UNIVERSITY OF BATH, LIBRARY EXTENSION

51.3800°N, 2.3279°W

ABSTRACT

- The library was chosen as it's the centre of the University with the other campus building names and numbers based on it's location. It was one of the very first buildings to be built and is where a significant portion of students spend their time. The design of the steel structure is very unique compared to the rest of the structures at the university. In addition it was also key to construct the library extension as quick as possible.

LIMITATIONS

- Below the lightweight elevated deck of the parade, the original library only offered six load bearing columns. These were reinforced to take the load of the new floors above, resulting in additional works to add more supports and limiting the space you could build out to.
- Being a supported cantilever structure, the length of the overhang of the front façade would be limited. A long span would be limited by deflection.
- The added support and restraint needed to support the whole cantilever structure limits the distance you can extend away from the original library. There is also a worry of overloading the cantilever structure at the tip resulting in greater deflection.

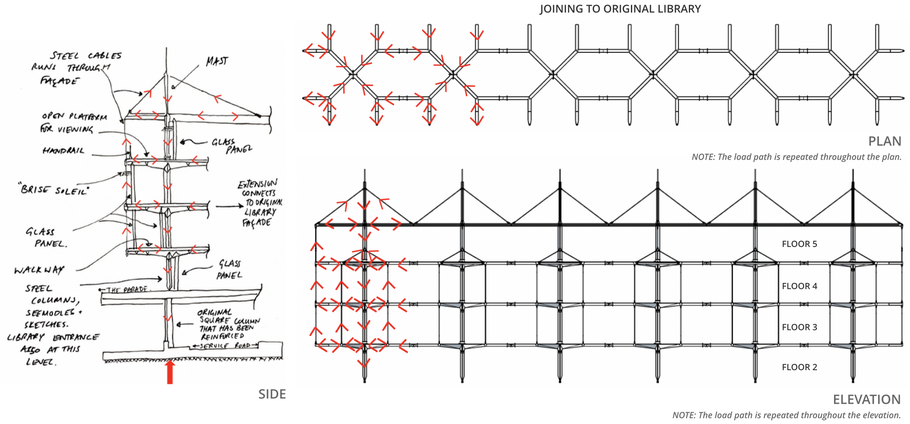
DESIGN

- The architectural ambition was to emulate the current natural environment.
  - The visual effects of the columns from below resembles a row of trees creating an open environment, which is achieved on the parade due to the cantilever structure.
- Structurally it is appealing with varying beam depths, this saves on materials used and again allows for an open environment.
  - However, this increases the cost for specific fabrication (not industry standard) and makes structural analysis much harder.
- It follows the canopy theme enveloped by other buildings on campus, the library achieves this by using steel 'branches'.
- The steel was chosen for its ease of off-site fabrication as well as being visually appealing as a lightweight structure on an already delicate platform. Its weldability made it an appealing choice for constructing on site as assembly would be ideal for quick construction.
- Steel has a high strength to volume ratio, compared to other materials such as concrete; another advantage.
- In terms of tension, which is the majority of the additional front façade, the only other good material in some tension would be reinforced concrete. Having said this, we do think steel is the most appropriate material for ease of construction.
- As a cantilever structure, there would be concern of the overall structural stability. This means that there should be adequate support and fixings to the original library structure. This is what the engineer would have focused on primarily. The members used should be of the correct dimensions and materials to support the actions on the structure. It must also be able to cope with additional actions due to modification to the library that may be done in the future.
- The south facing elevation uses a 'Brise Soleil' allowing the sun to enter the building at low levels in the morning, evening and during the winter, while blocking the sun during summer. This is used for the 3rd and 4th floors in the library, while the Parade level is shaded by the Floor 3 cantilever.
- External 'Brise Soleil', internal light shelves, and the walkway on floor 3 all combine to reduce direct solar gain to provide a comfortable working environment. This would have been a concern to the designer after the initial structural system was designed but still important to the users comfort while in the building.
- Additionally the concrete waffle floor slabs act as a diaphragm to increase stability in the overall structure.

