

## Physics Lecture 15 - Building the Simple But Fast (SBF) Car - Part 2

**Introduction** - This lecture continues on where **Lecture 14** left off- Explain to your Cub partner how Archimedes in about 100 AD first learned the laws of the lever and the applications of the balance:

“The little bird, the little fish, the little animal learn not by principle, but empirically. And when he learn to do, then there is to him the ground to start from to do more. ‘Dos pou sto,’ said Archimedes. ‘Give me a fulcrum, and I shall move the world!’ To do once, is the fulcrum whereby child brain become man brain.”

Bram [Abraham] Stoker (1847-1912) *Dracula* Chapter 25, 1897



### Car Construction E-Book

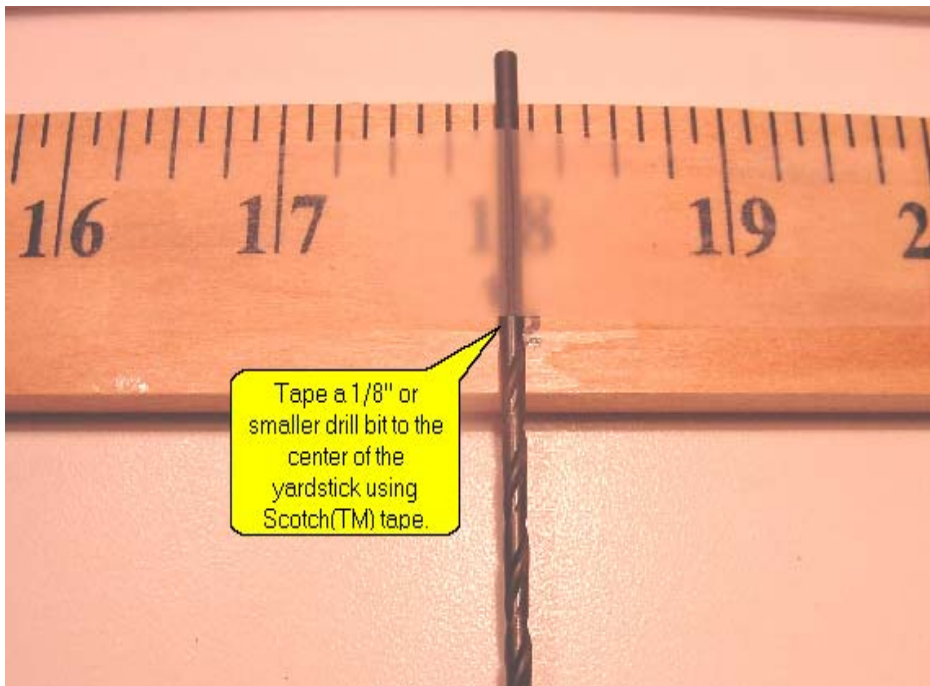


Let the Cub do as much of the hands-on work as possible and always practice safety first. Work as a team.



#### 12. Center Bit

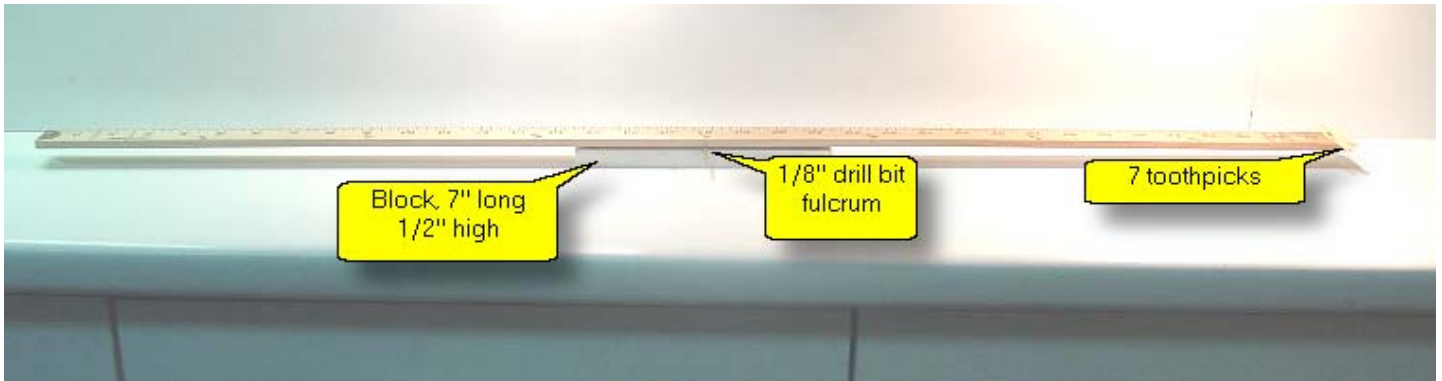
- We will start with **Item 12 Center Bit** to continue on from the last **Item 11** in the previous lecture.
- Next we will make an accurate balance out of ordinary stuff. First, we will make a fulcrum
- Tape a small drill along the 18" mark of a stiff wooden yardstick (e.g. Westcott brand) as shown in **Fig. 1**.



