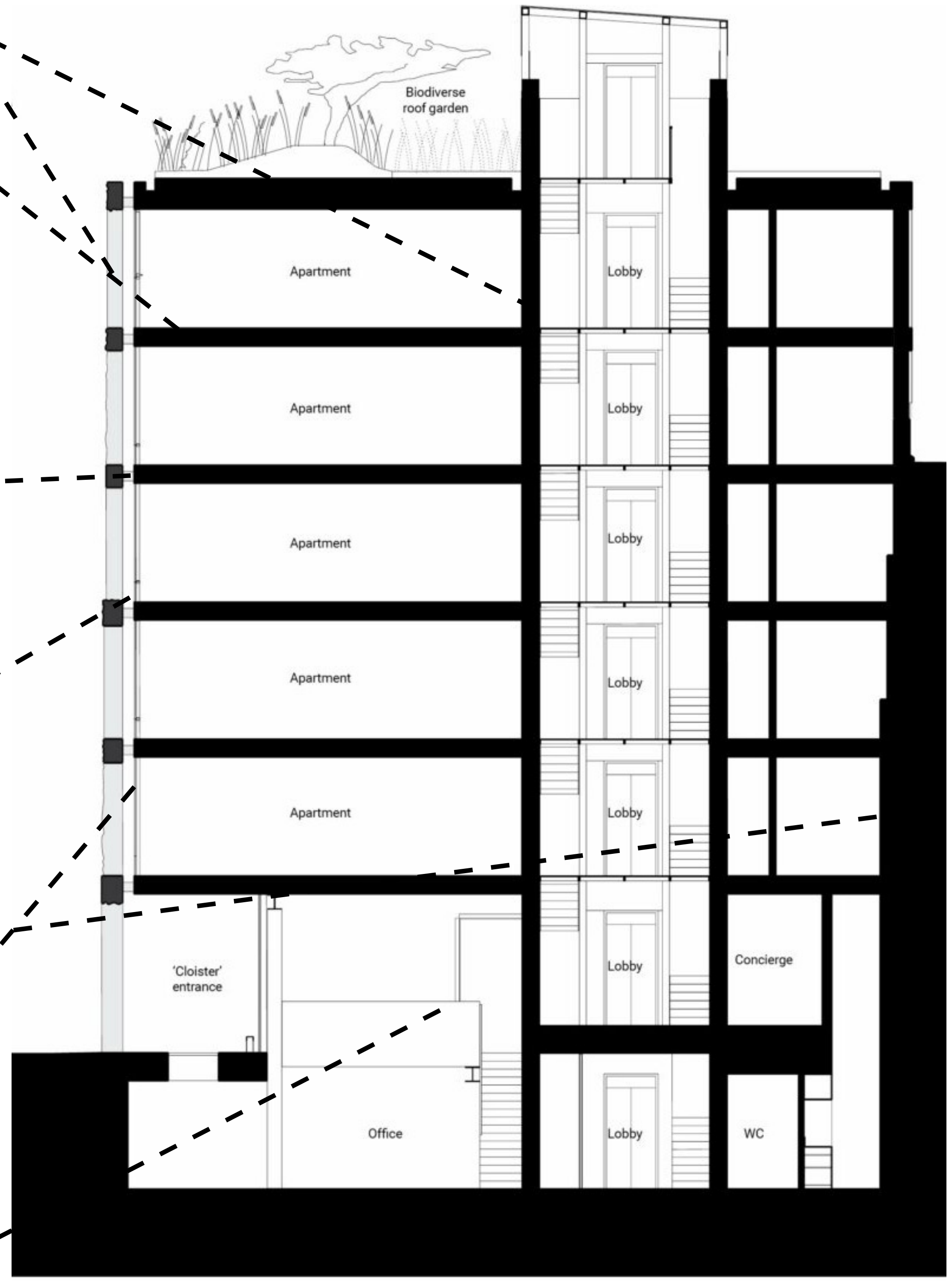
Brass window frames are used in the curtain wall that sits behind the limestone exoskeleton. Brass is an alloy consisting of copper and zinc. The addition of zinc greatly enhances its strength and ductility. Window frames require high tensile strength, hence the selection of this material.