CONSTRUCTION

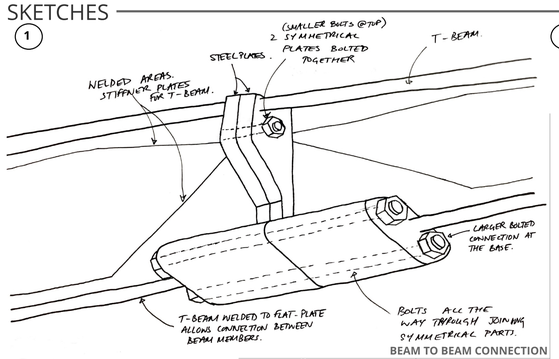
- Due to the lightweight elevated deck of the Parade, the extension would have been built from either side of the library using cranes to lift and place the materials from the existing light wells.
- Materials and plant could be delivered underneath the Parade or through the back access road. On-site welding would have likely used during construction. This means that some lightweight materials and PPE would have also been stored on the parade. Also there would have been a greater risk of fire due to it being a library so fire safety should have been considered.
- The columns and beams were bolted together on-site. This was due to the ease of transportation of smaller parts but it would have increased the risk of mistakes on-site.
  - For transportation, none of the individual beams and columns would be longer than 12m, which would allow for cheaper transportation to the site.
- The partial closure of the parade limited access for pedestrians. The back access road and green space situated behind the library would have served as the site entrance (see plan view sketch).
- Students and staff constantly require the resources from the library. Thus, frequently used/borrowed books were moved into porta-cabins.
  - A temporary stair entrance was created on the right side of the library (near the chaplaincy) to allow access during the works.
  - The library was left partially open as long as possible which may have hindered progress and would be accounted for in the risk management. As health and safety should be prioritised for reduced chance of delay.
  - The noise levels would need to be controlled where possible to minimise the level of disruption to the running of the university.
  - Dust would also be an issue as the site is close to pedestrian traffic.
- Asbestos that had been found in the original structure, had to be removed and disposed of safely before the works could be started.
- Two C-channel beams were used on the top cantilever instead of I-beams as it's easier to connect to the unique column cross section (see model and sketch 3).

LOAD PATH AND STABILITY SYSTEM



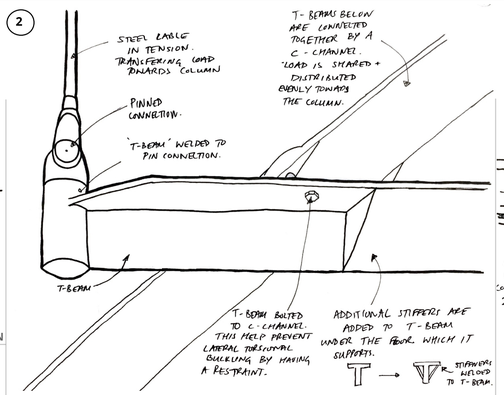
SKETCHES

1



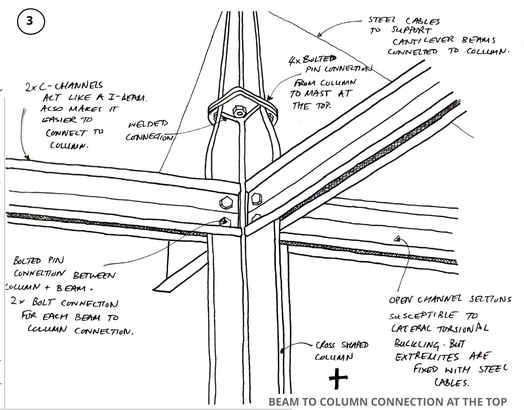
BEAM TO BEAM CONNECTION

2



PIN CONNECTION AT BOTTOM CANTILEVER

3



BEAM TO COLUMN CONNECTION AT THE TOP

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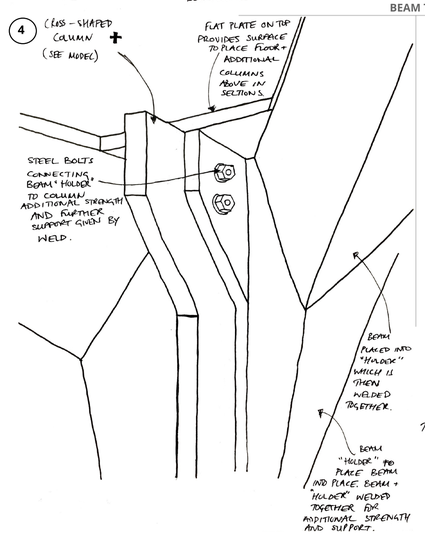

BEAM TO COLUMN CONNECTION CLOSE-UP

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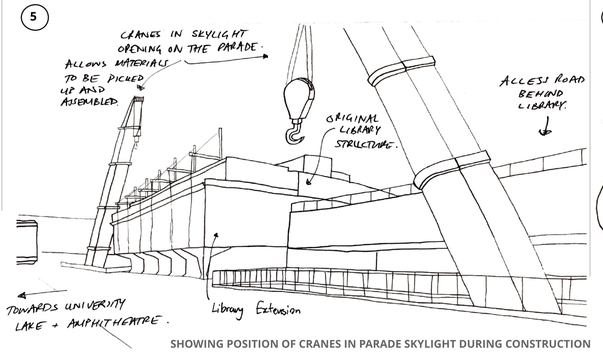