**Figure 1** - Tape a small drill bit on the 18" mark of a good wooden yardstick such as the Westcott brand available at Office Depot stores..

 **13. Toothpick Balance**

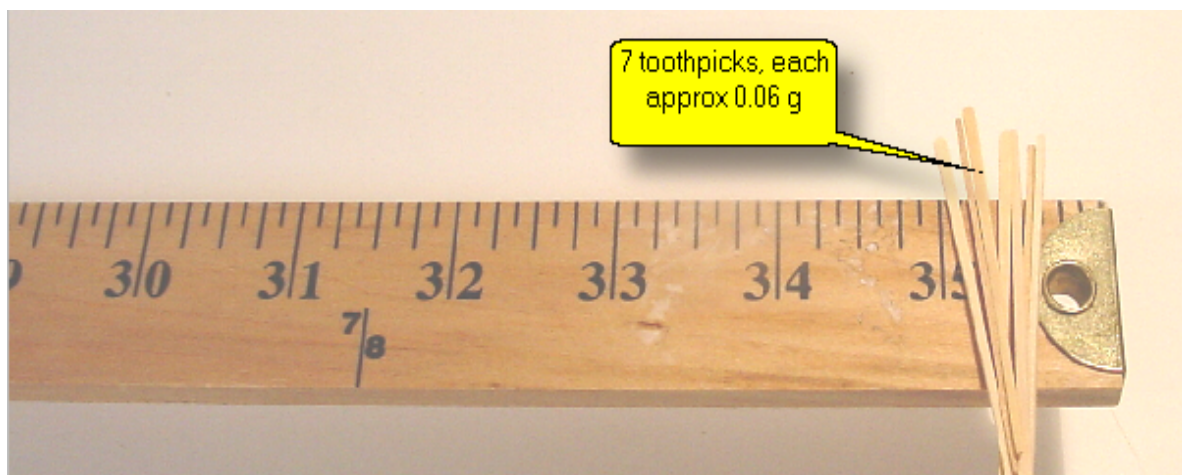
- Set the yardstick on a block or book about  $\frac{1}{2}$ " high and 7" long with the taped-on drill bit as a fulcrum.
- Add toothpicks to one end if necessary to cause balance. Here 7 were needed on the right end. See **Fig. 2**.



**Figure 2** - Set the yardstick with the drill bit down on a  $\frac{1}{2}$ " high book or block. Trim the balance by adding small flat toothpicks to the light end until the yardstick shows large preference for tilting to one side or the other.

 **14. Toothpick Closeup**

- The type toothpicks used here are the flat kind, each weighing approximately 0.06 gram, shown in **Fig. 3**.



**Figure 3** - Here is a closeup view of the toothpicks. Seven were required for this particular yardstick.

**15. Roll Quarters**

- The target weight for a complete car is 5 ounces. 5.00000 ounces = 141.748 grams
- Also note that 5.0000 oz = 141.75 g and 5.00 oz = 142 g, etc.
- Make a roll of 24 quarters + 1 penny like in **Fig. 4** which will weigh close to 138.592 g, say plus or minus 0.5 g.

Various Weights in Grams  
(Suggest use grams rather than ounces)

- 1) lead rod (3/8") = 19.0 g/inch
- 2) 1 quarter = 5.68 g
- 3) 1 penny = 2.51 g
- 4) 1 axle nail = 0.825 g
- 5) 1 toothpick = 0.060 g



**Figure 4** - Tape a roll of 24 quarters together and add one penny to the top of the stack.

**16. Quarter Stack Left**

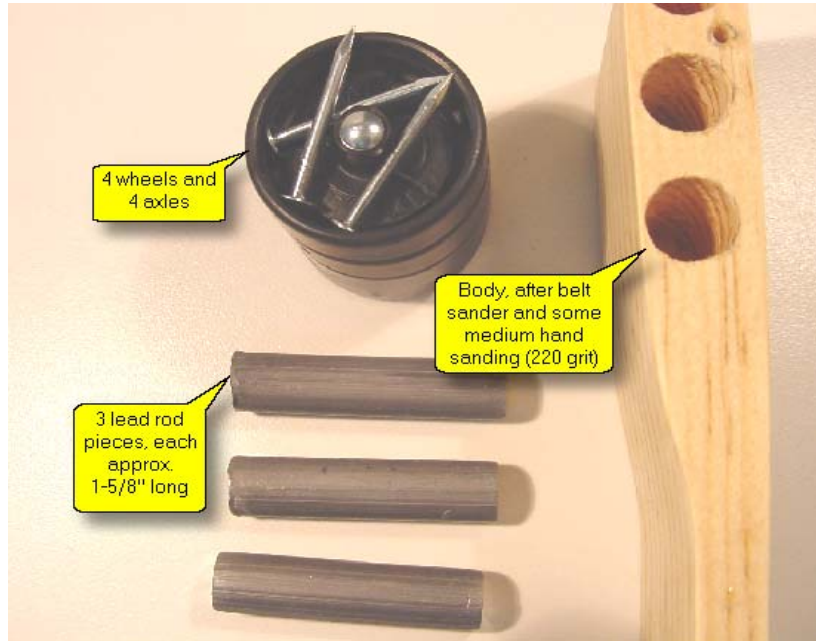
- Put the quarters + penny stack centered on the 2" mark as in **Fig. 5**



**Figure 5** - Center the roll of quarters on the 2" mark. The sides of the stack should extend from the 1 1/2 " mark to the 2 1/2" mark.

