

# Chapter 3

## DESIGN METHODOLOGY

When designing a race car chassis, the designer needs to conform to the rules and regulations of the series or formula in which the vehicle competes. To ensure competitiveness, the chassis also needs to have the required performance enhancing characteristics. This chapter discusses the involved considerations, constraints and the development of chassis concepts together with the evaluation and assessment of the different concepts.

### 3.1 DESIGN CONSIDERATIONS

Developing and creating a geometric form of a vehicle chassis can be a complex procedure and exercise. There is no methodical procedure or an analytical, fundamental solution in defining the perfect or optimal shape and structure of a vehicle chassis. This applies to both road and race car environments. The challenge for road cars is to make a vehicle economical and sustainable. The criteria race cars are to have the adequate stiffness, minimum weight and the desirable geometric properties to perform on a racetrack.

Most race car chassis developments are created to comply with the rules and regulations prescribed for the specific class or formula which they are built for. The rule maker's prescriptions for the formula or class will state everything from the type of car, engine, safety requirements as well as other design specifications. It will dictate the overall design of the car in order to ensure a fair race environment without reducing safety standards. The concept, funding and idea of all the rules and regulations are determined by the relevant organisations and societies governing the sport.

With the rules defining the foundations of the vehicle, race car designers will develop and create unique solutions for the various problems they encounter in the process in order to place the best performing vehicle on a race track. The biggest challenges involve the vehicle's weight, centre of gravity as well as the torsional stiffness of the chassis. It is crucial to ensure that a vehicle has the minimum mass for the available power. Furthermore, it is vital to have a torsional rigid chassis to achieve the required handling performance. Designers, therefore, work iteratively on various solutions, ideas and concepts in order to achieve the characteristics at a desired performance level.

### 3.2 PHYSICAL CONSTRAINTS

It is a challenging task to develop a concept from scratch with no previous experience, references or scientific data. Fixed variables and concrete information should be considered and referred to in order to form a basic outline, together with the physical constraints, of the chassis. The Formula SAE (FSAE) series rules and regulations form the primary outline for designing a FSAE chassis. The geometric characteristics, shape and mounting points of the engine will be the secondary references and determinants of the chassis outline.

#### 3.2.1 IMPLICATIONS AND INTERPRETATION OF THE FORMULA SAE RULES

As stated in the previous section, the rules of the FSAE series guide the vehicle chassis designer to the required geometric shape and characteristics. The rules provide the

necessary details and descriptions on what is required of the vehicle structure as well as the minimum required structural members and integrity. The FSAE rules and regulations are presented in a document compiled to include all the relevant and necessary design guidelines to ensure a fair and safe competition. The set of rules and regulations stipulate everything from the engine, driver ergonomics and aerodynamics. Only a brief discussion of the rules applicable to the race car chassis will be discussed. The complete set of rules with regards to the chassis can be found in Appendix A.

### **General design requirements**

The Formula SAE race car must be an open-wheeled formula styled vehicle with four wheels that are not in a straight line. The driver compartment must be completely enclosed from the front to the back of the roll bar main hoop, or firewall between the driver and the engine. This excludes the cockpit opening for driver entry.

The wheelbase of the vehicle must be no smaller than 1525 mm while the smaller track of the vehicle must be no less than 75% of the opposite wheel pair's track.

All the items appearing on the inspection sheet provided for the judges must be visible for the use of instrumentation. Access may be provided by removing body or access panels.

### **Driver's cell of the vehicle**

The driver's cell generally consists of all the structural components around the driver's cockpit and location.

#### General requirements of a vehicle structure

Formula SAE has the two options of constructing the vehicle. One being the conventional way of the driver's cell option as defined below. For the alternative option, permission and testing procedures are needed from the SAE. All components must be constructed from a single piece of uncut, continuous, closed section steel tubing as stated in Table 3-1.

Major requirements for a Formula SAE race car must include the following:

- Two roll hoops that are braced
- A front bulkhead with a support system and impact attenuator
- Side impact structures

#### Minimum Material Requirement

The baseline steel material of the vehicle's structure must be constructed of round, mild or alloy steel tubing with a minimum of 0.1% carbon. Table 3-1 lists the minimum dimensions.

The use of alloy steel forbids the wall thickness to be thinner than that used for mild steel.

Baseline properties for the steel selection may not be lower than the following values for bending and buckling strength:

- Young's Modulus (E) = 200 GPa
- Yield Strength (Sy) = 305 MPa
- Ultimate Strength (Su) = 365 MPa

For tube joint calculations:

- Yield Strength (Sy) = 180 MPa
- Ultimate Strength (Su) = 300 MPa

**Table 3-1: Minimum component structure dimensions**

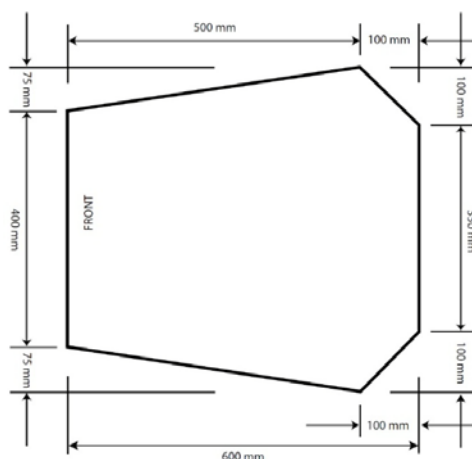
ITEM or APPLICATION	OUTSIDE DIMENSION and WALL THICKNESS
Main & Front Hoops, Shoulder Harness Mounting Bar	Round 25.4 mm x 2.40 mm or Round 25.0 mm x 2.50 mm
Side Impact Structure, Front Bulkhead, Roll Hoop Bracing, Driver's Restraint Harness Attachment	Round 25.4 mm x 1.65 mm or Round 25.0 mm x 1.75 mm or Round 25.4 mm x 1.60 mm or Square 25.0 mm x 25.0 mm x 1.25 mm or Square 26.0 mm x 26.0 mm x 1.20 mm
Front Bulkhead Support, Main Hoop Bracing Supports	Round 25.4 mm x 1.25 mm or Round 25.0 mm x 1.50 mm or Round 26.0 mm x 1.20 mm

Specific vehicle components

The rules describe several of the vehicle chassis components in detail. This specifies each component's material and dimension. It also describes the physical constraints and orientation of each component. Many components are used as chassis structural members in order to improve structural performance. The rules for the structural components also form the outline for the chassis design, as discussed in Chapter 4. Table A-1 in Appendix A lists all the components specified by the FSAE rules together with the relevant specifications.

