



# IJRASET

International Journal For Research in  
Applied Science and Engineering Technology



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# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

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**Volume:** 10    **Issue:** II    **Month of publication:** February 2022

**DOI:** <https://doi.org/10.22214/ijraset.2022.40237>

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# Analysis of Materials Used in Hyperloop Capsule

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**Abstract:** Hyperloop transportation system is the advancement of railway system. It can eliminate most of the problems which occurs when we use road as a medium of transport. It uses a capsule kind of a thing which carries upto 28 passengers. The main area of research done is on the materials used to make the capsule of the hyperloop. We have compared many materials and have come out with the best material as far as our knowledge is concerned . The capsule must be made of materials which possess very good properties and which are resistant to impact forces. We have come across 3 such materials and have included another interesting material which can be made in the near future. While selecting the material we have to do a pre feasibility study which covers aspects such as budget longevity availability etc. The four materials which we came across are steel , concrete, carbon fibre and vibranium.

## I. INTRODUCTION

Elon Musk was the first to propose this transportation system, and in this paper, he outlined the project's ultra-high-speed transit system. This transportation system was designed to convey passengers between San Francisco and Los Angeles in California (USA). This technology uses a capsule that travels at a speed of 1220 kilometres per hour inside the tube, covering a distance of 561 kilometres in around 30 minutes. This ultra-high-speed transportation system, known as the Hyperloop, became so well-known that numerous governments began development in preparation for its usage.

We came across 4 such materials. The most used material used is steel because of its high strength Another material used is carbon fiber because they have less weight when compared to other materials listed further. Vibranium is also a material which we came across but it doesn't exist in real world but can be developed using intelligent engineering. Concrete is also used because rigidity and stiffness.

## II. STEEL

One of the most often used low carbon steels is SAE AISI 1018. Carburized steel is the most common application. Because the majority of 1018 carbon steel is made by cold drawing, this cold rolled steel is referred to as C1018 (1018 cold rolled steel). Weldability, surface hardening quality, mechanical qualities, and machinability are all advantages of AISI C1018 steel (1018 CRS). Cold drawing improves tensile, yield, torsional, surface hardness, and wear resistance while reducing ductility.

1018 HR is an ASTM AISI SAE 1018 hot rolled steel with good toughness, strength, ductility, formability, weldability, and workability.

### Applications

Round bar, flat bar, steel tubing and pipes, and other semifinished and finished items are available in AISI SAE ASTM 1018 steel. Carburized parts such as gears, pinions, ratchets, worms, pins, chain pins, pins, machine parts, tools, and mould components are usually made of 1018 carbon steel.

### A. Specification & Datasheet

The chemical composition, density, thermal expansion coefficient, thermal conductivity, yield strength, hardness, and other properties of AISI 1018 carbon steel are listed below.

### B. AISI SAE 1018 Chemical Composition

ASTM AISI SAE 1018 chemical composition is presented in the following table.

| Steel Grade       | AISI SAE 1018 Chemical Composition (%) |           |       |       |
|-------------------|--|-----------|-------|-------|
|                   | C                                      | Mn        | P (≤) | S (≤) |
| 1018 (UNS G10180) | 0.15-0.20                              | 0.60-0.90 | 0.040 | 0.050 |

**C. AISI SAE 1018 Mechanical Properties**

Modulus of elasticity (Young’s modulus): 186 GPa ( $27 \times 10^6$  psi)

The following tables give AISI SAE 1018 steel mechanical properties of cold-drawn carbon steel rounds, squares, and hexagons.

| Steel (UNS)        | Tensile strength (Mpa) | Yield strength (Mpa) | Elongation in 50 mm, % | Reduction in area, % | Hardness (HB) | Processing, condition or treatment | Sample Diameter (mm) |
|--------------------|------------------------|----------------------|------------------------|----------------------|---------------|------------------------------------|----------------------|
| AISI 1018 (G10180) | 483                    | 413                  | 18                     | 40                   | 143           | Cold drawn                         | 16-22                |
|                    | 440                    | 370                  | 15                     | 40                   | 125           | Cold drawn                         | 20-32                |
|                    | 414                    | 345                  | 15                     | 35                   | 120           | Cold drawn                         | 32-51                |
|                    | 400                    | 220                  | 25                     | 50                   | 115           | Hot rolled (steel bar)             | 20-32                |

**D. Typical Heat treatment for SAE 1018 Case Hardening**

- 1) Reheat temperature: 790 °C (1450 °F), cooling method: water or 3 percent sodium hydroxide; • Carbon temperature: 900-925 °C (1650-1700 °F), cooling method: water or caustic;
- 2) Temperature for carbonitriding: 790-900 °C (1450-1650 °F), cooling method: oil
- 3) Temper temperature: 120-205 °C (250-400 °F) to relieve stress and improve crack resistance (not mandatory).