**17. Body/Lead/Wheels**

- As in **Fig. 6**, collect the body, 4 wheels, 4 axles, and 3 pieces of lead rod each approx. 1-5/8" long.

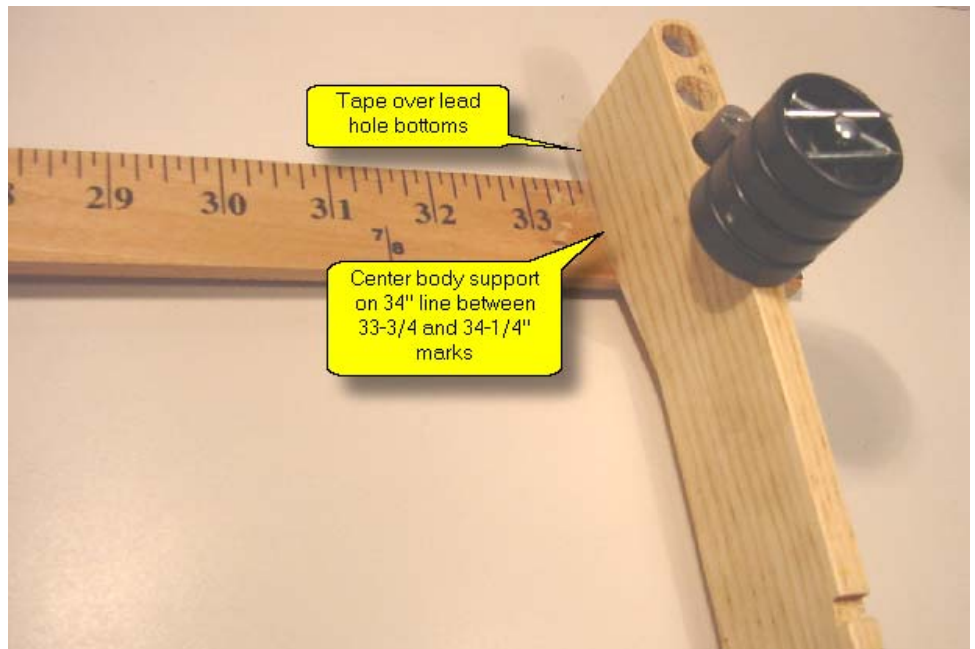


**Figure 6** - Showing pieces to be weighed first.

**18. Body & Parts Right**

- First put tape on the rear lead hole bottoms so the lead will not drop out. Then proceed as in **Fig. 7**.

Set the body and other parts centered on the 34" mark (also good idea to mark heavy lines across the yardstick on each side of the body at the 33-3/4 and 34-1/4" marks). Then next time you weigh the body you can put it back in the same or close to the same spot. Do the same for the quarters stack



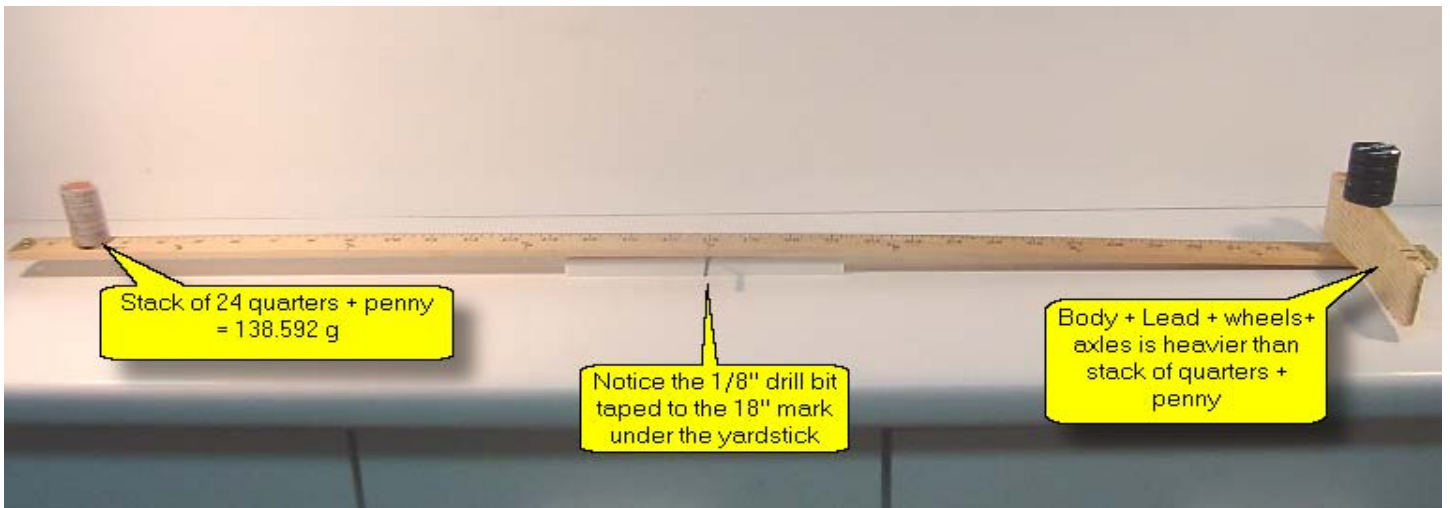
**Figure 7** - Stack the body parts centered on the 34" mark.