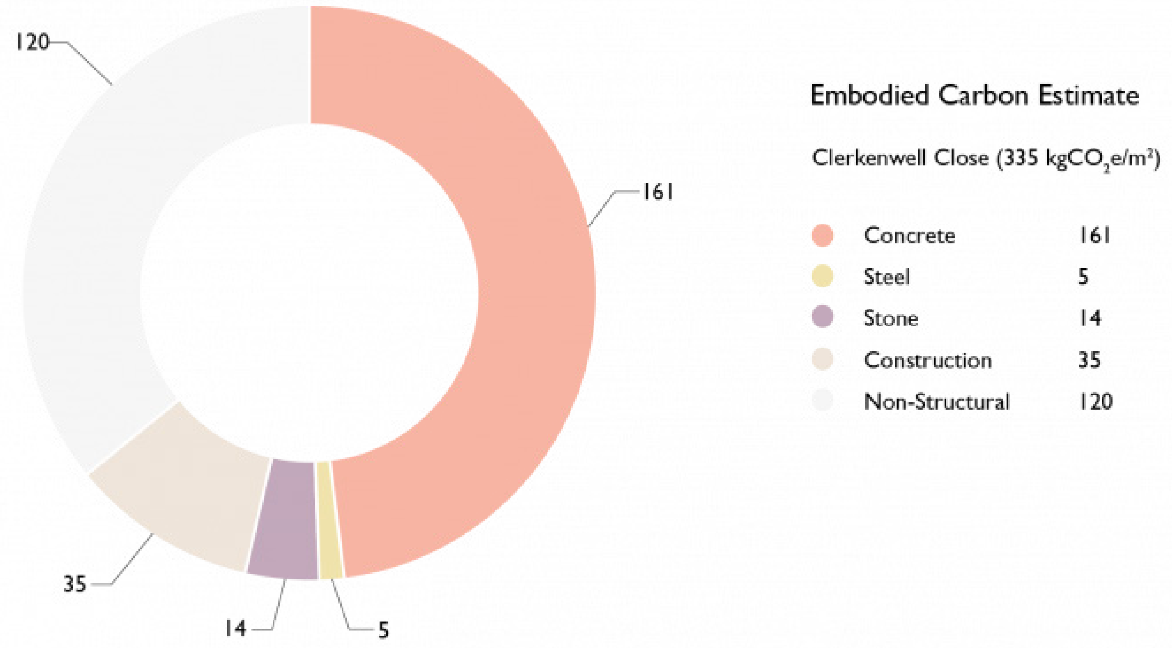
The adjacent **red-brick** party walls were elected to be kept intact. The northwest eleation's limetone grid cuts into the party wall to support the insertion of the floor and roof slabs (Marani, 2018). Red brick has a high compressive strength, thus the walls act as additional load paths for the building.



The glazed envelope consists of 200 **low-emissivity glass** panels. These panels limit the levels of infrared and ultraviolet light that enter the interior, ensuring that the building is thermally efficient.

Much of the interior finishes are **oak**. Though this timber is a medium density hardwood (approximately 720kg/m3), it is exceptionally strong and durable. This makes it ideal for the partitions and decorative features in 15CC.





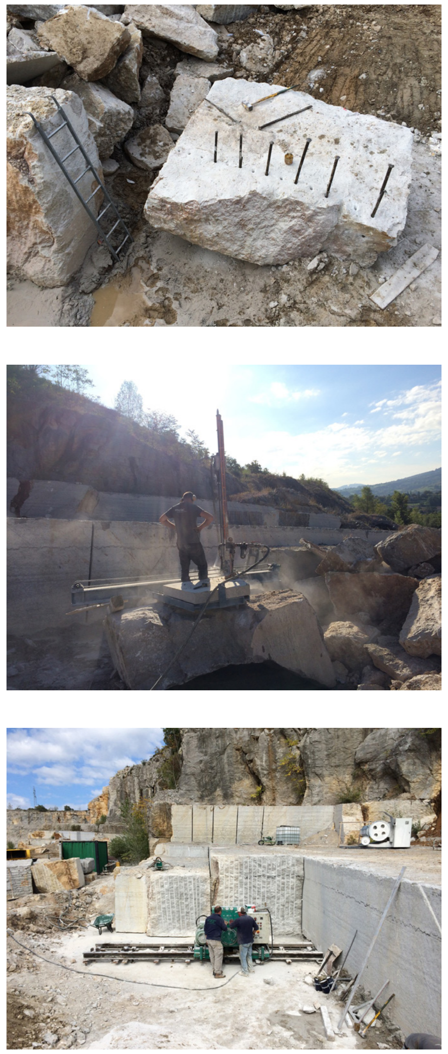
Pie chart showing the embodied carbon estimate of Clerkenwell Close from different materials. Webb Yates Engineers

The aim of the project was to create a superstructure that "ensures the use of stone is more than merely decorative" (Griffiths, 2018). With the idea of challenging the surrounding architectural language, the qualities of stone were compared to those of common materials such as steel and concrete.

One substantial differentiation between the materials is their impact on the environment. Stone requires much less processing compared to concrete: a reinforced stone beam has only 10% of the carbon footprint of a reinforced concrete beam.

Limestone is also inexhaustible, it is the world's second-most abundant material (Kart, 2022). Additionally, where concrete is a CO2 contributor, stone acts as the complete opposite. Limestone is made up of calcium oxide (CaO) and CO2 - "when CO2 is removed from the limestone", it acts "like a sponge by pulling CO2 from the atmosphere" (Kart, 2022). 15CC is thus a "build to reduce atmospheric CO2" solution (e-architect, 2021). Should 15CC be demolished in the future and have its stone reused, it will be a carbon negative building.

These environmental benefits were undeniably a driving factor for the use of limestone in 15CC.



Photographs of the quarrying process in France. GROUPWORK

The full facade of 15CC is a self-supporting, fully load bearing trabeated structure. It was therefore paramount for the architects to select a material for the exoskeleton which possessed a good balance of tensile and compressive strength.

Structurally, stone also trumps concrete in many aspects. Recent efficiencies in stone extraction methods have drastically increased its tensile and compressive strengths compared to reinforced concrete: limestone has a strength of 200N/mm2 whilst concrete has a strength of 40N/mm2.