**Cockpit**

In order to ensure that the opening giving access to the cockpit is of adequate size, a template shown in Figure 3-1 will be inserted into the cockpit opening. It will be held horizontally and inserted vertically until it has passed below the top bar of the side impact structure. The steering wheel, steering column, seat and all padding may be removed during this test.



**Figure 3-1: Template for the cockpit opening (Formula SAE Rules, 2012)**

A free vertical cross section, which allows the template shown in Figure 3-2 to be passed horizontally through the cockpit to a point 100 mm rearwards of the face of the rearmost pedal when in the inoperative position, must be maintained over its entire length. If the pedals are adjustable, they will be put in their most forward position.

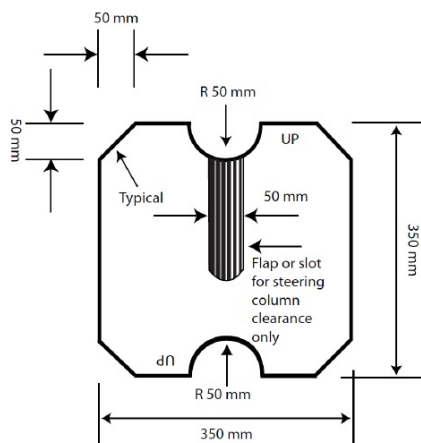


Figure 3-2: Template for the driver's leg space (Formula SAE Rules, 2012)

The template, with a maximum thickness of 7 mm, will be held vertically and inserted into the cockpit opening rearward of the front roll hoop, as close to the front roll hoop as the car's design will allow. Only the steering wheel and padding that can be easily removed may be removed for this test. The seat may not be removed.

**General chassis rules**

A fully operational suspension with shock absorbers, front and rear, must be fitted to the car. All suspension mounting points must be visible for inspection, either by direct view or by removing any covers.

There is no minimum ground clearance requirement. Any vehicle with contact to the ground that creates a hazardous condition or causes damage will be disqualified. The wheels of the car must be 203.2 mm (8.0 inch) or more in diameter. The track and centre of gravity specifications of the car must combine to provide adequate rollover stability. Rollover stability is evaluated on a tilt table using a pass-fail test. The vehicle must not roll when tilted at an angle of sixty degrees to the horizontal in either direction, corresponding to 1.7 G's.

The chassis frame must accommodate drivers whose stature ranges from 5<sup>th</sup> percentile female to 95<sup>th</sup> percentile male as stated by the Formula SAE rules. This is to ensure both safety and ergonomic requirements. This template is illustrated in Figure 3-3.

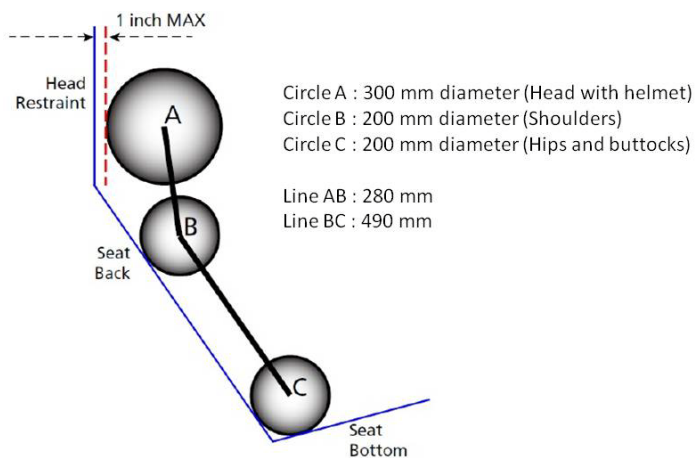


Figure 3-3: Illustration of the dimensions of a 95<sup>th</sup> Percentile male (Formula SAE Rules, 2012)

### 3.2.2 ENGINE MOUNTING POINTS

The chassis structure will also accommodate the vehicle's power source. For the purpose of this study, the Yamaha 600cc YZF motorcycle engine's default mounting points will be utilised. The engine has eight mounting points which is situated on the engine's structure itself. For the FSAE chassis, only six mounting points will be used due to geometric and symmetric aspects and considerations. The mounting points will determine the structure or bulkhead of the chassis behind the driver cockpit where the engine will be mounted on the chassis.

### 3.2.3 SUSPENSION MOUNTING POINTS

The study does not consider the suspension development of a FSAE vehicle. The suspension mounting points will be determined by a specific suspension design. The front and rear sections of the chassis structure will need to have a particular shape in order to allow for future developments of independent suspension components.

## 3.3 DESIGNING WITHIN PHYSICAL CONSTRAINTS

Considering all of the above parameters and characteristics, a basic outline of the chassis structure can be formed with the minimum requirements in terms of structural integrity, practicality and safety standards. The outline will not determine the final product, but it will guide the designer to obtain a starting point and to define the basic geometric shape of the chassis frame. The elementary geometric shape is governed by the FSAE rules in terms of obliged structural members.

### 3.3.1 ROLL HOOPS & BRACINGS

The chassis frame must have front and main roll hoops. As discussed, both roll hoops must extend from the lowest frame member on one side, up, over and down to the lowest frame member on the opposite side of the frame. Both the front and main hoop must be supported by two hoop braces, one on each side. The minimum width between the main hoop's lower end points is 380mm. The distance between the front and main hoops is not specified in the FSAE rules, but the distance between the driver's helmet and the line connecting the top of the front and main hoops is prescribed (See Figure 3-4).