**19. Balance Car Parts 1**

- Proceed to balance car parts vs. quarters + penny as shown in **Fig. 8**.
- Notice with the front lead piece out the body is lighter than the 138.6 g reference weight ( 24 quarters + 1 penny) and heavier with it in..
- So likely only a part of the front lead piece will be needed for balance even allowing for a few grams of Bondo to be added next.
- Summary:

Body + 4 Wheels (& 4 axles) + 3 lead (1-5/8") > 138.6 g

Body + 4 Wheels (& 4 axles) + 2 lead (1-5/8") < 138.6 g



**Figure 8** - *The Body + 4 Wheels (& 4 axles) + 3 lead (1-5/8") is heavier than 138.6 g.*

- Next we will proceed to Bondo the rear 2 lead pieces in and then reweigh to see how much of the 3rd (front) lead piece is needed considering all the Bondo that will added..



## 20. Bondo Can

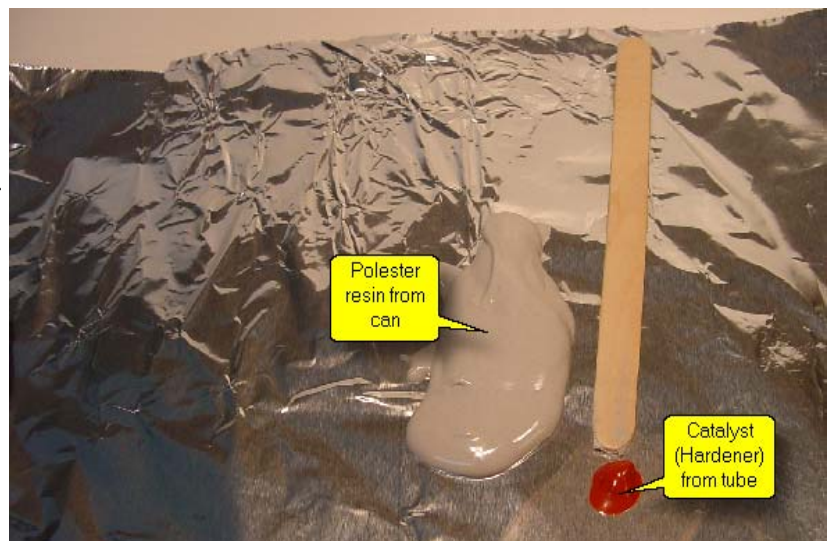
- Bondo, **Fig. 9**, is a polyester resin body filler. Because of vapors, be sure and replace lid after removing small amount. Bondo sets much harder than wood putty, sands better, and takes paint better.
- Use only in a well-ventilated area.
- Wood filler or putty may also be used but Bondo sets harder and smooths well.
- You will need a small mixing stick and the catalyst which usually comes in a tube with the Bondo can.



