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Design & Experimentation of Side Impact Beam for Hyundai Verna

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Abstract -*Motor vehicle crashes will continue to occur in spite of all human efforts to prevent them. India has a high number of deaths due to avenue injuries & Indian automotive safety standards have been criticized as being insufficient and ineffective. India has the world's sixth-largest car market but is still the only country among the global top ten car markets without proper new car safety regulation or testing programs. Among front, side, and rear-impact collisions, side impacts are the most likely to be fatal. They're much more likely to be fatal for the basic reason that there's a lot less material between you and the 1500 KG of another vehicle careening toward you. Up till now, many kinds of research are carried out to investigate the detrimental effect of side impact & ways to reduce it. In overseas countries, the utmost significance is given to automotive safety with the growing of many organizations together with Insurance Institute For Highway Safety (IIHS), Euro NCAP & plenty extra. Recent Crash Test performed by Euro NCAP for Indian motors raised a big question about the extent of safety. As better late than never, Indian government soon start BNVSAP (Bharat New car safety assessment program) to check automobiles for safety angle. In this research attempt is made to design & develop competitive side impact beam w.r.t current market demand & achieve as much as cost cutting*

Key Words: IIHS, Euro NCAP, BNVSAP, SI beam, BIW, RSM model, UTS results, FEA, MSC PATRAN, NASTRAN, OPS, and LWA. RR Beam, NR Beam, NC Beam, RC Beam.

1. INTRODUCTION

A side effect collision takes place when a vehicle is hit on its side at an approximately ninety-degree angle. Another call for those injuries is "T-bone" injuries. Among the potential reasons for a side impact accident are distracted driving, drunk driving, and failure to yield. For example, a driver who fails to follow the road rules related to the right of way at a four-way stop sign may enter the intersection at almost the same time as the car to its right and crash into that car.

Driver and passengers involved in side impact collisions mostly get severely injured as compared to another type of collisions. The reason behind this is the availability of very low survival space. Due to the fewer space available occupant affected by severe injuries such as head injuries, ear injuries, neck injuries, back injuries, rib injuries, shoulder and arm injuries, or hip and leg injuries. This space varies from 5 cm to maximum of 25 cm, which decides how safe the car is. Every cm between you and a life-ending amount of energy is a life-preserving cm of survival space. Mercedes-Benz E-Class sedan is the safest mainstream car when it comes to side impact crash survival with 24 cm of survival space.

Designing a car with effort focuses on increasing crash survival space is necessary. With such Moto, many researchers have been continuously conducting experiment since the era of the nineties These researchers have proved that major role of absorbing impact energy & reducing the intrusion of impacting body is played by Side impact beam. Hence, the location and appropriate design of the SI beam is very important to pass stringent regulations like Insurance Institute of Highway Safety (IIHS) Side Pole.

1.1 Life-threatening injuries in side impact

Head, thorax, and pelvis are the main body areas injured and the interior door surface is the most frequent impacting part. The thoracic injury is the highest making injury in non-roll-over, non-ejection side impacts. After the study, it is found that in car-to-car crashes, side impacts gave rise to more severe injuries than frontal impacts. For disabling injuries to be reduced the neck and legs need better protection; as regards life-threatening injuries, chest injuries become up to four times more frequent with advancing age. Injuries were twice as common on the struck as on the opposite side. [1]

When fatalities alone are considered, multiple body regions are frequently injured as head (64%), chest (85%) and abdomen (26%) predominated injuries in the struck side occupant. On the opposite side, the head was most frequently injured (85%) followed by the chest (73%) and abdomen (49%). In both positions, in this series, the occupants had more neck injuries than in the non-fatal series. Dalmotas found that, with regard to occupants restrained by seat belts, there was more injury to the shoulder, chest, pelvis, and legs among impact-side occupants, whereas there was more injury to the neck, abdomen, and arms in far-side occupants. [1]

2. LITERATURE REVIEW

Dhaneesh K P et al. [2], demonstrated the different advanced concept to enhance the performance of side impact beam. To minimize the resulting intrusion in side impact it is very essential to increase the strength of the material. By keeping this view author selected DOCOL1200 material, which is kind of high strength steel. The acceptable value for Maximum displacement according to FMVSS 214 regulation is 154 mm & with the current design, deformation noticed to be 180mm. By performing a number of iterations author has optimized the design and finally updated the material. The maximum displacement in the final case is 140 mm which is less than the upper limit value of FMVSS 214 new regulation.