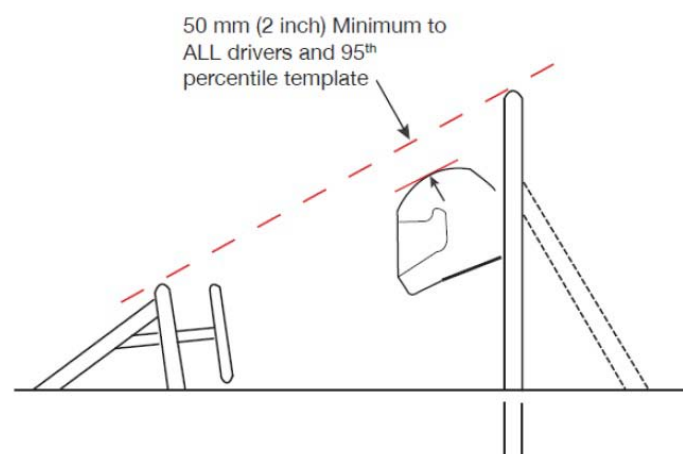


Figure 3-4: Illustration of the main and front roll hoop height relationship (Formula SAE Rules, 2012)

The front and main hoop will thus form the basis for the rest of the structures (Figure 3-5). All the components and structures discussed next will connect to the two roll hoops to form the basic structure of the chassis frame.

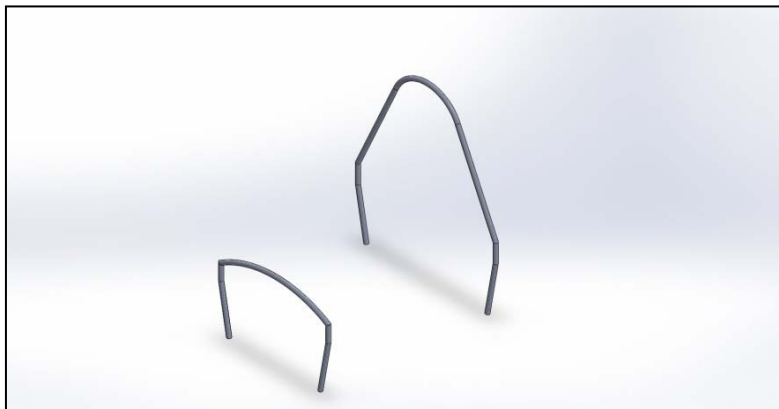


Figure 3-5: SolidWorks® representation of the main and front roll hoops

### 3.3.2 FRONT BULKHEAD & SUPPORTS

The front bulkhead of the chassis frame must form the structure at the very front of the frame. Non-crushable objects should all be rearward of the bulkhead structure. The bulkhead will form the frontal plane of the whole structure and must be integrated securely into the frame itself. The front bulkhead should be supported rearward towards the front roll hoop by at least three frame members on each side as shown in Figure 3-6. The supporting frame members are required to be at the top and bottom of the bulkhead whilst the third is required to be diagonal. The six support members and bulkhead can accommodate the braces required by the front bulkhead.

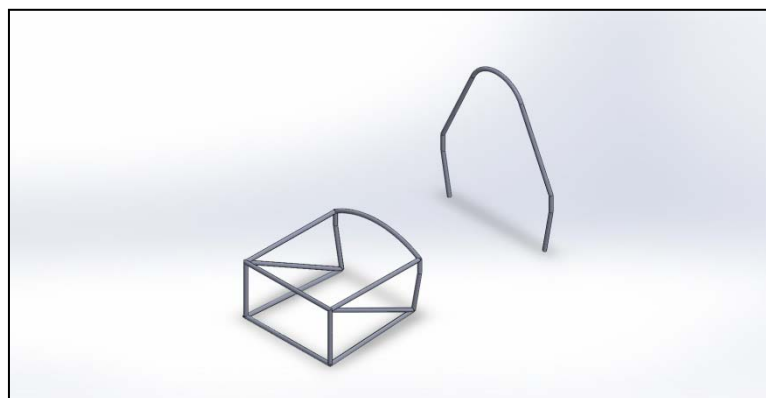


Figure 3-6: SolidWorks® representation of the front bulkhead and its three supports

### 3.3.3 SIDE IMPACT STRUCTURES

The chassis frame requires three frame members on each side of the structure as shown in Figure 3-7. All of the side structures must connect the front and main roll hoop. The bottom member must connect the lower end points of the roll hoops. The upper member will connect them at a specific height above the ground, whilst the third member will provide diagonal triangulation between the horizontal members. Figure 3-8 shows a representation of the front structure of the chassis with the side impact structures.

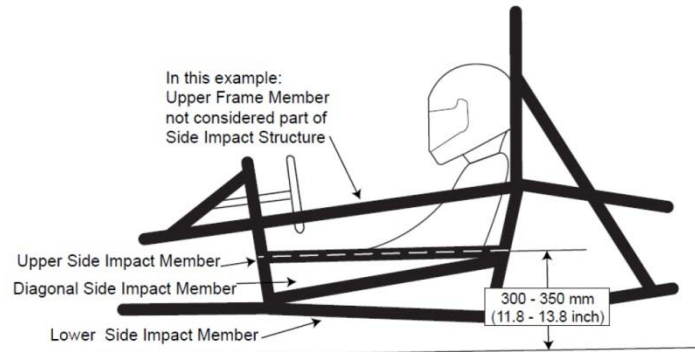


Figure 3-7: Illustration describing the side impact structures (Formula SAE Rules, 2012)

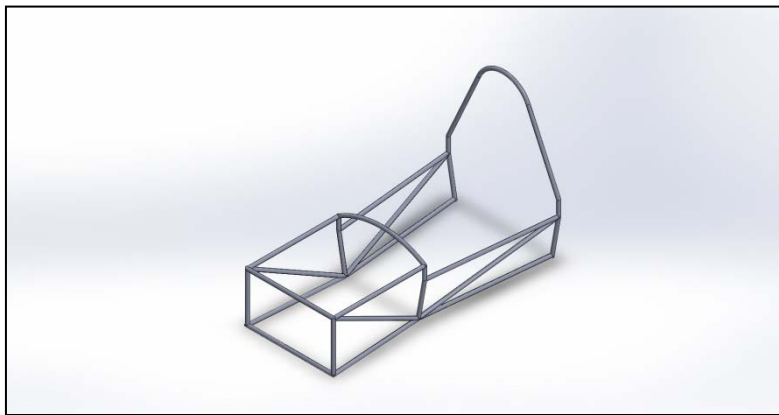


Figure 3-8: SolidWorks® representation of the side impact structures

### 3.3.4 REAR STRUCTURE

There are no guidelines or regulations with regards to the rear structure of a chassis frame according to the FSAE rules. The rear structure of the chassis is responsible for accommodating the engine, the driveline and the rear suspension system. Due to the various power sources available and driveline options, the FSAE rules don't state anything regarding this area of the chassis as this will differ for the different engine geometries used and design philosophy. The geometry of the rear of any FSAE chassis will thus be determined by the components of the vehicle itself. The geometry and mounting points of the engine are, therefore, used as the primary guideline for the design.

