LIGHTWEIGHT STRUCTURES IN TECHNICAL ENGINEERING

Brian Willer
Instructor: Edgar Stach, Assistant Prof.

Precedent Study

The model of the space shuttle was a precendent study given to help understand light weight structures and technical engineering and how they might be later applied to the design of a building. The project requested a three-dimensional model of the problem and further research into the technical matters of the problem. Structural analysis was requested both through the use of the model as a visual tool and in depth research as its counter. Materials and construction types were all looked at and researched for the precendent study, as well as, spacial relationships.

The Beginnings of the Space Shuttle

The contract for the new space shuttle came to four major aerospace companies: Lockheed, Grumman, McDonnell Douglas, and Rockwell International, with Rockwell finally being awarded with the contract. Every component of the shuttle had to be ready for the completion date of September 28, 1979. The program called for a vehicle that could be relaunched and reused almost 100 times before it was scheduled to be retired. The entire system consists of three major parts: the Orbiter, the External Tank(ET), and two Solid Rocket Boosters(SRB's). The Orbiter and the SRB's are refurbished after every shuttle mission, the only part of the system that is replaced everytime is also the biggest, the External Tank. The Orbiter is broken down into three space defining elements; the forward fuselage, midfuselage, aftfuselage, and two secondary elements in the wings and the vertical stabilizer.

The forward fuselage contains all the elements necessary to maintain the crew of the shuttle during space flight. The forward fuselage is further broken down into the upper and lower fuselage, the forward Reaction Control System(RCS) module, and the crew compartment. The crew compartment sits inside the forward fuselage supported by the outer shells structure. The crew compartment houses the air and water system for the shuttle which is supplied from cells in the midfuselage.

The midfuselage is made up of the cargo bay which is the largest part of the Orbiter. The cargo bay is sealed from the forward fuselage by a bulkhead and an airlock. Other important subsystems are contained in the midfuselage including three fuel cells which generate all the electricity for the shuttle, and fuel cells containing hydrogen and oxygen for the forward fuselages atmospheric control. The cargo bay is equipped to hold satellites and even a small space lab which is used to conduct tests on the effects of the outerspace environment.

The aftfuselage contains the most volatile of any of the Orbiter's mechanical systems, the main rocket engines. It is the sole purpose of the aft fuselage to support the massive structure of the main engines which produce a lift-off thrust of 375,000 pounds each and weight 6500 pounds apiece, dry. The aft fuselage also holds the Orbital Maneuvering System(OMS) which sits on top. The vertical tail finishes the aft.

Structural Analysis

The Orbiter is about the size of a DC-9 commercial airliner with a wingspan of approximately 78 ft. and an overall length just over 122 ft. The Orbiter is broken down into five different structural systems, the forward fuselage, the midfuselage, the aft fuselage, the two wings and the vertical stabilizer. Again the structural system of the overall system is broken down into the Orbiter, the External Tank, and the Solid Rocket Boosters. The External Tank is the largest structure on the space shuttle measuring in at 154 ft. in length and 27.5 ft. in diameter. It houses two tanks that store liquid propellent for the journey to space. The structure is comprised of aluminum-alloy members and more recently aluminum-lithium. This material is used now because it reduces the weight of the ET by 7500 lbs. This was necessary for missions to the new International Space Station.

The Solid Rocket Boosters are constructed much like the External Tank. Each booster is 116 ft. long and 12 ft. in diameter. They hold solid propellent and are reused after every mission.

The forward fuselage is actually two structural elements, the outer shell and the crew compartment. The outer shell consists of aluminum frames that give the Orbiter its outward appearance. The crew compartment consists of 2024 machined aluminum ally panels that are welded together to make the compartment pressurized. The crew compartment is supported within the forward fuselage at four attachment points.

The midfuselage measures 60 ft. long by 15 ft. wide and is the largest structural piece of the Orbiter. It is a primary load carrying structure between the forward and aft fuselages. It contains the cargo bay and many other subsystems for the Orbiter. Most of the fuselage is taken up by the cargo bay which can carry up to 29.5 tons of cargo into space and return with 14.5 tons. The doors of the cargo bay are made out graphite-epoxy composite material. The doors are the largest structures made of this particular material. The midfuselage's structure are frames constructed from a combination of aluminum panels with riveted or machined integral stiffeners and a truss for the center section. The midfuselage is then skinned with low-temperature reusable surface insulation which is topped with integral machined aluminum panels, as well as, some aluminum honeycomb sandwich panels. The midfuselage is also responsible for carrying the load of the wings, the connection goes through the back section of the fuselage.

The aft fuselage's primary role in the structural system of the orbiter is to house the big main engines. The aft fuselage includes a truss-type interior structure made out of diffusion-bonded elements, that directly supports the rocket engine. The outer structure is relatively conventional though, consisting of members that resemble stud wall construction. The job of the aft fuselage is to transfer the load of the main engines into the midfuselage and external tank. The Orbital Manoeuvreing System is made of graphite epoxy skins and frames, much like the cargo bay doors. An aluminum bulkhead and reusable insulation separate and protect the midfuselage from the aft fuselage.