T. L. Teng et al.[3] focused their study on a Ford Taurus model. The full-vehicle FE model was developed & analyzed in a dynamic side impact test. The author mentioned two important injuries thorax injury & pelvic injury as well as the causes, detrimental effect on occupants seating in the car. The impacting force to the dummy pelvic area by the intruding side structure is potentially the most injury-causing factor. Likewise, the intrusion at the mid-door and window sill levels would potentially influence the thorax area of the dummy. Placement, shape, and material are factors that dominate the effectiveness of protection afforded by the side-door beam. To minimize damage to the individual's involved, optimal design of side-door beam will be the future driving force in the passive safety of research.

Avinash P. Pawar et al. [4], replaced currently used S-shaped side impact beam in Ford Taurus having material high strength steel (AISI 4340) with a better design.For the new design, high strength steel (AISI 4340) is considered & put effort to reduce the total weight of the car without sacrificing the safety of the passenger. For static analysis instead of using complex door assembly preference given for simplified model for same. Impact force of 501945.5 N applied to study intrusion behavior for the regular S-shaped beam, circular beam, and rectangular beam. As per the requirement, initial mean crush resistance up to first 150 mm should be greater than 10 KN and observed crush resistance in S-shaped steel beam is 15.7 KN were as in thermoplastic glass epoxy fiber composite is 5KN as it is below the criteria due to improper location of the beam and can be increased with improved beam placement. For displacement from 150 mm – 300 mm, the Intermediate mean crush resistance should be greater than 15.6 KN and for 300 mm – 450 mm displacement, peak crush resistance should be greater than 31.2 KN. For both intrusion beams, observed crush resistance is well above the required criteria. However, crush resistance offered by the composite beam is way more than that of the steel beam. As composite beam offers 125 kN crush resistance as compared with 77.1 kN offered by steel. It can be seen that composite beam absorbs more energy than that of steel. Thus intrusion of hitting a body in the passenger compartment can be drastically reduced by using composite beams in the car side door.

Dinesh Ugale et al. [5], analyzed an RADIOSS Ford Taurus public domain free model to access the effectiveness of DSI beam at 50kph side impact and 30kph pole impact test modes as per IIHS regulation. The author did four-run of simulation for side impact analysis. By observing the results of run1, 2, 3, 4 for 1.5mm and 3.5 mm thick DSI beam, for both side impact and side pole impact, it is concluded that the orientation of Dynamic Side Intrusion beam for all design configurations doesn't have a prominent effect on the velocities of side structure because higher forces are acting on the side structure from the impacting barrier and pole will affect the effectiveness of DSI beam. It is observed that front door absorbs more energy. A similar trend is observed inside pole impact as well.

Vijayan.P et al. [6], tested three different material simultaneously using finite element analysis to investigate their effect on structural modification and impact absorption. The maximum allowed crush resistance for FMVSS standard is 152 mm at initial load condition of the average 1020kg load. The car door panel of the outer and inner panel is modeled separately & considered the thickness of 1.2mm for an inner and outer panel of the entire concept. BY employing magnesium alloy in mono & hybrid construction light weight and crash resistive structure developed

Goichi Ben et al. [7], have developed CFRP and Al hybrid beams as impact energy absorption members for side collision. In their research, Three kinds of unidirectional CFRP laminate (T700, M40, and T800) and three types of adhesive (Urethane, High-strength, and High elongation) were used, respectively. Eighteen numbers of specimens are experimentally tested. Careful observation of impact behavior of hybrid CFRP and Al beam shows the breakage of adhesive and not the breakage of CFRP laminate. If we neglect the value of initial peak load we get to see a good agreement of the load –displacement relation with a minimal error of absorbed impact energy was 7% between both results.