15CC in many ways mimics ancient building methodologies - the use of stone as a superstructure resembles megalithic architecture such as Stonehenge.

The project illustrates that a return to construction with stone is realistic and possible. There are few limits to its structural abilites and its environmental benefits make it all the more sustainable as a building

Render of the first iteration with a steel exoskeleton. GROUPWORK

Photographs of the different finishes on the limestone. GROUPWORK

The limestone blocks were extracted from a quarry in France, cut to size , transported and erected on site. The 3 different finishes on the columns and lintels reflect the processes of extraction and subdivision. Respectively, some are in a roughly textured 'as found' state; a banded state as a result of hand drilling at the quarry; and a smooth state created by saw cutting by the mason.

limestone +

Pinpointed **metal fastenings** connect the load-bearing facade to the concrete floor slabs. These points are the main paths which transfer both the live and dead load from the inner frame to the masonry exo-skeleton.

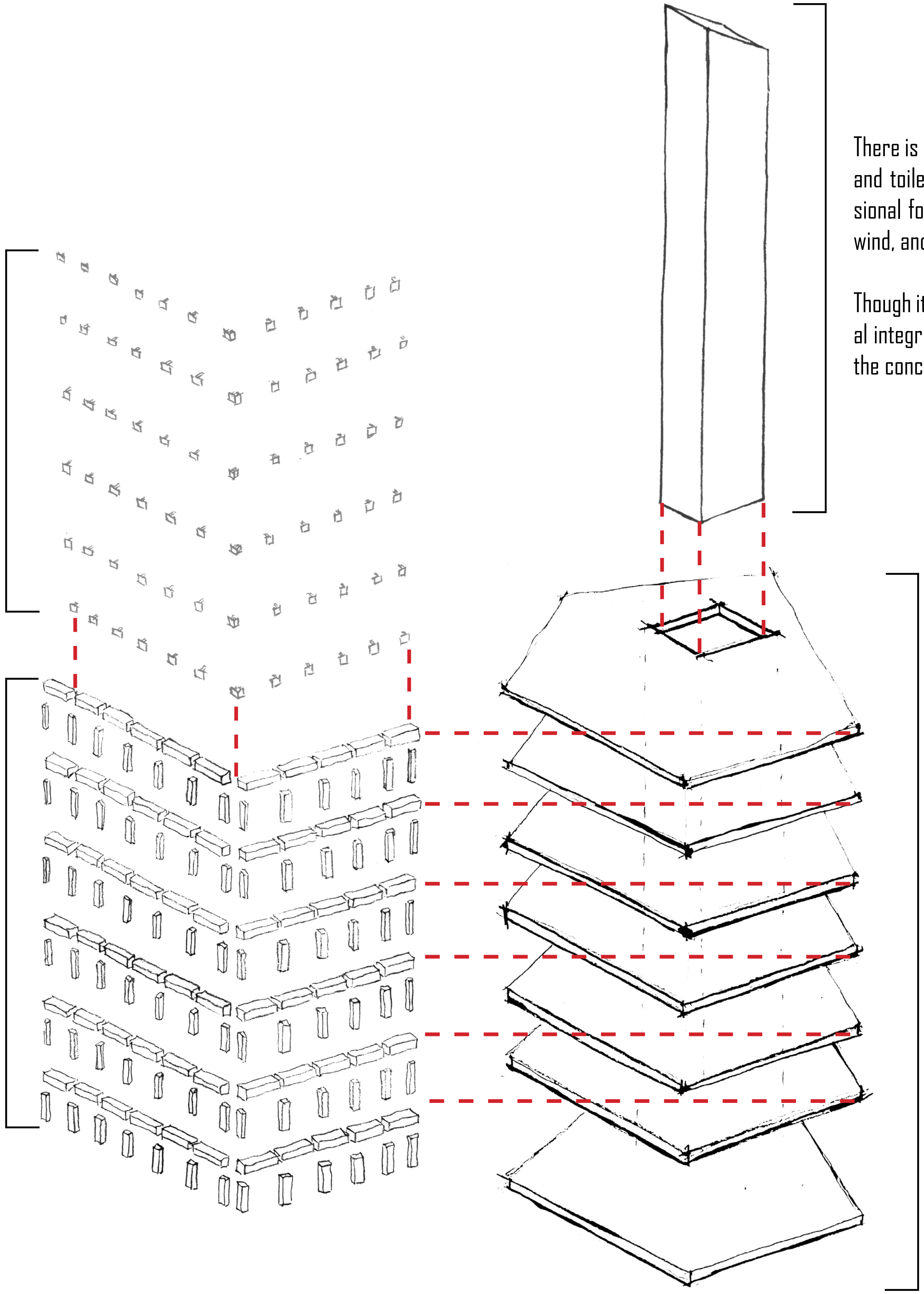
They comprise of galvanised mild steel I-beams connected to metal bosses which in turn are bolted onto steel plates. These plates are then embedded into the concrete floor slabs (Marani, 2018).

These connection points also create a 300mm gap between stone and slab which allows the stone frame to act as a brise soleil.

As a fully **load-bearing exoskeleton** stone structure, the whole facade of limestone columns and lintels are the **primary structure** of the building.

The meeting points of the vertical and horizontal stones are connected to the steel I-beams, which in turn are embedded into the concrete floor slabs. These are the components which transfer both the dead and live loads from the building onto the exoskeleton structure.