**III. CONCRETE**

**A. Hyperloop Concrete Structure and Tubes**

Hyperloop tubes must be sturdy, stiff, resilient, and airtight. The shape and size of the tubes are currently made of concrete and steel, however an alternate tube design in concrete (ultrahigh performance steel fibre reinforced concrete) UHPFRC is also being studied. The hyperloop’s structure is made up of huge concrete tubes. These tubes will mostly be erected on pylons, with some ground level and underground pieces thrown in for good measure.

**B. Properties of Hyperloop Concrete**

- 1) The tubes has condition similar to a vacuum.
- 2) It almost eliminates air resistance.
- 3) During moment, the pod levitates which in turn reduces the force of friction.
- 4) As it moves faster, because of straight tubes.

| Grades of concrete | Modulus of Elasticity in KN/mm <sup>2</sup> |
|--------------------|---|
| M20- M25           | 30  |
| M25-M30            | 31  |
| M30-M35            | 32  |
| M35-M50            | 33-35                                       |
| Grades of concrete | Tensile strength                            |
| M20- M25           | 2.2 N/mm <sup>2</sup>                       |
| M25-M30            | 2.6 N/mm <sup>2</sup>                       |
| M30-M35            | 2.9 N/mm <sup>2</sup>                       |
| M35-M50            | 3.2-3.5N/mm <sup>2</sup>                    |
| M50-M60            | 3.5-4.1N/mm <sup>2</sup>                    |

**C. Advantages**

- 1) These pipes can withstand tensile stress (due to internal pressure).
- 2) They are economical, hence used for every type of sewers.
- 3) High compressive strength.

**D. Disadvantage**

- 1) Can crack, due to dry shrinkage and moisture expansion.
- 2) Require formwork.
- 3) Low tensile strength and toughness.
- 4) Require a bulky structure.

**IV. CARBON FIBRES**

**A. Introduction**

Carbon fibres are of five to 10 micrometres in diameter

They Are Mostly Made Of Carbon Atoms

It was first founded in 1860 by Joseph swan

It was used in light bulbs

Its chemical formula is C60

**B. Properties**

- 1) High strength to weight ratio
- 2) Corrosion Resistant And Chemically Stable
- 3) Good fatigue resistance
- 4) Electrically conductive in nature
- 5) Very rigid in nature
- 6) Low coefficient of thermal expansion
- 7) Good Thermal conductivity

| Material                            | Grade / Type         | Design / Application | Longitudinal Tensile Strength (ksi) | Longitudinal Tensile Modulus (Msi) | Shear Modulus (Msi) | Density (g/cm <sup>3</sup> ) |
|-------------------------------------|----------------------|----------------------|-------------------------------------|------------------------------------|---------------------|------------------------------|
| Carbon Fiber/Epoxy (Unidirectional) | Standard Modulus     | Bending              | 300                                 | 15                                 | 0.6                 | 1.55                         |
| Carbon Fiber/Epoxy (Unidirectional) | Standard Modulus     | Torsion              | 20                                  | 2.2                                | 4.5                 | 1.55                         |
| Carbon Fiber/Epoxy (Unidirectional) | Intermediate Modulus | Bending              | 325                                 | 20                                 | 0.6                 | 1.57                         |
| Carbon Fiber/Epoxy (Unidirectional) | High Modulus         | Bending              | 250                                 | 30                                 | 0.6                 | 1.59                         |
| Carbon Fiber/Epoxy (Unidirectional) | Ultra High Modulus   | Bending              | 200                                 | 45                                 | 0.6                 | 1.70                         |
| Steel                               | 4130                 |                      | 100                                 | 30                                 | 12                  | 7.7                          |
| Titanium                            | 6M-4V                |                      | 120                                 | 16                                 | 6.2                 | 4.34                         |
| Aluminum                            | 6061-T6              |                      | 35                                  | 10                                 | 3.8                 | 2.7                          |

**C. Characteristics**

- 1) Physical strength, lightweight
- 2) Good vibration damping arm
- 3) Electromagnetic Properties Rings

**D. Application**

- 1) Automobile, sporting goods
- 2) Audio equipment, robot
- 3) Large generators, retaining.