Raja Sharmi Raja Husin et al. [8], pointed their research to optimize the crashworthiness of side door structure by applying structural optimization techniques rather than numerically analyzing and experimentally validating currently used side structure and door trim. In this research, the performance of a side door beam is predicted using only the door beam and not the BIW system. In considering the effect of the BIW system, an equivalent modeling is utilized. Author implement response surface method (RSM) to determine the thickness and the cross sectional
shape of a side door beam. This ensures optimization of energy absorbed by side door beam with respect to the mass density. The design variables considered in research were the thickness and the shape cross section. After summarizing the FEA results on 25 thin-walled beam models, a final RSM model developed. In RSM model linear, quadratic and cubic polynomials are used in order to validate the selection of design points and the orders

Rajesh Male et al. [9], done parametric research for side impact. They considered the effect of material, thickness, an outer diameter on a characteristic of side impact beam. In the analysis, the tube is considered as a deformable body while the loading device and supports are considered as rigid bodies for reducing the computation time. The load carrying capacity, energy absorption characteristics of a SIB tube can be tested by static bending test or three-point bending test method (Federal Motor Vehicles Safety Standard No. 214).SIB is tested at a velocity of 2mm/s. We get an idea about the effect of each parameter on the load carrying capacity and energy absorption characteristics of the tube. The increase in UTS results in more force, the energy required to bend and also results in an increase in buckling of the tube. The buckling of the tube reduces with increase in the thickness of the tube and increases with increase in OD of the tube.

Ramesh Koora et al.[10] carried out their research for crush beam of Nissan titan chassis. Crush beams of the U-shaped cross section having length 450mm considered for both inner and outer side. Crush beams are made of mild steel. To evaluate transmission of forces author considered various section planes in chassis.The author proposes four designs and investigated individually energy absorbed in each case. Baseline model, increased cross section, baseline with reinforcement & tailored rolled blanks were the four proposed design among which tailor rolled blank showed maximum energy absorption of 12196 J.

MohdFadzliAbdollah et al.[11], shows efficient use of FEA (Finite Element Analysis) in structural modification & evaluating impact energy absorption of the different material. As part of practical experimentation, the author conducted Charpy impact test. Since aluminum possesses the higher strength to weight ratio than that of conventional steel it is selected as a potential material for side-door impact beams. Proton Wira which is Malaysian manufactured car is considered for adopting side door impact beam dimensions. Impact beam with outside & inside diameter of 40.2 mm & 34.2mm respectively having length 830 mm is seen to be installed in the side door of the car. Universal impact tester utilized to capture impact energy absorption using Charpy impact test.

HarijonoDjojodihardjo et al.[12], performed two types of analysis. The first is a static analysis of equivalent impact load calculated using equivalent energy principle, and the second is a dynamic analysis to calculate the dynamic characteristics of the impact beam for comparative study purposes. The analytical approach is considered as a baseline to utilize finite element analysis using both in-house MATLAB program as well as the commercially available MSC PATRAN and NASTRAN.The author suggested numerical methods, such as FEM or analytically-modified transfer matrix method for problems involving complicated geometries, loadings, and material properties. By using the direct equilibrium approach, the nodal forces in the Finite Element Approach can be related to the nodal displacement with the use of shear force and bending moment relationships. Appropriate boundary conditions should be applied so that the structure remains in place instead of moving as a rigid body. The author used CATIA for developing the geometrical model of the impact beam. The existing design is made of ISO 31CrNiMo8 steel while glass-fiber reinforced polymer (GFRP) E-glass or Epoxy (Scotchply 1002) is considered for new design. Although the carbon-fiber-reinforced polymer (CFRP) has the highest specific modulus and specific strength among the fiber reinforced polymer, the E-glass/Epoxy still being chosen due to its impact energy absorption.

In this thesis K.Veeraswamy et al.[13] employed Carbon,Epoxy AS4/3051-6as material for side impact beam. The Finite element models of a door and consequently the moving solid block are utilized for the analysis during this thesis. Efficacy of top beams is compared by checking the beams according to the FMVSS 214 aspect impact standard. C-section impact beam of length 947 mm long 105 mm wide with a standardized thickness of 2.3 mm is used. The encumbrance of the beam is 2.44 Kg.The impactor is taken into account as a rigid body with mass 20kg and diameter of 200 mm cylinder. The fundamental question of this examination work is to supplant the present side effect beam with the better outline and utilizing a composite material rather than steel to diminish the aggregate weight of the car without yielding the security of the peregrinator. Along these lines in this study as per the fundamental standards of crashworthiness which express that the interruption of the striking conveyance ought to be least and the vitality retaining capacity of the distorting structure ought to be high, the utilization of the composite side effect pillars on the car entryway has been proposed and its viability in diminishing interruption has been assessed.