The columns, which are spaced 3200mm centre to centre, vary in sizes depending on their position in the load path. They are bonded to each other and the lintels with just under 30mm of mortar and gravitational force. The columns are cut to specific engineered sizes - each column is sized differently according to the specific loads that they take. The columns at ground level range between 800-900mm in width, whilst the ones at the top reduce to 250mm (Buxton, 2018). It is also to be noted that the columns on the corners are the smallest in size as they take on little to no load. The great difference in column sizes depicts how the load paths in the building are not uniform, and that each component must be carefully considered in the design process, despite the 'simple' building methodology that it takes on.



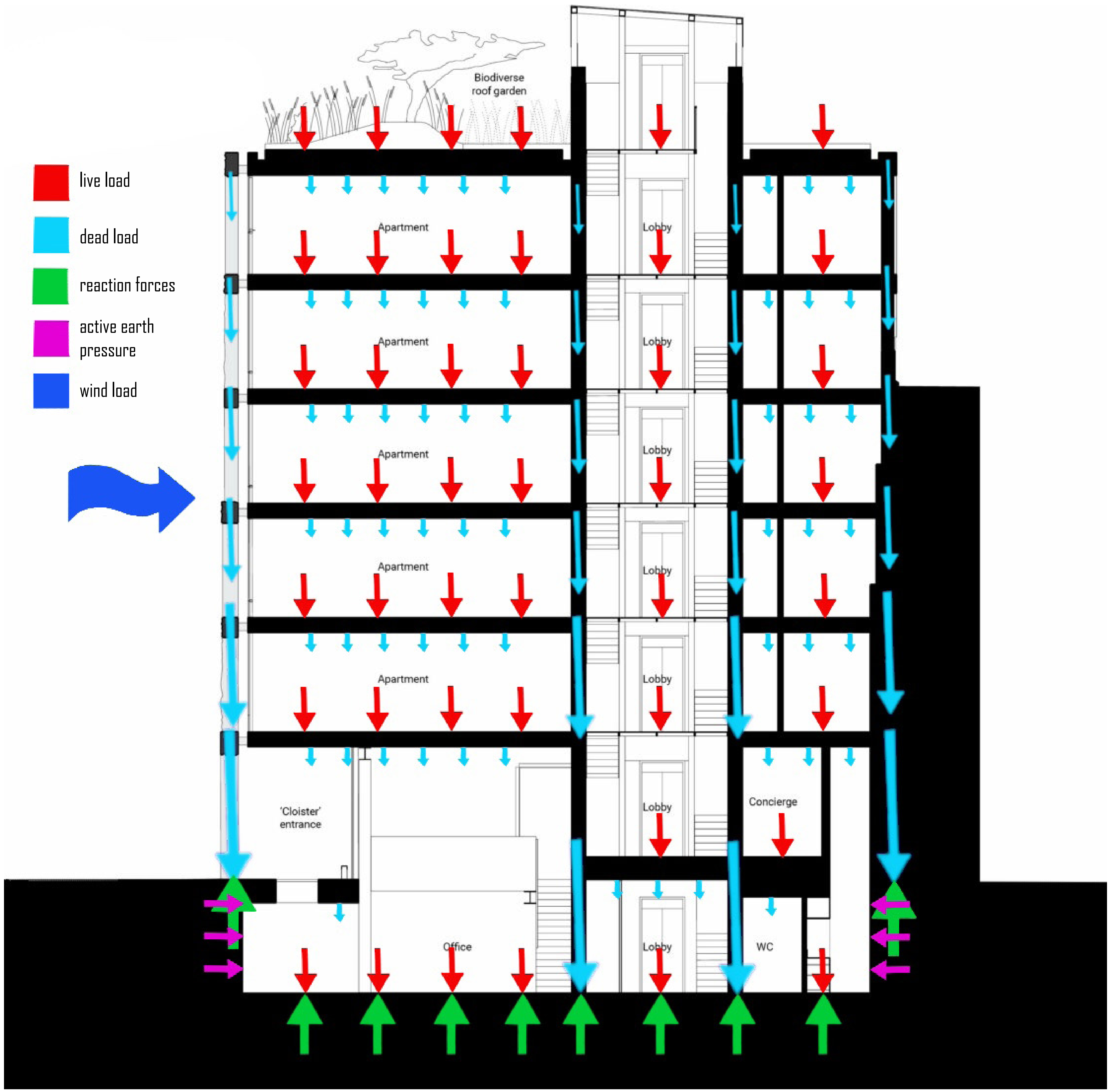
Exploded isometric sketch of 15CC's different structural members, drawn by author

There is a **concrete core** in 15CC that holds the stairwell, elevator shaft and toilets. Its main structural purpose is to combat destructive tor-sional forces, allowing the building to withstand lateral loads, such as wind, and provide stability to the overall structure.

Though it provides 'structure', the core is not crucial to 15CC's structur-al integrity as the stone exoskeleton takes most of the load. Therefore, the concrete core is the building's **secondary structure**.

200mm reinforced **concrete floor plates** span up to 8m out from the concrete core (Wilson, 2019). The applied live loads, be it occupants or furniture, are distributed over the entire slab by vertical shear. The load is then transmistted to the external metal fastenings and travels down the stone structure.