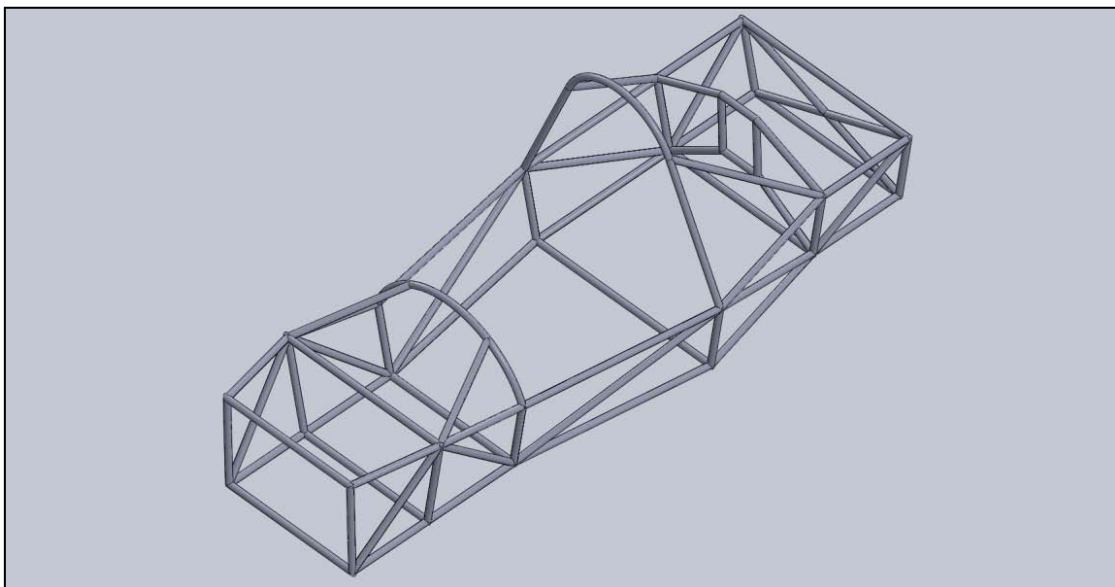
## 3.4 CONCEPTUAL DESIGN PROCESS

The chassis formed by the above constraints can guide the chassis designer towards an initial concept. As discussed earlier, there is no analytical procedure for designing such a structure. The success of the design is dependent on ensuring that the weight and stiffness targets are adequate and that the chassis accommodates all the components. The chassis also has to comply with the necessary safety standards. There are many ways to approach such a design challenge. Various chassis geometries and structures are considered and analysed. To ensure that the chassis is structurally sufficient, it is crucial to focus and exploit the areas of the chassis frame where the rules and regulations of the FSAE competition allow freedom of design. The rear structure, the shape and structure of the bulkheads and its supports as well as the bottom structure of the chassis frame are areas that can be exploited.

There are several combinations and permutations for laying out a chassis frame structure. Combinations include different styles of triangulation, bulkhead designs together with the orientation and usage of individual structural members. Each prototype was designed using SolidWorks® computer aided design (CAD) software. The CAD model prototypes were tested using finite element (FEA) software to determine the relevant chassis structural properties and physical characteristics. All of the models were derived from the primary structural requirements specified in the FSAE rules as discussed in the previous section. The rear structure was designed according to the mounting points of the engine geometry, whereas the bulkheads and other supporting members were designed to accommodate simple and conventional suspension geometry.

Figure 3-9 shows the concept developed for a basic chassis frame for the FSAE competition. Numerous models were developed and considered for the design. After close analysis and consideration, three concepts were identified. The differences between the identified concepts were the result of the way the design of each concept was approached as well as the involved design philosophy. All of the concepts were primarily based on the requirements and rules specified.

Every concept or design had several iterations involving changes in structural member usage and geometric orientations, in order to develop a chassis which had the desirable structural and mass properties. The first concept was a conservative and conventional model, whereas the second concept was a more innovative model in the way structural members were used. The third concept was an unconventional approach in the way the bulkheads and front structure were designed and orientated.



**Figure 3-9: SolidWorks® representation of a basic FSAE car chassis**

All the iterations of the concepts were analysed using the SolidWorks® FEA simulation software. The weight, torsional stiffness and factor of safety of all the concepts were studied. All the concepts were tested identically using the SolidWorks® FEA software. The test method consisted of fixing the chassis frame at the rear end while two forces were applied at the front of the chassis frame. The two forces have identical magnitudes, but opposite directions. The two forces form a couple, creating a moment in the middle of the front bulkhead (Figure 3-10). The forces were systematically increased to study each concept's

structural characteristics. The deflections were determined with the SolidWorks® software, by increasing the forces, which allowed each concept's torsional stiffness to be calculated and examined. The stresses together with the safety factors were also measured in order to determine which concept could withstand the highest torsional loads prior to failure. SolidWorks® also provided each model with its accompanying weight and centre of gravity position.