3. SIDE IMPACT BEAM

Side impact door beams are a safety feature of modern cars designed to protect the driver and passengers. The side impact protection beam has to absorb the energy in the door area and maintain high survivability for the vehicle's occupants. Door deformation has to be limited in order to provide a side airbag with enough space between the vehicle's door and the seat. The most common solutions for side impact beams are extruded aluminum sections , round steel tubes, and press-hardened or ultra-high strength steel sections.

With the increasing size and height of vehicles on the road, including SUVs and vans, side impact beams have become a more popular safety feature for cars of all sizes. The beams provide extra protection during instances when smaller cars may be struck by a larger SUV

Fig 3.1: Hyundai Azera showing the side impact beams and the side impact airbags deployed.

3.1 Current side impact beam

The inspiration for this project lies in the car as shown in the Fig 3.2. This is Hyundai Verna met with a very heavy accident. The impact of the accident was so detrimental that it completely deformed front left section of the car. After careful observation, we got to know that in the side door inclined beam is fitted in order to resolve the and resist the incoming side impact force. This inclined beam is called side impact beam which is the type of passive safety. Current side impact beam is circular hollow section 1.25" in diameter having a thickness of 2mm. The only reason for selecting such low thickness must be weight reduction.

But in order to compensate such low thickness, Hyundai is using Advanced High Strength Steel (AHSS) which is 10% lighter and 200% stronger in material than a regular steel plate. Mainly applied to the parts in the crushable zones and the passengers' cabin, the vehicle's structural rigidity is effectively maximized to provide enhanced passenger protection.

Just like its impressive properties cost is also impressive. You are able to maintain high strength to weight ratio but at a high cost. So this definitely raises the simple question that, "Is there no any cost effective alternative ? Can't we break the constraint on the use of higher thickness for the pipe? With step towards finding answers to this obvious question, the project work has been started.

4. MATERIAL SELECTION

As already stated, AHSS (Advanced high strength steel) is used for side impact beam of the car. But this project aims at finding cost-effective solution. Because there is no need of rocket science to understand that after using such high strength alloy steel, one has to get high strength for the structure.

Thus proper material selection plays very crucial role in this project. There are thousands of engineering material available in market at present. So properly defined criteria must be set in order to select best possible material among them. A brief & specific criterion for material selection is as shown in Fig 4.1.

Fig 3.2: Side Impact Beam Of Hyundai Verna

Aluminum is lighter material than steel , but in last decades much experimentation carried out with Aluminium.Thus solely neither we go for steel nor aluminum. There is want for the intermediate way. What if we use very lighter material inside hollow side impact beam? This will make hollow beam solid without increasing its weight drastically.

Thus it is very clear that we need to select two material one for the outer beam which is hollow and second material to be filled inside this hollow section. As this project aims for cost effective solution lets select mild steel for the hollow pipe. So real challenge for us to select material to be filled inside it which will show same results as current advanced high strength steel or enhanced results than it.

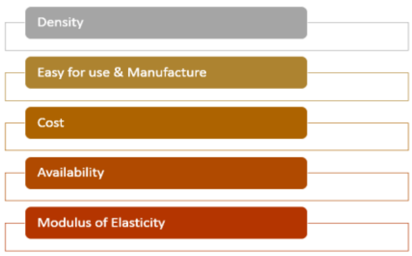


Fig 4.1: Material selection criterion

By keeping this criterion in mind almost 48 material were considered for material selection as shown in Table
So abiding to project aim we cannot select the material which is either expensive or already lots experimentation carried out with that material. At the same time material should be low in density and high in modulus of elasticity. Actually, if we observe all the materials & their properties listed in Table 4.1, there are many properties like strength, ductility, corrosion resistant, toughness, etc. which are always desired for any engineering application. For this

project also, we are aiming at such versatile material. Concrete seems to versatile because of its lighter density, high compressive strength, corrosion resistant, low in cost, easy to cast, readily available and much more. Thus we are selecting concrete as a second material for the purpose of reinforcement.