+ structural analysis



Load path diagram of 15CC, drawn by author
Long section of 15CC, GROUPWORK

Just like any building, settlement and movement analysis was carried out to guarantee that the structure would not fail under stress during expected movements. It had to be established that the "building fabric, adjoining properties or the stone columns during construction, the striking of temporary works, and in the permanent condition" would not be unduly stressed (Webb Yates Engineers, n.d.). Thus, every possible load exerted by or on the building must be considered.

The live loads, including occupants, rain water, furniture and vegetation, are uniformly distributed across the floor slabs and onto the stone exoskeleton. They are paired with the combined dead loads of the building, originating from the self-weight of the building elements, and travel down the stone structure to the ground, where it meets an combined equal and opposite reaction force.

Southwesterly winds in London act as a strong dynamic horizontal load on 15CC. This force is resisted by the stone structure, the inner concrete core and passive earth pressure which prevents wind-induced sliding, uplift or overturning.

From the sectional drawing, it appears that the foundation of 15CC is shallow. This suggests that the soil underneath the site is stable and has adequate bearing capacity. It is also certain that there is a continuous foundation wall surrounding the basement. Pressure from the surrounding soil mass and groundwater is exerted on the basement walls. There could also be some shear resistance occuring below the basement as a result of friction with the underlying soil.

Structural analysis

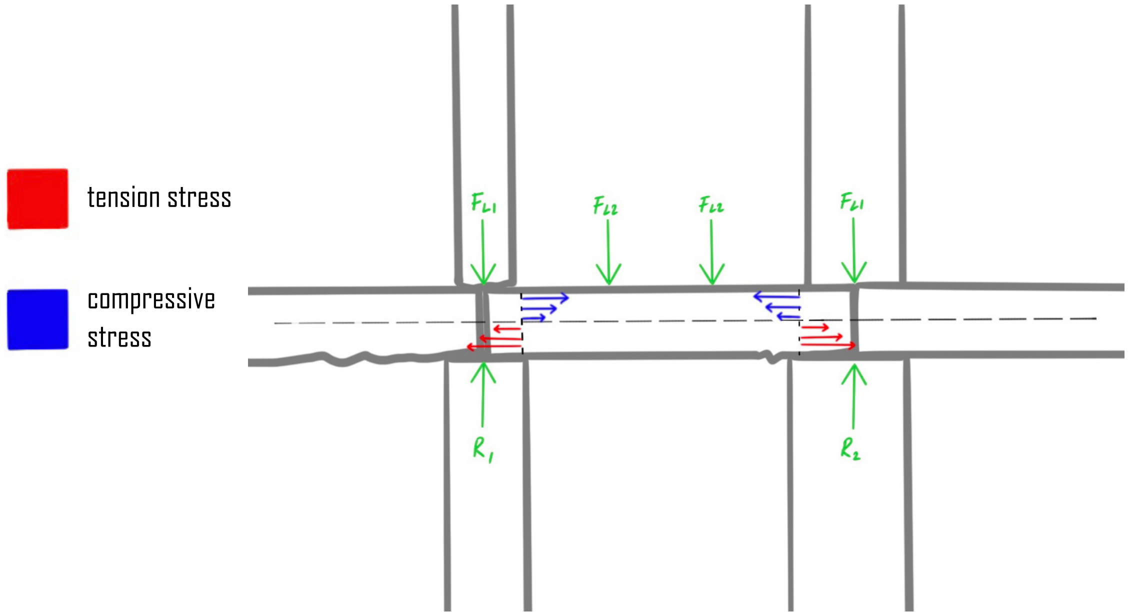


Figure 1: bending forces in stone lintel, drawn by author

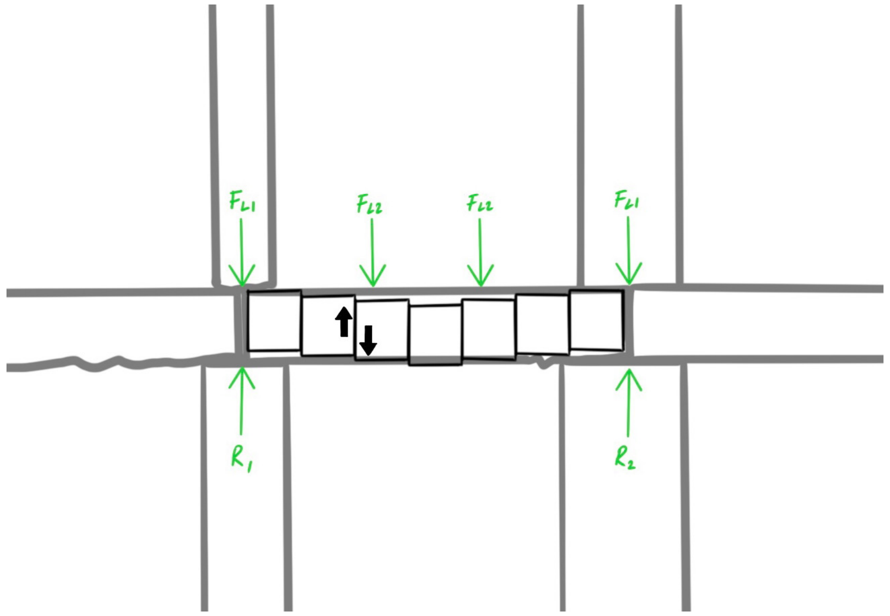


Figure 2: shearing in stone lintel, drawn by author

The horizontal stone lintels experience bending and deflection due to the non-concurrent pattern of forces travelling from the column. Figure 1 depicts possible bending stresses occuring in the lintel, where compression an tension is occuring to resist tranverse forces. Figure 3 shows an axonometric cross section of this.