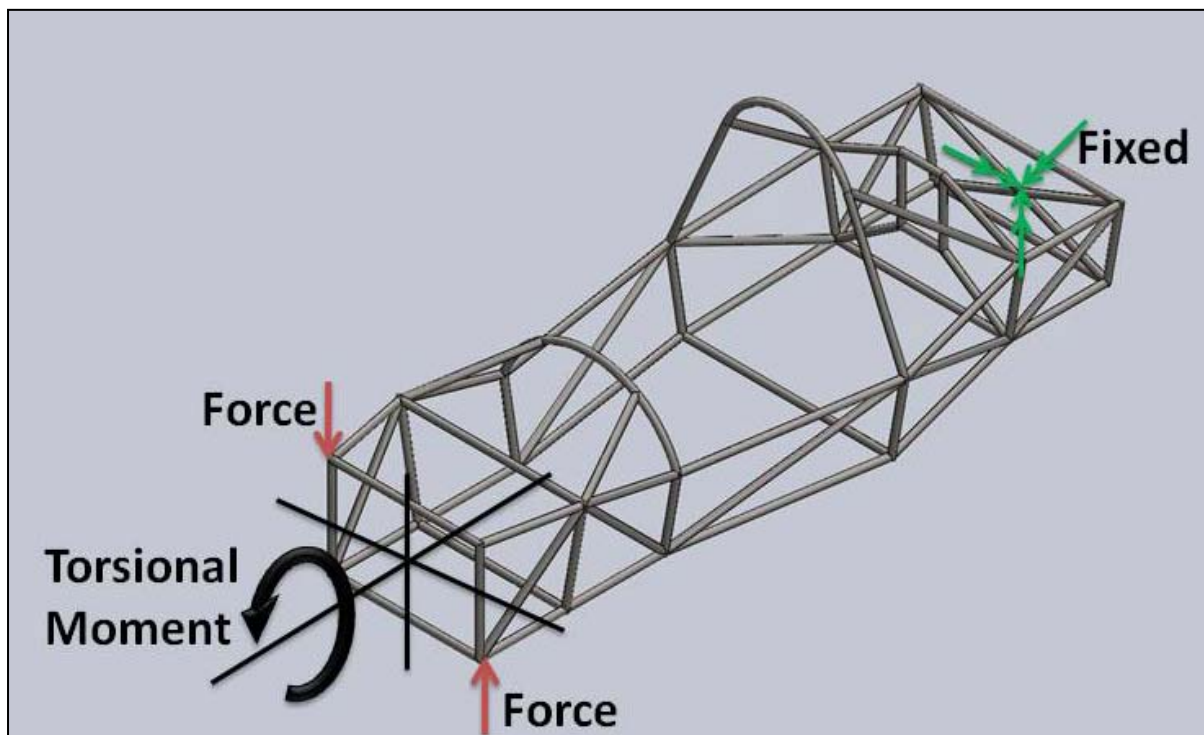
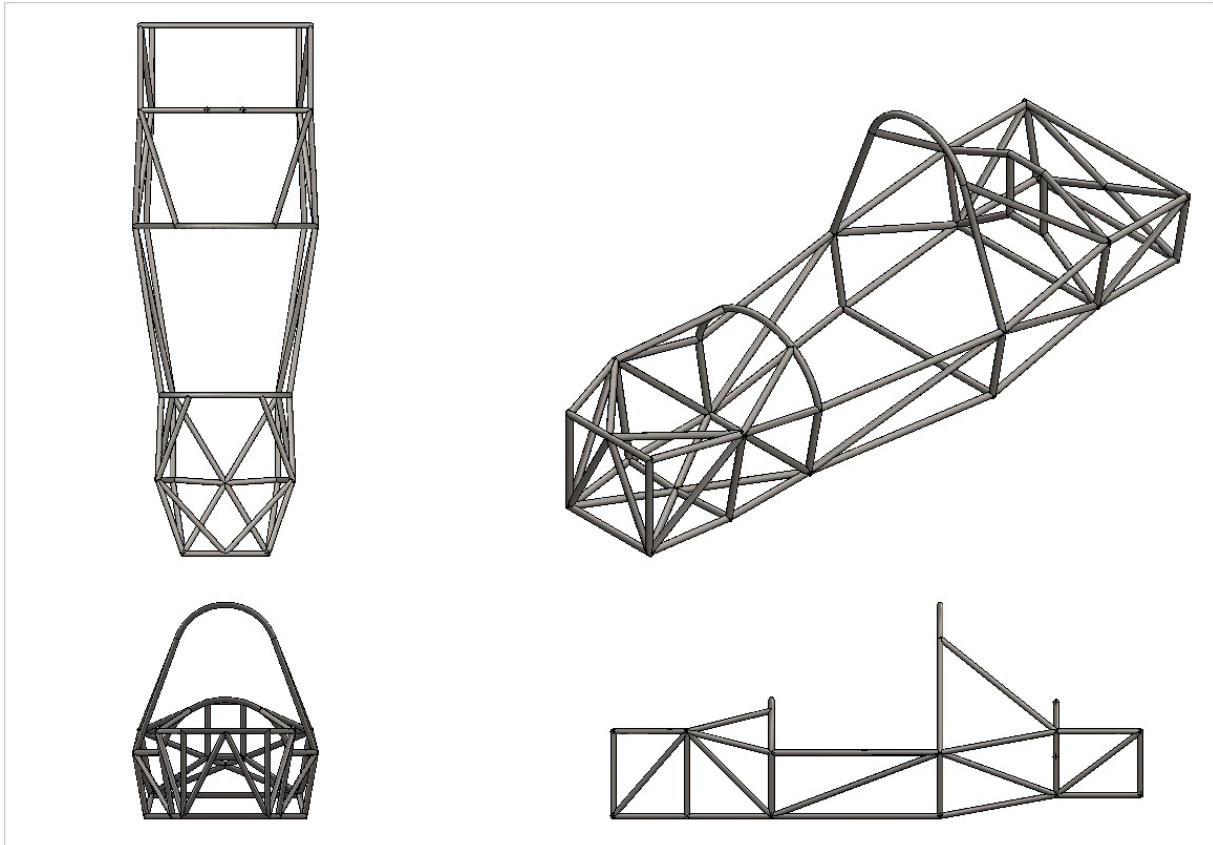


Figure 3-10: Schematic representation of the test method showing the chassis fixture point and the applied forces.

The final iterations of each of the three design concepts or philosophies are presented and discussed in the following three subcategories. The three concepts developed were designed with identical wheelbase lengths, engine and suspension mounting points.