SR NO	CATEGORY	Material	Young's Modulus (109 N/m2, GPa)	REMARK
1	PLASTIC	ABS plastics	1.4 - 3.1	VERY LOW DENSITY, HENCE LIGHTER. BUT MODULUS OF ELASTICITY IS VERY LOW.
2		Chlorinated PVC (CPVC)	2.9	
3		Polybenzoxazole	3.5	
4		Polycarbonates	2.6	
5		Polyethylene HDPE (high density)	0.8	
6		Polyethylene Terephthalate, PET	2 - 2.7	
7		Polyamide	2.5	
8		Polymethylmethacrylate (PMMA)	2.4 - 3.4	
9		Polyimide aromatics	3.1	
10		Polypropylene, PP	1.5 - 2	
11		Polystyrene, PS	3 - 3.5	
12		Polytehylene, LDPE (low density)	0.11 - 0.45	
13		Polytetrafluoroethylene (PTFE)	0.4	
14		Acetals	2.8	
15		Acrylic	3.2	
16		Glass reinforced polyester matrix	17	
17	SPECIAL MATERIAL	Silicon	130 - 185	STRENGTH TO WEIGHT RATIO IS OPTIMUM,BUT VERY COSTLY
18		Sapphire	435	
19		Graphene	1000	
20		Tungsten (W)	400 - 410	
21		Tungsten Carbide (WC)	450 - 650	
22		Osmium (Os)	550	
23		Diamond (C)	1220	
24		Carbon nanotube, single-walled	1000+	
25		Carbon Fiber Reinforced Plastic	150	
26		Aramid	70 - 112	
27		Beryllium (Be)	287	
28		Gold	74	
29		Silicon Carbide	450	
30	COMMON ENGINEERING MATERIALS	Brass	102 - 125	HEAVIER THAN STEEL
31		Brass, Naval	100	
32		Bronze	96 - 120	
33		Copper	117	
34		Aluminum Bronze	120	ALREADY USED IN VARIOUS RESARCH
35		Phosphor Bronze	116	
36		Aluminum	69	
37		Glass	50 - 90	BRITTLE
38		Grey Cast Iron	130	HIGH IN DENSITY
39		Steel, High Strength Alloy ASTM A-514		
40		Steel, stainless AISI 302	180	
41		Steel, Structural ASTM-A36	200	
42	GREEN MATERIAL	Concrete	17	BSET TO CRITERIA
43		Concrete	40	

Table 4.1: Material selection

5. THEROTICAL CALCULATIONS

Side impact beam in the car most of the times subjected to transverse loading in a side impact. In order to solve this problem theoretically, we can assume this beam as a simply supported beam with central loading as shown in Fig 5.1

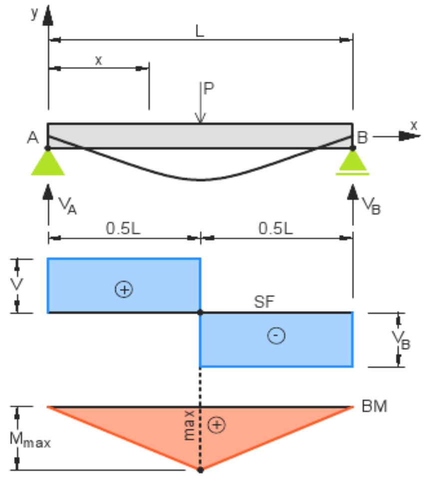


Fig 5.1:FBD of side impact beam

Maximum bending moment

$$BM=\frac{P*L}{4}$$

$$\text{Maximum Shear Force} = \frac{P}{2}$$

The three-part formula for bending is

$$\frac{M}{I}=\frac{\sigma}{y}=\frac{E}{R}$$

From these equations, we get formula for flexural strength

$$P=\frac{I*\sigma*4}{y*L}$$

5.1 Analytical Work

Ansys 17.1 is used for analytical work.As we have to test the material till its failure Ansys Explicit Dynamics work is used to carry out analysis.

For CAD modeling of side impact beam, Solidwork 2012 is used. Four models for square, circular,square reinforced with concrete & circular reinforced with concrete were generated using solid work.

Analytical work carried out, helped lot to visualize deformation pattern of side impact beam for applied load. One such modeled beam and its analysis is shown in Fig 5.2