It has to be noted that the shear strength of stone is 1/10th of its compressive strength (Ching, 2014, p.12.10). Thus, it is possible that tranverse shearing is also occuring at the cross-section of the lintels. This is shown in Figure 2.

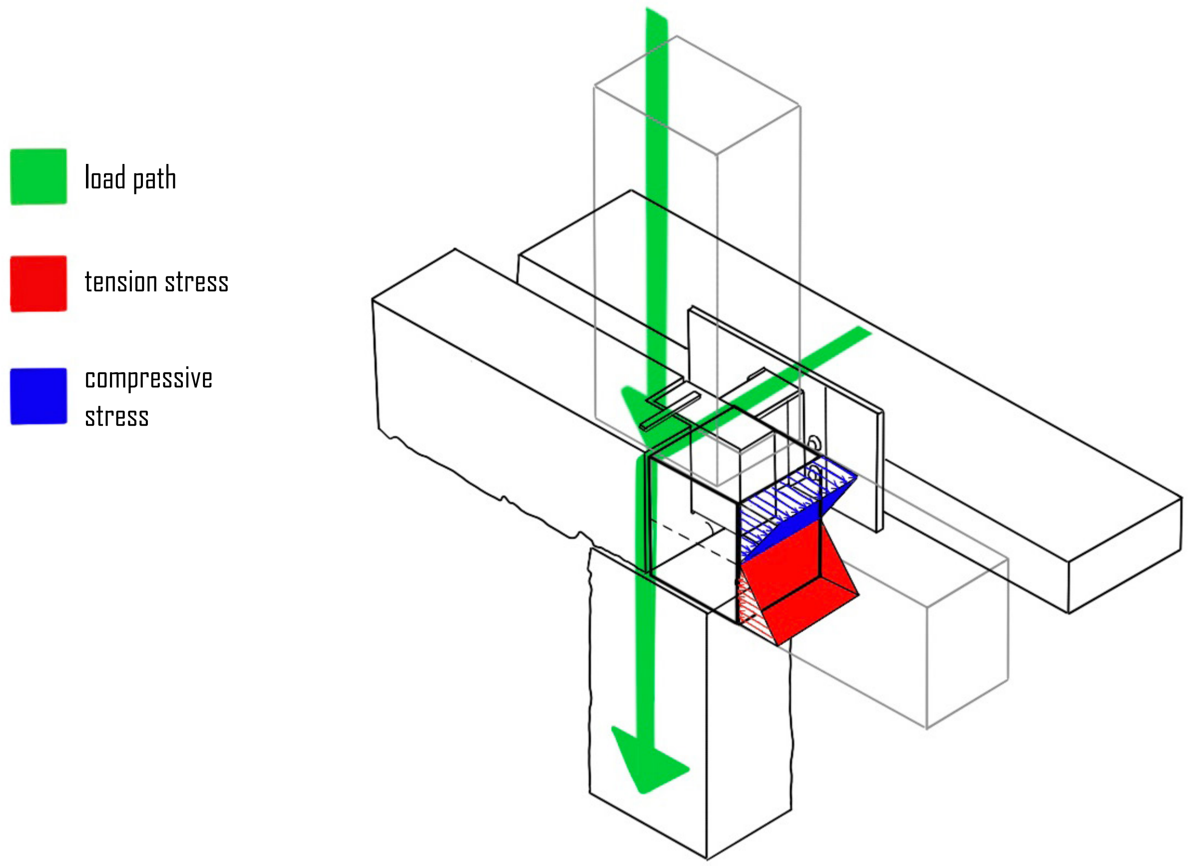
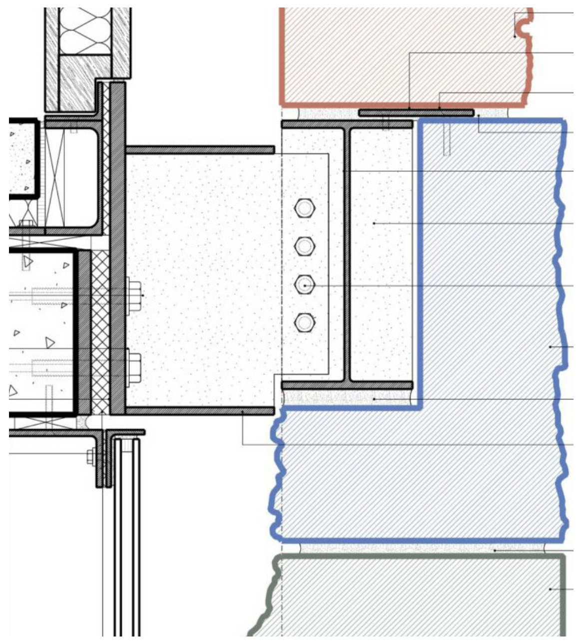
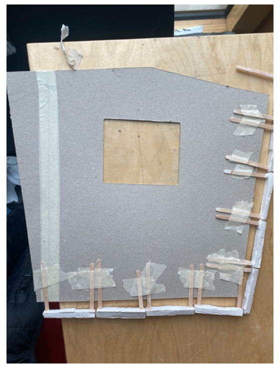
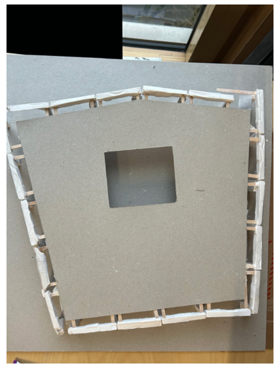