**Figure 9** - Bondo can, catalyst tube, and mixing (popcicle) stick.

## 21. Bondo Piles

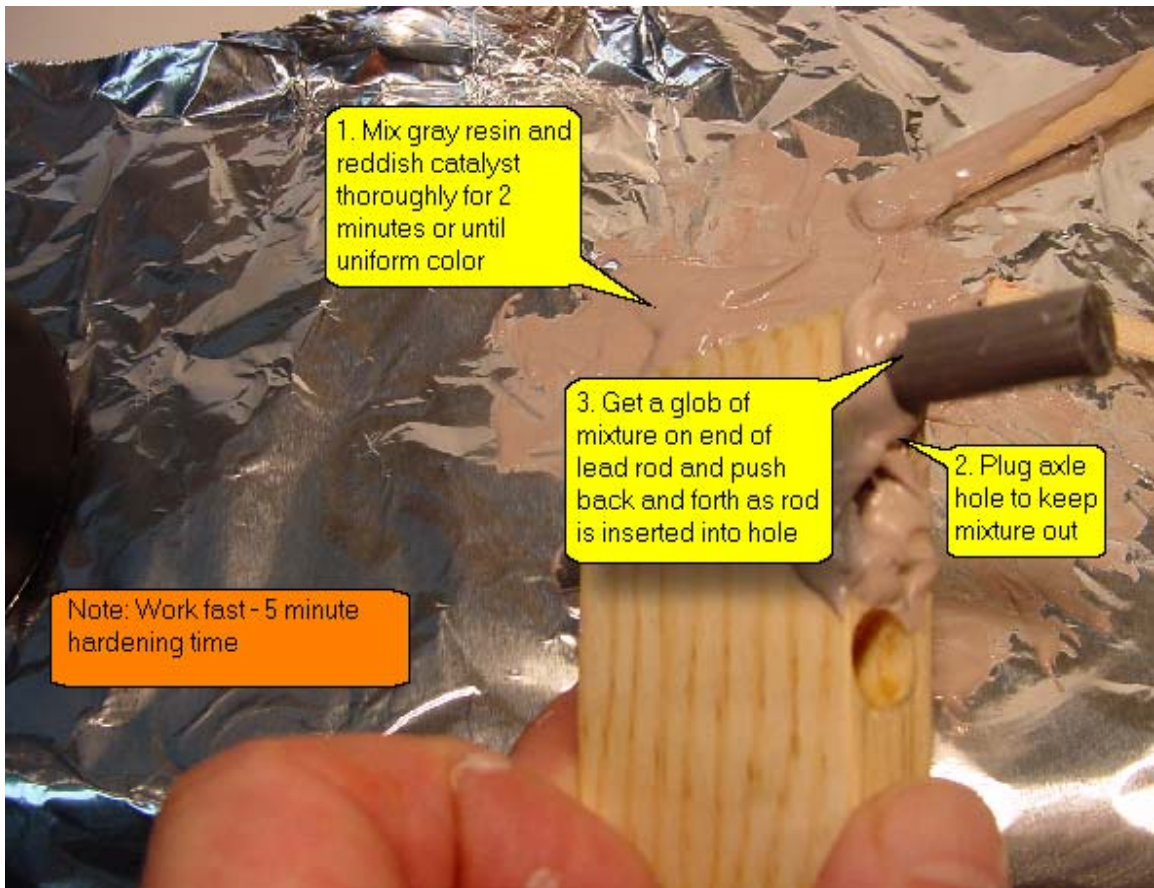
- As in **Fig. 10** put about a tablespoon volume of Bondo on a flat protected surface and squeeze out about a pea sized dollop of catalyst.



**Figure 10** - Showing that the catalyst needed is only a few percent of the Bondo.

## 22. Bondo Mix

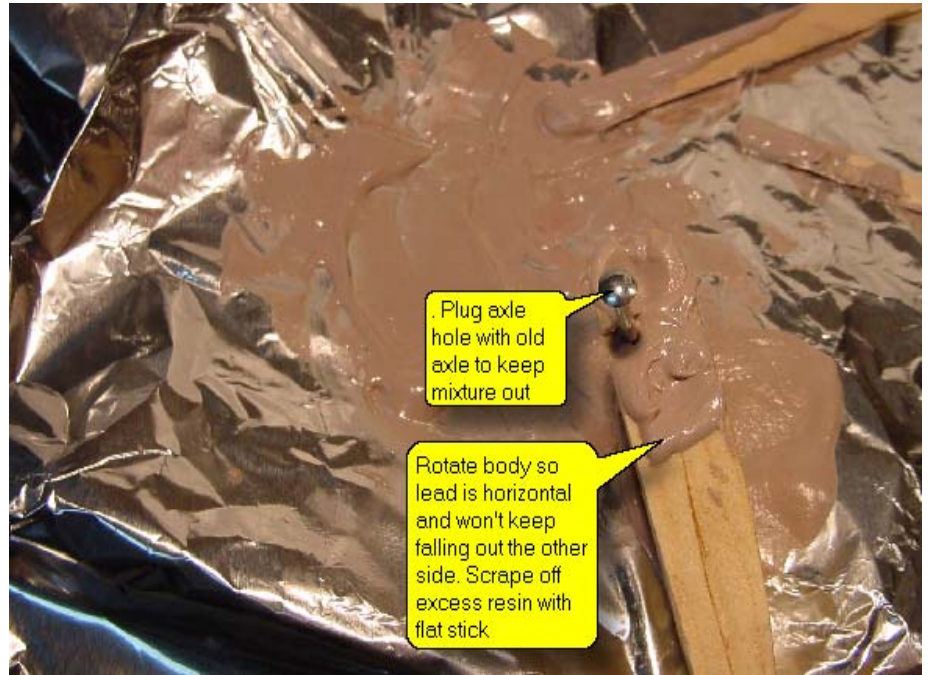
- We will work first on the driver's side as in **Fig 11**..
- Plug the axle hole with an axle nail or other object to keep the mixture out.
- Mix Bondo & catalyst thoroughly for a minute or two until mixture is a uniform pinkish-gray color.
- Get a glob of mixture on the end of a lead piece and insert with twisting into the rearmost hole.
- Put more mixture in rear hole outside cavity on top of the lead after lead is pushed in.
- Turn the body over to get to the passenger side being careful not to let lead piece slip out. Keep lead piece horizontal as you switch to working on the passenger side. Go to next **Figure 12** quickly.
- Work reasonably fast as mixture begins to harden in 5 minutes.