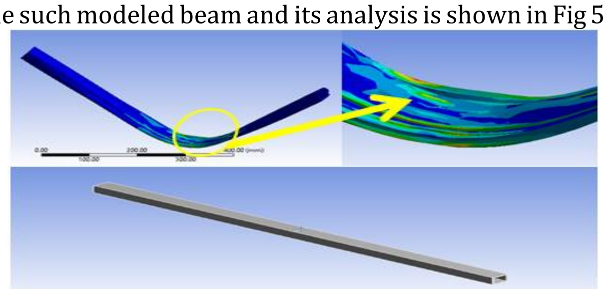


Fig 5.2: Modeling & Analysis of side impact beam

6. EXPERIMENTAL WORK

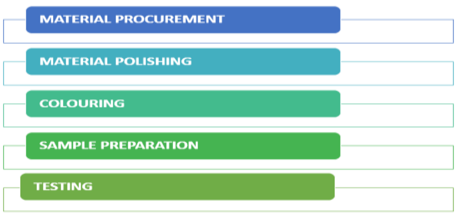


Fig 6.1: Agenda of experimentation

As shown in Fig 6.1 as very initial stage material procurement done. Pipes of hollow square & circular sections were procured.But Material was very rusty when procured. So cleaned it with polish paper. Then for the purpose of reinforcement two concrete mixture prepared.First was normal concrete & second was rubberized concrete. This will give rise total fourteen number of samples as shown in Table 6.1 .Raw material and concrete ingredients are as shown in Fig 6.1

Sr No	Notification	Meaning
1	HR1	Hollow Square section
2	NR1	Square section 1 reinforced with normal concrete
3	NR2	Square section 2 reinforced with normal concrete
4	NR3	Square section 3 reinforced with normal concrete
5	RR1	Square section 1 reinforced with rubberized concrete
6	RR2	Square section 2 reinforced with rubberized concrete
7	RR3	Square section 3 reinforced with rubberized concrete
8	HC1	Hollow Cicular section
9	NC1	Circular section 1 reinforced with normal concrete
10	NC2	Circular section 2 reinforced with normal concrete
11	NC3	Circular section 3 reinforced with normal concrete
12	RC1	Circular section 1 reinforced with rubberized concrete
13	RC2	Circular section 2 reinforced withrubberized concrete
14	RC3	Circular section 3 reinforced with rubberized concrete

Table 6.1:List of samples prepared

Fig 6.2: Concrete and samples preparation

After preparing fourteen samples they were kept for curing of 28 days in water. Properly cured concrete has an adequate amount of moisture for continued hydration and development of strength, volume stability, resistance to freezing and thawing, and abrasion and scaling resistance.

6.1 Testing

Bend testing (also flex or flexural testing) is commonly performed to measure the flexural strength and modulus of all types of materials and products. This test is performed on a universal testing machine (tensile testing machine or tensile tester) with a 3 point or 4 point bend fixture.

Fourteen samples were tested on UTM for bending test.Beam was placed on support rollers freely as shown in the Fig 6.3 .Then to avoid beam slipping initial preload is applied on beam. This simulates boundary conditions of the simply supported beam. The beam is loaded centrally. When test started, load started increasing continuously. This gradual loading made beam deformation. After certain load, beam started deforming plastically and some beams broke at maximum load.

Fig 6.3: UTM testing setup

7. RESULTS & DISCUSSIONS

Fourteen samples were tested on UTM for bending test. The test is carried out to evaluate force vs. displacement of the beam to applied loading. Graphs of square and circular sections are as shown in graph 7.1 &7.2 . The test started with the hollow rectangular section. This section started deforming gradually with increasing load. No crack is formed but material deformed in the central portion in large scale. The maximum force recorded as 3700 N with deformation of 11 mm. Deformation pattern is as shown in Fig 7.1.

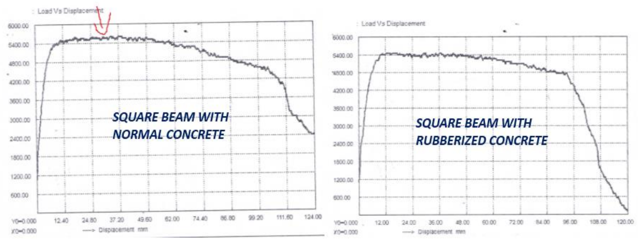
Fig 7.1: Deformation Pattern

Square sections reinforced with normal concrete are tested after testing of the hollow square section. Unlike hollow section, no material deformation observed centrally, it just gets cracked after absorbing maximum force. Concrete inside hollow beam offered resistance to deformation which resulted into increase in Maximum force as 5833 N showing almost 71% load absorbing capacity that of the solid beam. As compared to normal concrete rubberized concrete has shown well results. Flexural strength of square sections with rubberized concrete was found to be 6633N and deformation at maximum load is 16 mm.Thus square sections with rubberized concrete show almost 81% strength of the solid beam. Also, RR beams take the maximum load without deforming much as compared to NR beam. Numerically RR beam shows 47% less deformation as compared to RR beams. But after taking of maximum load NR & RR beams were intensively ruptured in tension zone at extreme fibers as shown in Fig 7.1 .After rupture beam stopped taking the load.