Figure 3: axonometric diagram showing the load path and bending forces in and around the metal fastenings, drawn by author



Sectional drawing ofa metal fastening connection with the limestone exoskeleton, GROUPWORK

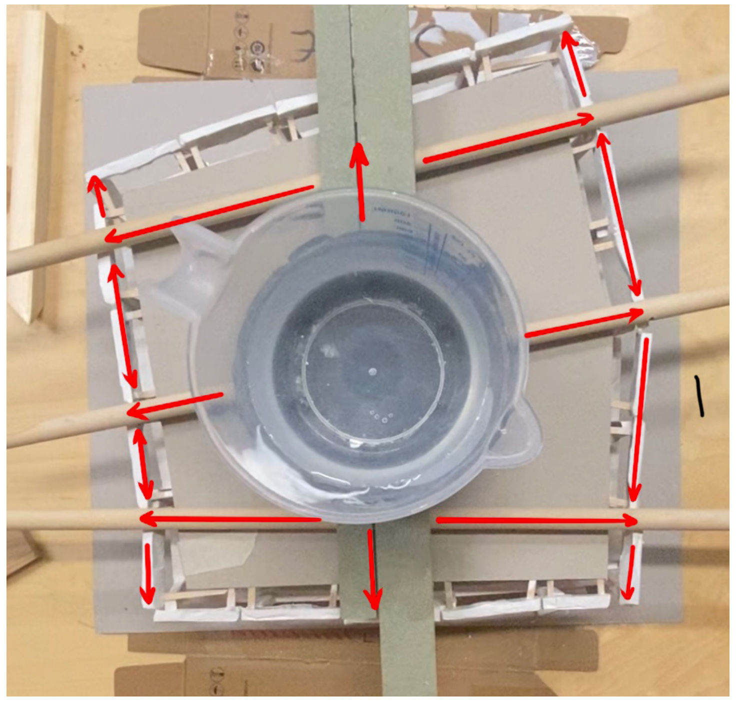


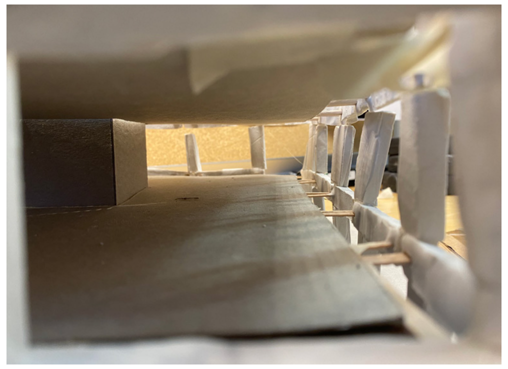


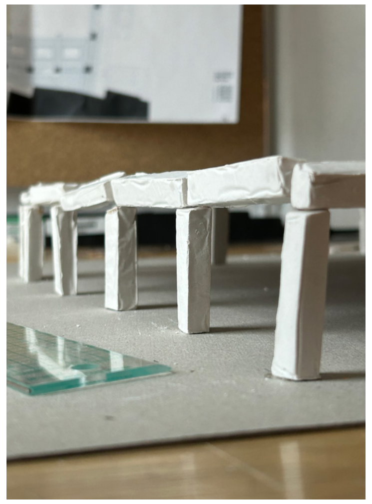
This 1:50 model represents the top two floors in 15CC. We selected to model the top floors because they are unobstructed by party walls and have all sides encased in the stone structure.

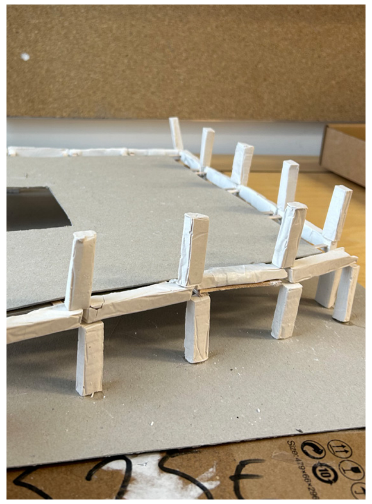
The limestone exoskeleton was modelled using plaster casted blocks. Wooden sticks were casted in these blocks and act as the connections to the double-layered greyboard floor slabs. These connections were sandwiched 40mm deep into the floor plates.

The columns were also casted in different sizes, much like as they are in the real building due to their different positions on the load path. The floor plates rested on their respective sets of columns. The upper-floor columns were glued down to the lintels of the bottom floor, whilst the bottom floor columns were glued down to the base. The glue in the model acted as the mortar.