#### 3.4.1 CONCEPT I (CONVENTIONAL DESIGN CONCEPT)

The first concept, shown in Figure 3-11, was designed using conventional techniques and the basic descriptions found in the Formula SAE regulations. The design technique split the chassis frame into four different bays, separated by the bulkheads or roll hoops. The bulkhead structures together with the bays of the complete structure were placed in the conventional positions. Both the front and main roll hoop structures were designed as closed structures. The conventional positioning of the structural members was also applicable to the triangulation of the structure and the way the additional structural members were orientated.

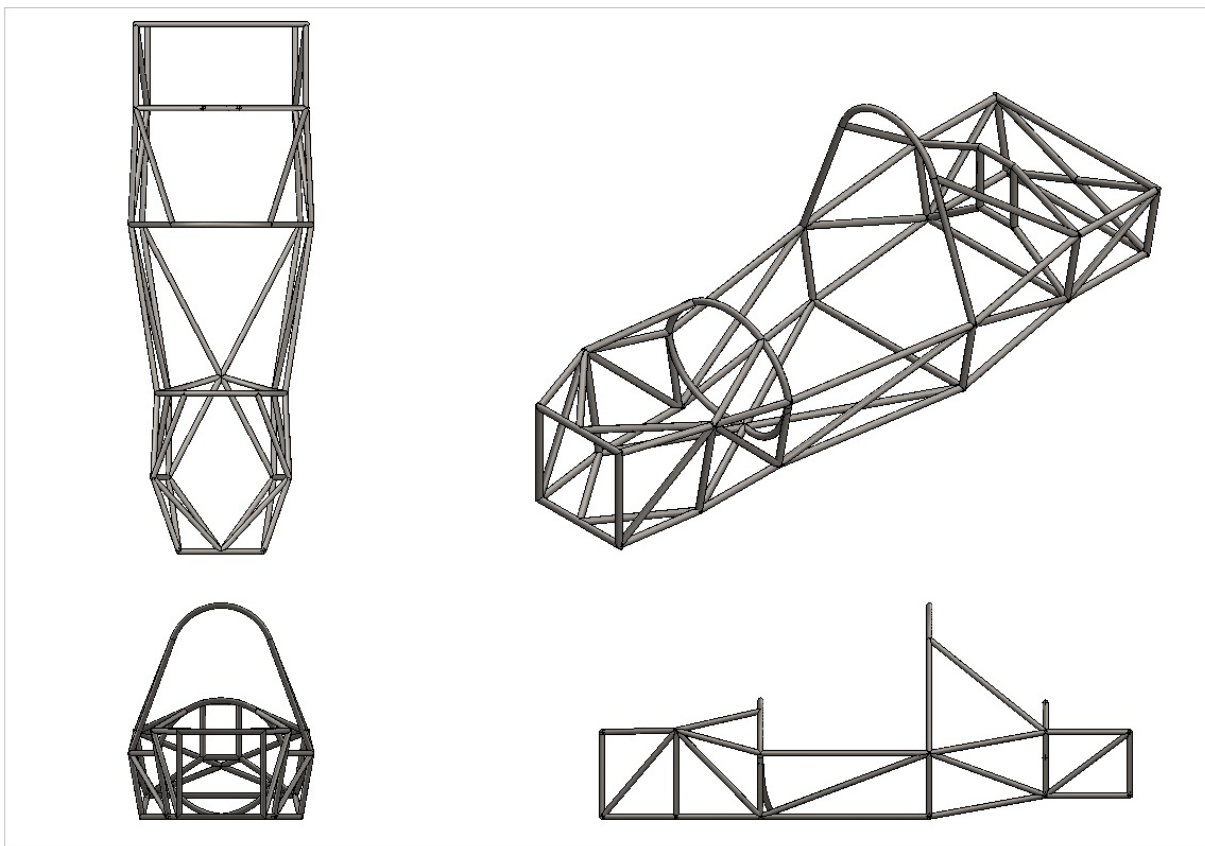


**Figure 3-11: Illustration of Concept I**

One of the key features of this concept was the star-forming triangles at the bottom between the front bulkhead and the front roll hoop. This ensured adequate stress distribution between the front structural members. Another feature was the structural members within the front bulkhead, which translate the forces from the top and bottom structures adequately with very little weight addition. It can also be noticed that the middle bay of the cockpit has no triangulation or structural members at the bottom. Numerous iterations and developments done in the FEA software showed that members in this space, will contribute more to the chassis frame's weight, than to its torsional stiffness. Such members would therefore have decreased the torsional stiffness efficiency.

#### 3.4.2 CONCEPT II (INNOVATIVE DESIGN CONCEPT)

The second concept, shown in Figure 3-12, was designed with a more innovative approach in terms of the usage of structural members. The bottom structure of the front and cockpit bay was designed as one structure, connecting the main roll hoop with the front bay structural members. This concept differs from the previous one as the front roll hoop was not designed as a continuous, closed structural member.