**Figure 11** - Putting the lead in place using Bondo body filler compound.

### 23. Bondo Passenger Side

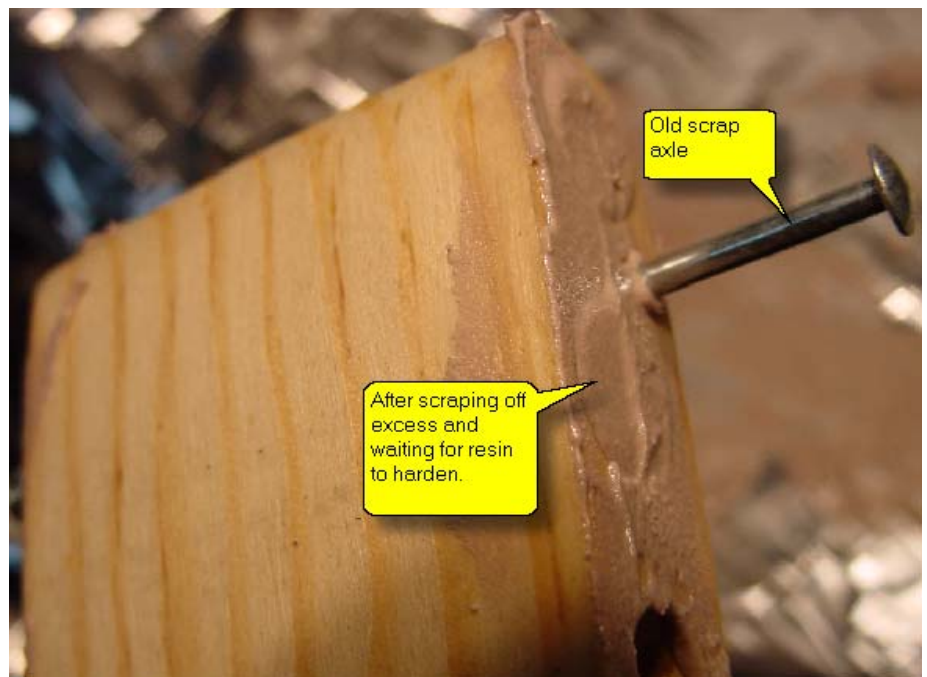
- Be sure the axle hole on passenger side is plugged as in **Fig 12**.
- Rather than immediately laying body on side as shown, try to keep the rear horizontal to keep lead piece from slipping out.



**Figure 12** - Filling the lead holes on the passenger side with Bondo.

### 24. Smooth Around Axle

- As in **Fig 13**, smooth around axle and scrape off excess Bondo.
- Allow 30 minutes to harden.