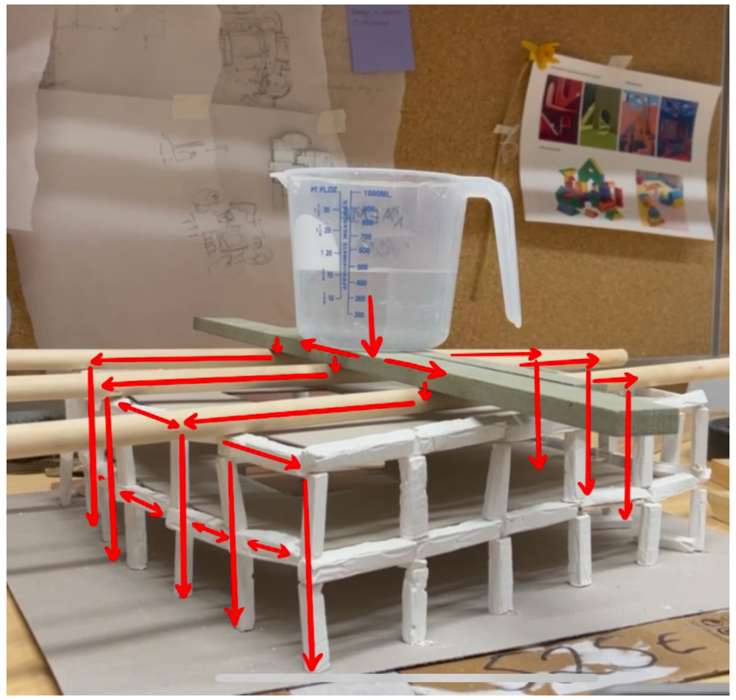




The greyboard floor plates were not 'reinforced', thus we decided to create a system which transferred the applied loads straight to the exoskeleton. The setup prior to load testing featured 3 wooden dowels spanning across the top floor of the model and resting directly on the plaster structure. A separate beam was placed perpendicularly above the dowels as the loading platform for weights.

The diagrams to the right is our assumption of the path that the load follows through the model to the base.

Following the load tests (further documented on the following page), it became evident that this setup and system was flawed. The load was not uniformly distributed across the whole plaster exoskeleton structure as the wooden dowels only met 6 points on the model.






The model was tested with loads in increments of 0.5kg. It reached failure and collapsed at a total load of 11.5kg.

To our surprise, despite plaster being a brittle material, the columns did not buckle nor crumble throughout the load testing. The model, at failure, collapsed in a lateral motion rather than perpinducular to the base.

This test suggests that 15CC under extreme loading would see its stone exoskeleton to be the first structural component to fail as it is the primary load bearing structure. Assumptions could be made that the exoskeleton would collapse laterally with the columns 'slipping' off before they individually crumble. It would be also be reasonable to presume that the columns would refrain from buckling due to their short and wide form.

However, much like any other test, these hypotheses could be inaccurate due to flaws in the model and testing system. The 'lateral collapse' may have been a result of the absence of a core to the model: 15CC's concrete core is the structure which combats lateral loads and horizontal shifts. The manner that the model failed at could have also been due to the orientation of the loading setup. The faces of the exoskeleton which the dowels rested on were the ones that failed. Should there have been dowels which rested on the perpendicular faces, the applied load would have been distributed more uniformly across the plaster structure and an alternate failing motion could have occured instead.

Amendments to these flaws may have not only resulted in the model being able to resist a higher load, but different behaviours could have also prevailed. Any future tests will require more careful considerations in these aspects.



15 Clerkenwell Close undeniably triumphs for its load-bearing stone facade. What I believe is the building's largest success is its ability to strongly critique the architectural norm of post-war brick facades with concrete of steel frames - an architectural language that has sprawled across the UK for decades.

Though a standard 'modern' and cubic building at first glance, 15CC embodies architectural qualities that date back centuries before the post-war era. Its accomplished use of stone as the primary material does not simply challenge an aesthetic or structural principle, but it also criticises the environmental impacts of other common materials. Stone is strong, durable and a material that embodies a significantly low carbon footprint. 15CC manifests that a revert to ancient building techniques is feasible, and quite possibly more favourable as well.

15CC is a very well executed building and personally, there a few criticisms to make. One minor alteration, however, that could be beneficial would be an attempt to fit in with its neighbouring streetscape. This directly contradicts its narrative purpose but it could be favourable to many, as seen with the controversy that it has faced in recent years, where a threat of demolition was imposed. Perhaps it can still embody all its principles whilst conforming to the site without a dominanting stance.

One may suggest that testing the limit of stone as a material would see 15CC as an even greater success. Utilising stone in more features of the building, such as the floor slabs, would futher unconventionalise the building in a triumphant way.

15CC has informed me that buildings do not always require columns, pillars or masonry walls to give structural support. It shows that many unique forms can be struturally sufficient as long as a clear load transfer path is paved and material selection is carefully considered to support a building's various functions. I have been integrating this concept into my final design studio project - 'floating' spaces which are connected to an external load-bearing frame structure is a form that I am more than eager to explore.

Photograph of 15CC, GROUPWORK

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