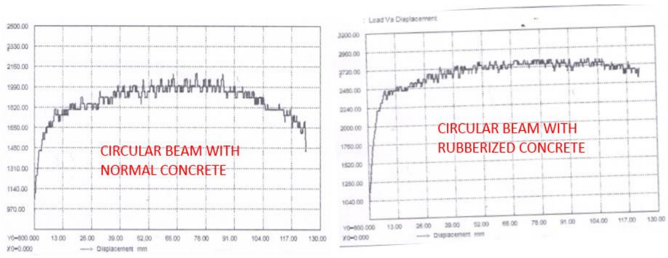
	F m	D fm	D max
HR1	3700	11	131.9
NR1	4850	32.3	126.9
NR2	5450	37.2	124.6
NR3	7200	21	65.1
Average	*5833*	*30*	*106*
RR1	7200	21	79.2
RR2	7250	16.7	121.1
RR3	5450	10.3	122.9
Average	*6633*	*16*	*108*
HC1	1120	10	103
NC1	2100	63.3	123.6
NC2	2000	69.1	122.7
NC3	2380	89.9	122.2
Average	*2160*	*74*	*123*
RC1	2560	63.5	120.2
RC2	2610	67.3	126.1
RC3	2800	50.3	122.8
Average	*2657*	*60*	*123*

Table 7.1: Deformation Pattern of sections

Circular hollow section showed the flexural strength of 1120 N & deformation of 10 mm with normal yielding. Its deformation pattern is as shown in figure 10.10.Flexural strength of 2160 N recorded for CN beams & corresponding deformation as 74mm.This strength is found to be 74% of the solid circular beam of the same dimension. Very impressive results were seen for circular sections reinforced with rubberized concrete.CR beam sustained the flexural load of 2657 N with the corresponding deformation of 60 mm.CR beam has shown almost 90% strength of the solid beam. Also unlike NR & RR beam NC & RC beam did not show any intensive rupture. Only normal yielding is observed as shown in Fig 7.1.In addition to it, RC beam showed 19% less deformation as compared NC beam.



Graph 7.1: Loads Vs Displacement plot for square section



Graph 7.1: Loads Vs Displacement plot for circular section

CONCLUSION

1) Steel and concrete can be used together as composite material
2) In the case of square sections 55% weight saving achieved by using normal concrete & 59%by rubberized concrete w.r.t the solid beam.
3) In the case of circular sections 59% weight saving achieved by using normal concrete & 64% by rubberized concrete w.r.t the solid beam.
4) The performance of rubberized concrete is better than normal concrete. Rubberized concrete absorbs more force with minimum deformation as compared normal concrete.
5) After the failure of the section, it stops taking the load. Square section reinforced with concrete showed rupture and stopped taking load. Such a behavior can be detrimental to passenger safety in the car. As either, it will break or transmit sudden shock to a passenger in the car.
6) Whereas circular section has not shown any rupture. With increasing load gradually circular section showed normal yielding. So circular section can keep on taking load till it fails. In this case, no sudden shock will be transferred to the passenger as the beam is absorbing impact load for its deformation.
7) Bonding of rubberized concrete is seen to be best with circular sections only. By using rubberized concrete in circular sections we have almost achieved 90% flexural strength of the solid beam with minimal deformation.

Section	Therotical	Experimental	Error %
	Fm (N)		
HR	3672	3700	0.8
HC	1221	1120	-8.3
	ACTUAL	Solid Square	% of solid strength
NR Avg	5833	8224	71
RR Avg	6633	8224	81
		Solid Circular	
NC Avg	2160	2952	73
RC Avg	2657	2952	90
	W reinforced	W solid	Weight saving %
NR Avg	3.44	7.72	55
RR Avg	3.17	7.72	59
		Solid Circular	
NC Avg	2.45	6	59
RC Avg	2.14	6	64

Table No 7.2: Conclusion of results

8) Thus by considering we can say that circular section filled with rubberized concrete is the best choice for side impact beam of the car.

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