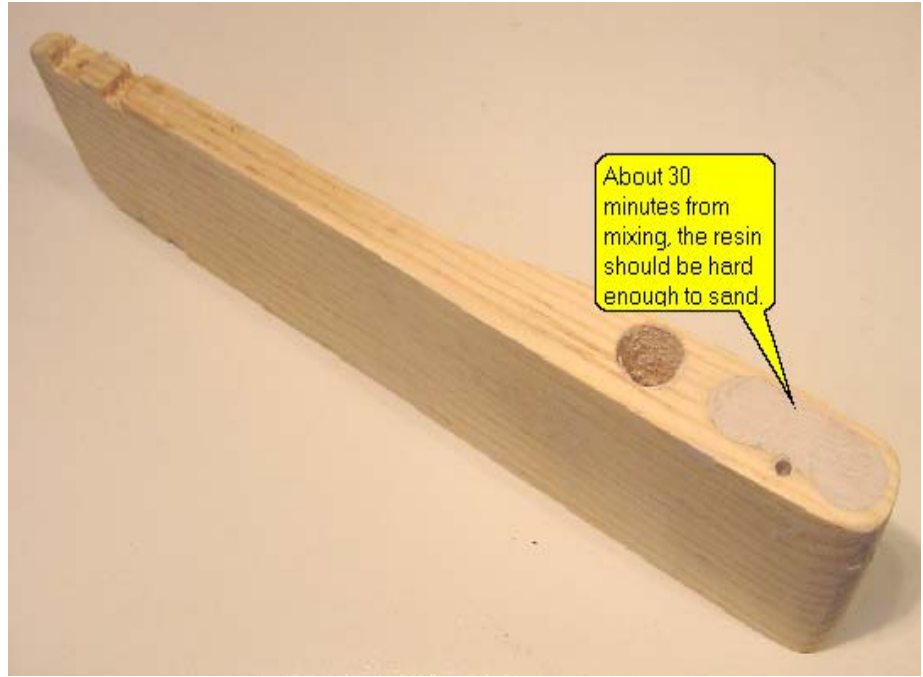


**Figure 13** - Scrape Bondo from around axle and let harden..



 **25. Bondo Sand**

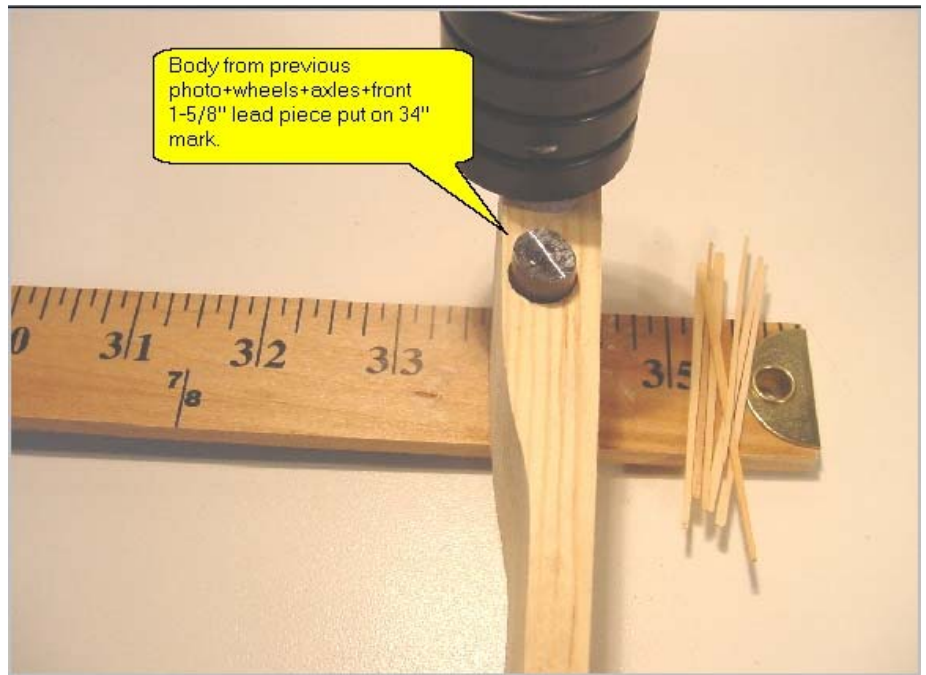
- After hardening sand down surface with 120 to 220 grit or other medium sandpaper as shown in **Fig. 14**.



**Figure 14** - Sanding driver's side Bondo.

 **26. Balance Car Parts 2**

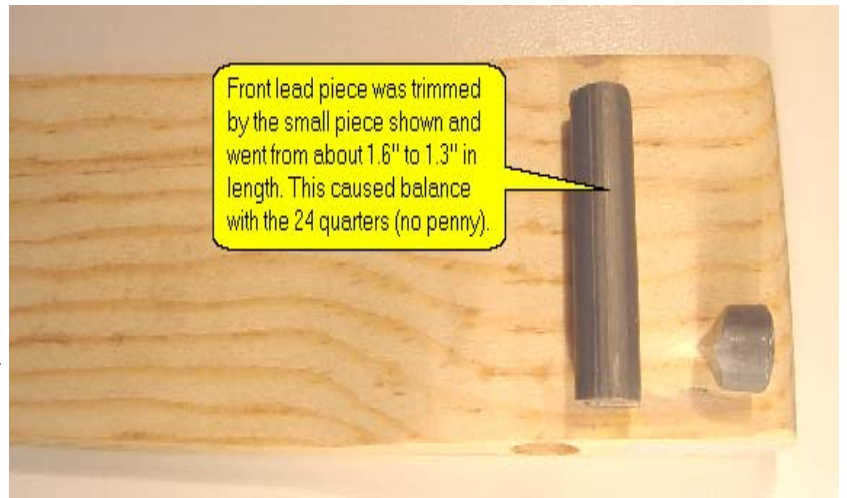
- Next we will balance car parts a second time as in **Fig. 15**.
- Notice the 7 trim toothpicks are always left on the right end of the balance.
- It takes 24 quarters + 1 penny + an extra quarter to balance the parts now.



**Figure 15** - Now put body parts and 1-5/8" front lead piece on balance.

**27. Trim Front Lead**

- The extra quarter weighs about 5.68 g (See previous **Item 15** ) and this is  $(5.68/19)$  or approx 0.3" of lead which weighs 19 g per inch.
- So we need to cut off about 0.3" of lead as shown in **Fig. 16**.
- The balance now is 24 quarters even (no penny) which is  $138.6 - 2.5 = 136.1$  grams. So we have room for a few grams of Bondo.