**V. VIBRANIUM**

Hyperloop Transportation Technologies has claimed that it would use a new form of sensor-embedded carbon fibre in its capsules to make them capable of transporting passengers through a practically airless tube at speeds of up to 760 mph in a manner that is safer than ever before. The new substance is known as vibranium by the business. Anyone who has even a rudimentary understanding of Marvel Comics may recognise this name.

**A. Advantages**

- 1) It is stronger than steel and 1/3 of its weight
- 2) It is completely vibration and sound absorbent which means that it makes no sound even during any impact with an obstacle
- 3) It conducts electricity
- 4) It has magnetic properties
- 5) It is wind assistant
- 6) It deflects kinetic energy

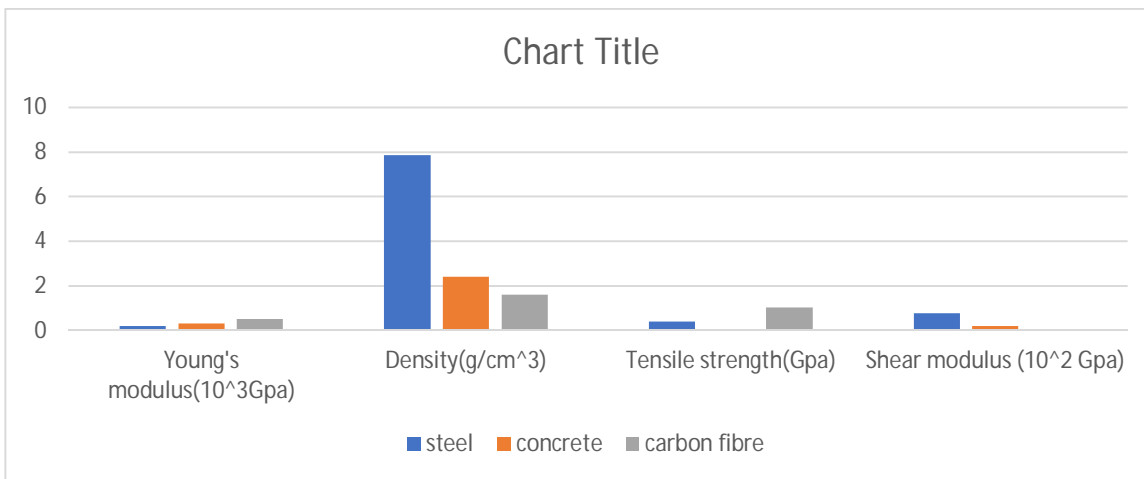
No natural material can have those qualities in the actual world. According to Drexel University's leading professors, sophisticated nanoparticles can be used to achieve various vibranium qualities while creating materials structures. For example, using sophisticated ceramic materials like boron carbide for lightweight armour or using piezoelectric materials that can convert vibrations into power. Some of the traits are visible in materials (with more than one element to form alloys or compounds), according to Ravichandran, a professor of chemical engineering, but not to the same extent as in vibranium. He cites visco elastic materials as an example, claiming that while they are good at absorbing sound, they aren't stiff enough to perform like vibranium. Other materials may be more impact resistant, however

So vibranium just exhibits the best properties of all materials .

**B. Scope for Real World Vibranium**

The greatest material we have for a real-world analogue of vibranium is probably graphene. However, some individuals are concerned about nano composite structures and designing materials that use nano particles that act like sand from a bowling ball that has been thrown out of a window. They're doing it in such a way that when energy comes in from a blast or a collision, it's distributed out over the nano particles. They can disperse the energy over a large number of atoms, ensuring that no new atom bears the entire weight and that no chemical connections or fissures are formed.

**VI. CONCLUSION**



From the above data we can conclude that carbon fiber has out performed in all the parameters but because of its cost we prefer steel to be used since it is more practical as it is widely available and less cost.



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