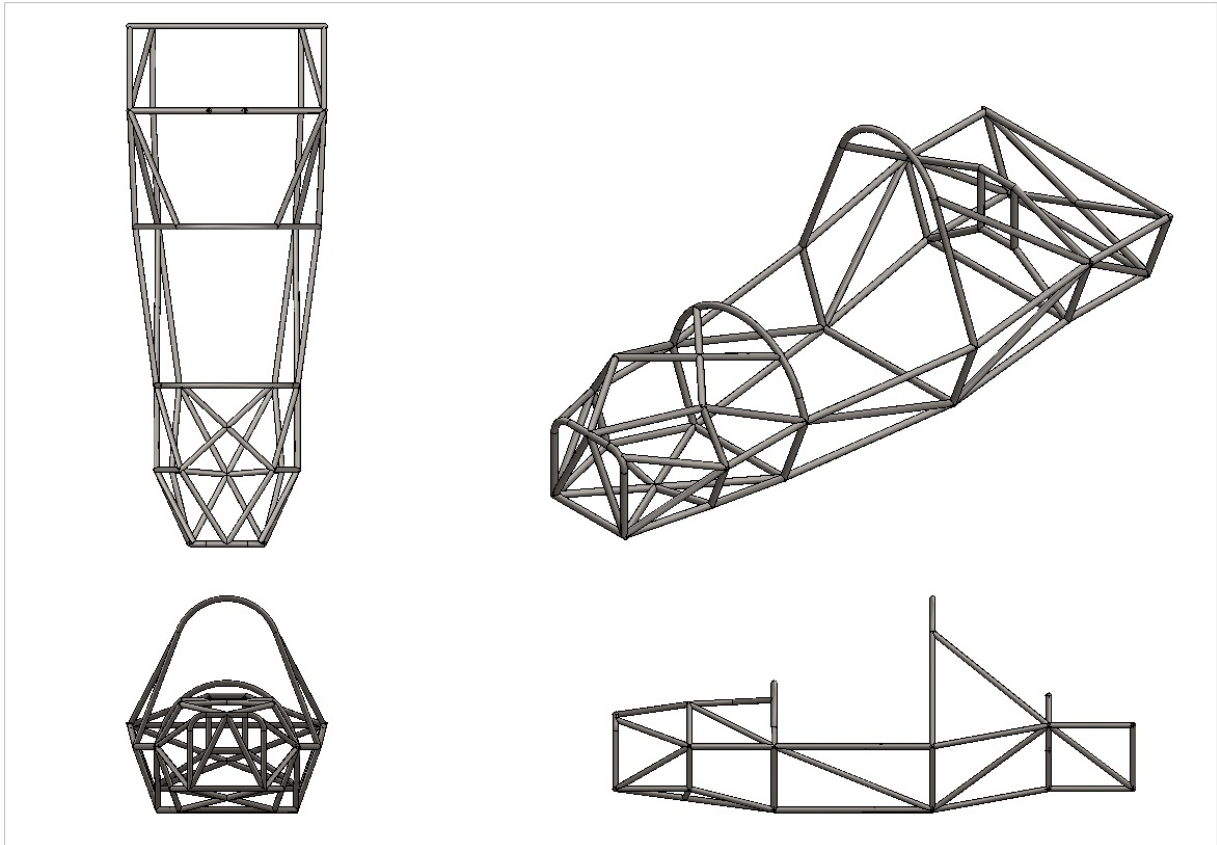


**Figure 3-12: Illustration of Concept II**

A crucial characteristic of this design is that the bottom structure can translate axial forces effectively from the front part of the chassis frame towards the rear, but will be weak against the impact of bending loads due to the structural member lengths. For this reason, the bottom structure was supported on both sides, connecting the middle joint of the bottom structure to the end of the front roll hoop arc. The reason why it was shaped in an arc was to satisfy the Formula SAE cockpit regulations. The rest of the triangulation of the structure was similar to the previous concept. There was no triangulation within the front bulkhead.

### 3.4.3 CONCEPT III (IMPROVED BULKHEAD DESIGN CONCEPT)

The third and final concept's design approach was rather novel compared to that of the previous concepts as shown in Figure 3-13. The concept was developed in order to increase the torsional stiffness without increasing the weight. The primary goal was to form more triangular shapes within the structure. With this technique, more stiffness was obtained with less material. It included an increase of ten degrees between the members housing the suspension components and the horizon. The front bulkhead was also slightly higher relative to the bottom of the front and rear roll hoops. This design further exploited the use of structural members to form more triangles and complex geometric orientations in the middle of the front bay in order to translate the forces more adequately.



**Figure 3-13: Illustration of Concept III**

Another alteration was in the front bulkhead. Not only was it narrower than the previous concepts, but it also utilised curved structural members at the two top corners. The geometric shape and front bulkhead braces also allows for the front bulkhead to accommodate two triangulated structural members to disperse the stresses more effectively. The front bulkhead was also connected by the bottom structure to the front roll hoop. The middle joint of this triangulated structure was furthermore connected to the structure housing the suspension. Due to the height difference of the connecting point, these members contributed to the corner-shaped design of the structure. There was no members at the bottom of the cockpit bay, due to the effect it had on the torsional stiffness effectiveness as it added more weight to the structure while not contributing to the chassis frame's torsional stiffness.

### 3.5 CONCEPT DESIGN COMPARISON

All three of the discussed concepts were a result of several iterations of testing and analysis using the SolidWorks® FEA simulation software. The analyses within the FEA simulations were used to determine each concept's physical characteristics. The characteristics included torsional stiffness, weight, centre of gravity position and the factor of safety. Each concept was altered in terms of structural member orientation, structural member angle and length, together with structural design techniques. This was done with the help of the FEA software results, such as the stresses and displacements of each concept frame. All the iterations of every concept were necessary to find the most desirable characteristics of each concept and design.

**Table 3-2: Concept characteristics**

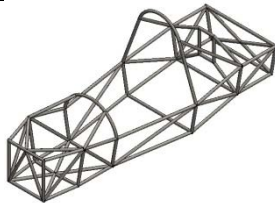
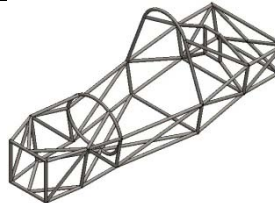
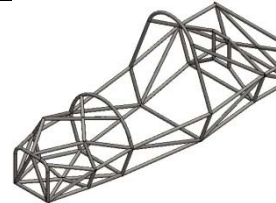
	<b>Concept I</b>	<b>Concept II</b>	<b>Concept III</b>
<b>Torsional efficiency</b>	10.28 [N.m/deg]/kg	8.10 [N.m/deg]/kg	13.95 [N.m/deg]/kg
<b>Torsional stiffness</b>	348 N.m/deg	281 N.m/deg	472 N.m/deg
<b>Weight</b>	33.9 kg	34.7 kg	33.8 kg
<b>Centre of gravity height</b>	247 mm	239 mm	273 mm
<b>Maximum allowable torsion</b>	460 N.m	460 N.m	833 N.m
			

Table 3-2 summarises the results produced by the FEA analysis of the final iteration of each concept or design. From all the different iterations of the different concepts, a concept could be identified for a race car chassis frame. To identify the best vehicle chassis design for a Formula SAE race environment, all of the mentioned characteristics in Table 3-2 was studied and analysed. Each of the concepts had its own advantageous qualities.