SHOWING POSITION OF CRANES IN PARADE SKYLIGHT DURING CONSTRUCTION

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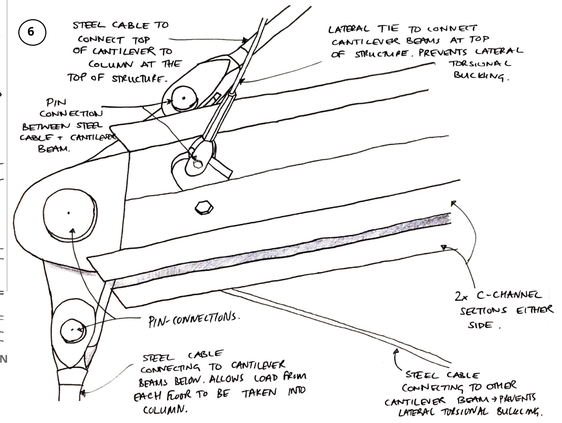
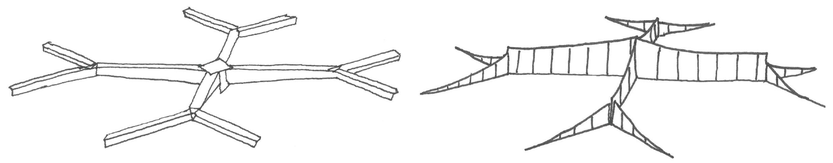


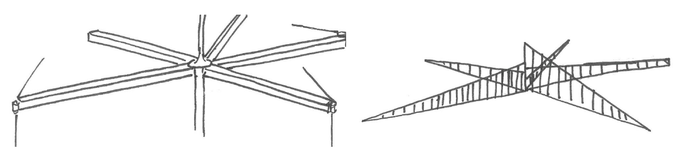
PIN CONNECTION AT TOP CANTILEVER

BENDING MOMENT DIAGRAM



FOR THE FIRST FOUR FLOORS OF THE LIBRARY FAÇADE

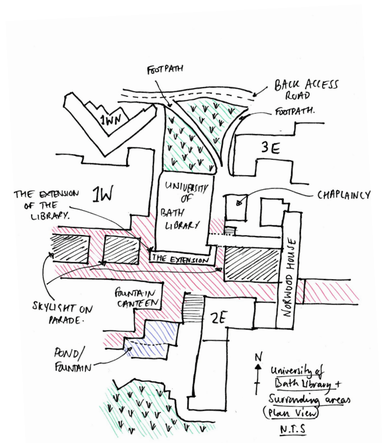
Assumptions made: pin connections to original façade and continuous UDL



FOR THE TOP CANTILEVER BEAM OF THE LIBRARY FAÇADE

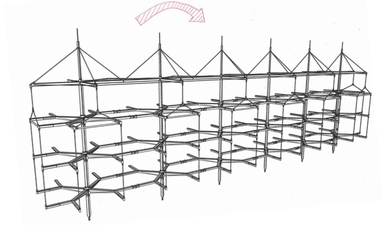
Assumptions made: pin connections to original façade

PLANNING & CONSTRUCTION PROCESS



PLAN VIEW SHOWING LIBRARY & SURROUNDING AREAS. SKYLIGHTS EITHER SIDE ON PARADE WOULD HAVE BEEN USED TO LIFT PARTS OF EXTENSION USING A CRANE. THE PARADE WOULD HAVE BEEN CLOSED OFF PARTIALLY DURING THE WORKS.

The above images show the before and after shots of the extension. The 2 bottom images show snapshots during the construction. Initially, the columns would have been transported to the site and then lifted and positioned into place carefully using a crane (sketch 7). At the top, the columns would've needed to be supported to prevent them from falling over or swaying with pin connections at the bottom. This is shown in the bottom left image and would've been the next step. Then the beams to support floor 3 would've been connected to the column (sketch 4). These beams were connected to the adjacent beam from the other columns using the connection shown in sketch 1; providing stability and tying the structure together. C-channels are placed around the ends of the cantilever beams to slot the waffle slabs for the floor. The steel cables would be attached between each floor (sketch 2), finally being attached to top of the columns. The connection of steel cables would be done for all the floors sequentially to allow access for the floor slabs to be placed.



STEEL SKELETON & STABILITY SYSTEM OF LIBRARY EXTENSION

Steel ties and beams at the top of the columns are used to prevent the cantilever structure from overturning as shown by the arrow

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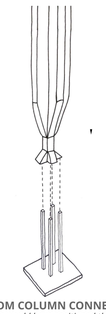
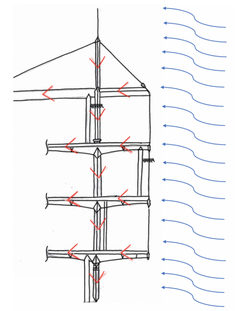


BOTTOM COLUMN CONNECTION

The crane would have positioned the column above the connection on the parade and then slowly moved down into the slot. Afterwards, it would be welded together and bolted down.

WIND LOAD PATH



Reference: [1] David, M., Lee.R., 2011. Alec French Architects: *Thirty years of practice 1980-2010*. Bristol: Alec French Architects.
[2] Maple Sunscreening Ltd, 2019. *Brise Soleil* [Online]. Available from: https://www.maplesunscreening.co.uk/brisesoleil-explained [Accessed 28th February 2019].
[3] Images for before and after, and the construction snapshots were obtained from the University of Bath archives.

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