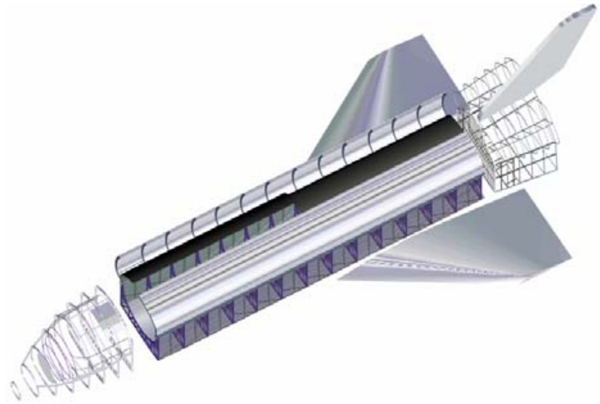
The vertical stabilizer is the finishing touch on the aft fuselage. It does not share any of the structural characteristics of the aft fuselage though. The tail is actually a split rudder so that is can double as a speed brake. The vertical tail consists of an aluminum structure formed from ribs, webs and stringers to make a load carrying torque box supporting a split rudder. Other controlling surfaces include a body flap that is attached to the lower section of the aft fuselage, it is used during descent from space for pitch control. Structurally it consists of conventional multi-rib and aluminum honeycomb skin.

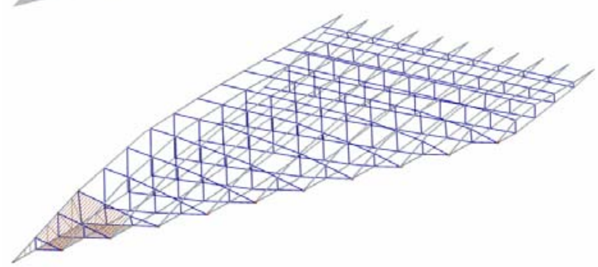
The wings of the Orbiter are unique compared to conventional aircraft. Instead of a traditional wingbox, it is comprised of a truss like system. The wing is constructed of a conventional aluminum alloy, using a corrugated spar web, ribs and riveted skin-stringer and aluminum honey comb sandwich panel covers.

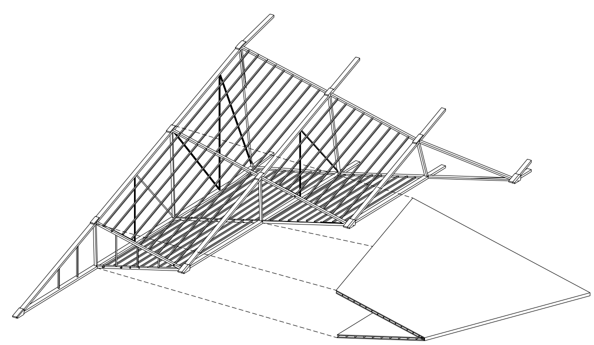
The sandwich panels consist of a layer of aluminum alloy then a layer of aluminum in the shape of a bee's honeycomb, then another layer of aluminum alloy. The shape of the honey comb gives in tremendous strength in compression. The sandwich panel is also used in traditional airplane manufacturing, normally as flooring. The total thickness of the sandwich panel does not exceed 3/8 of an inch.

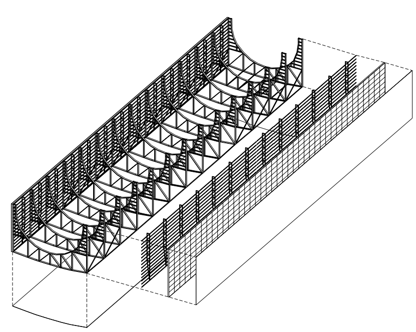
The construction of the wing is to give it extra rigidity as it reenters the Earth's atmosphere. It does not reenter as one might think at a very steep pitch, but rather in comes in at a 34^{o} pitch so there is a lot of stress on the wing, as the force is trying to push it into the fuselage. Each wing carries a two piece elevon which controls turn and bank or pitch up and down. Each elevon is 9.8 m long and 2.65 m wide. They are attached to the wing by 6 hinges and rub strips carry seal panels to smooth the join between elevon and wing. The wing structure is 9 percent of the total weight of the Orbiter.

The materials for the Orbiter are very conventional except for some exceptions with the insulating materials and the cargo bay doors. Aluminum alloy is used through out the entire craft, from structural elements to the skin of the spacecraft. Aluminum has a high strength to weight ratio, and relatively low cost. There for it is perfect for the shuttle which is built on a budget and needs to be extremely light to be lifted off the Earth's surface easily.









Edgar Stach is a Professor of Architecture at the University of Tennessee, Knoxville. Email: stach@utk.edu

Brian Willer is a 4th year architecture student, University of Tennessee. Email: bwiller@utk.edu