The torsional efficiency of a frame is defined as a relationship between the frame’s torsional stiffness and its weight. It is a crucial characteristic as it describes a chassis frame’s ability to resist torsional loads with the minimum material. It quantifies the chassis frame’s structural integrity. The first and second concepts were the ones with the lowest efficiencies, whereas the third concept was significantly higher in terms of its values of stiffness, weight and maximum torsion.

Torsional stiffness defines a race car chassis ability to resist torsional loads received from the suspension components, generated by cornering forces. A stiff frame is very favourable as suspension designers are then able to calculate the suspension kinematics more accurately. The frame is assumed to be infinitely stiff relative to the values involved in the suspension design. Adequate frame stiffness in the Formula SAE competition is in the order of 300 N.m/deg (Michael & Gilbert, 2009). All of the designed concepts were well above this value, with the third concept being the highest.

In any racing environment, it is very important to keep the weight to a minimum. A chassis with minimum mass ensures that its acceleration is a maximum. It is therefore crucial to ensure that the weight of any race car chassis is as low as possible. This also applies to braking and cornering. From the three concepts, the third concept had the upper hand in terms of its weight performance. It had been a valuable deciding factor due to the importance of this characteristic. Chassis weight lower than 35 kg is acceptable in the FSAE competition.

**Table 3-3: Centre of gravity characteristics**

	<b>Weight</b>	<b>C.O.G. height</b>	<b>Ratio (m / r)</b>
<b>Concept I</b>	33.9 kg	247 mm	0.137
<b>Concept II</b>	34.7 kg	239 mm	0.145
<b>Concept III</b>	33.8 kg	273 mm	0.124

Another important characteristic for a vehicle's handling performance is the geometric position of its centre of gravity. The lower the centre of gravity is the better. This characteristic represents the position upon which all the forces the vehicle experience, act on. Ideally, it should be level with the ground, but that is practically impossible. Table 3-3 shows the different concepts' mass, centre of gravity height and finally, the ratio between the mass and centre of gravity height for the same track width, described by the relationship in (2.1)

Table 3-3 shows that the third concept's centre of gravity is the highest which is regarded as a negative characteristic at first. But its ratio with regards to weight is the most favourable due to its lower weight. The first two concepts have a lower centre of gravity height but are influenced negatively by their respective higher weights.

The factor of safety (FOS) of any structural design is one of the most crucial aspects, especially in any race environment, if not the most important. It is a challenging subject for any race car designer in order to find the correct balance to ensure the chassis satisfies safety standards without degrading the performance factors. The FOS characteristic quantifies the chassis structure's strength integrity. The designer would tend to design a chassis with the minimum material, but with the relevant safety requirements.

All three the concepts complied with the prescribed structural requirements stated in the FSAE regulations. The designer would tend to design a chassis structure with a safety factor as low as possible to keep the weight to a minimum, but still within limits to ensure safety. The third concept had the ability to maintain a FOS above 1 up until an applied moment of 833 N.m. This characteristic illustrates the best combination of strength and low weight design.

The five characteristics discussed can be divided into three main categories, namely stiffness (torsional stiffness and efficiency), weight (weight and centre of gravity) and strength (Factor of safety). The three categories are the primary design factors discussed in Chapter 3.

### 3.6 CONCEPT ASSESSMENT AND SELECTION

All the discussed factors and characteristics were compared in order to find the concept with the highest performance potential. This allowed a final concept to be identified for further study and evaluation.

**Table 3-4: Scoring table in terms of positions**

	<b>Concept I</b>	<b>Concept II</b>	<b>Concept III</b>
<b>Torsional Efficiency</b>	2	3	1
<b>Torsional Stiffness</b>	2	3	1
<b>Weight</b>	2	3	1
<b>Centre of Gravity</b>	2	1	3
<b>Maximum allowable torsion</b>	2.5	2.5	1
<b>Average position</b>	2.1	2.5	1.4

Table 3-4 presents a summary of the results of all three concepts in terms of each performance characteristic relative to its rivals. For example, if a concept scored a 1 for a specific characteristic, it means it is the best for that category. A 3 denotes it is the worst in

the category. The last row of the table indicates the average position of each concept, determined by each characteristic's performance.

**Table 3-5: Scoring table rated in percentages compared to the best concept in the category**

	<b>Concept I</b>	<b>Concept II</b>	<b>Concept III</b>
<b>Torsional Efficiency</b>	73.7%	58.1%	100%
<b>Torsional Stiffness</b>	73.7%	59.5%	100%
<b>Weight</b>	99%	98.9%	100%
<b>Centre of Gravity</b>	98.9%	100%	98.8%
<b>Maximum allowable torsion</b>	55.2%	55.2%	100%
<b>Average percentage</b>	76.4%	71.6%	99.8%

The different characteristic values are calculated as percentages. Concepts, which aren't the best, are expressed in terms of the best, being 100%. Table 3-5 indicates the result.

Both tables illustrate the strong and weak characteristics of each concept. The first concept showed average quantities in terms of its performance, but it had no outstanding characteristic. The second concept showed advantageous qualities in terms of torsional stiffness and low centre of gravity, but the accompanying weight degraded this concept significantly. The third concept was excellent in terms of the balance it maintained between torsional rigidity and the accompanying weight. Its only weakness was its high centre of gravity, but it had the advantageous low weight. The third concept also had the highest torsional stiffness and the highest safety factor with respect to the torque it could disperse. Both these characteristics indicated its beneficial structural integrity and concludes that it used material more efficiently than its rival concepts.

The selection process between the different concepts involves a clear understanding and intensive study of the different concepts and their various properties. All three concepts were tested exactly the same way using the SolidWorks® FEA software, with the same material used for each model. The results produced indicated that the third concept had a significant advantage over the other two concepts and it was selected as the final chassis concept for this study.

### 3.7 CONCLUSION

This chapter discussed the design methodology of a FSAE chassis. The concepts developed conformed to the FSAE rules and were evaluated identically. After the assessment of the concepts, a final chassis concept was selected for further study.

The chosen chassis frame's characteristics and properties will be discussed in detail and quantified in the following chapter. This includes the chosen chassis frame's weight, centre of gravity, torsional stiffness and strength.