**Figure 16** - Cutting off 3/10 " of lead from front lead piece.

**28. Bondo Front Lead**

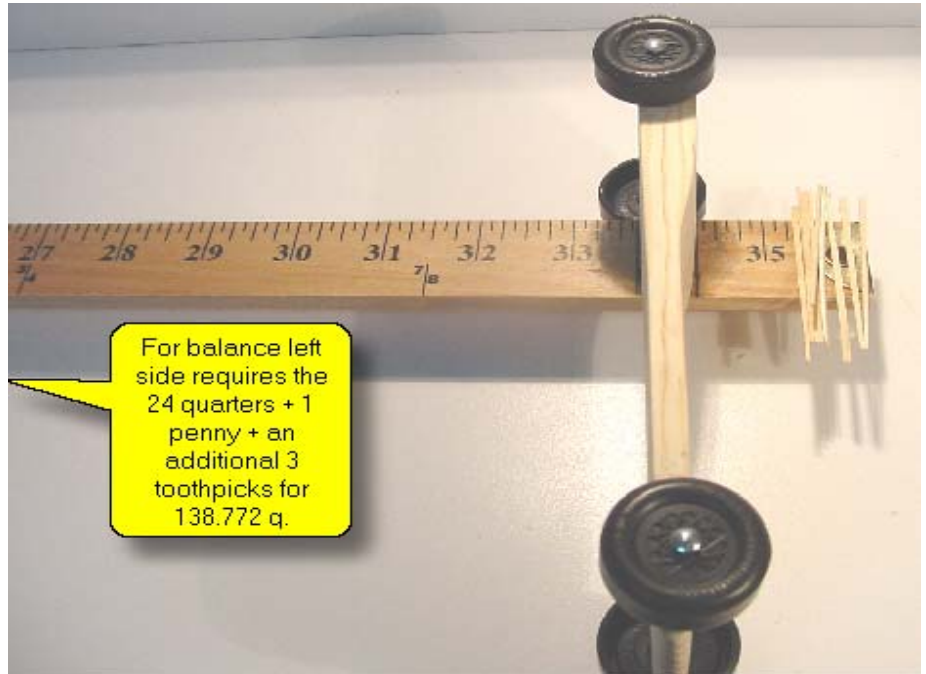
- Mix enough Bondo for the front lead piece and insert similar to the earlier procedure for the rearmost lead pieces. **Fig. 17** shows the procedure.
- Let set and sand smooth as before.



**Figure 17** - Using Bondo to secure the front lead piece.

**29. Balance Car Parts 3**

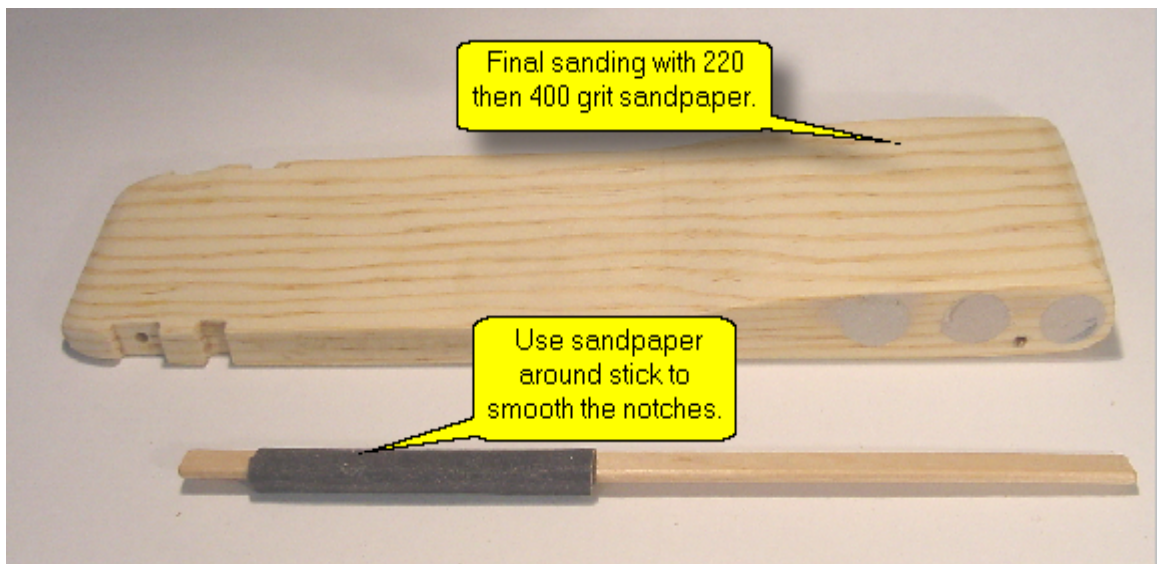
- We now check weight a 3<sup>rd</sup> time using the balance and find we are only 3 toothpicks heavier than our target weight of 24 quarters + 1 penny. See **Fig. 18**.



**Figure 18** - Our 3<sup>rd</sup> weighing shows we are just barely over our target weight of 24 quarters + 1 penny.

**30. Final Sanding**

- Do final sanding with medium-fine 220 and then fine 400 sandpaper.
- Wrap the sandpaper around a small stick to smooth inside the front notches as in **Fig 19**.

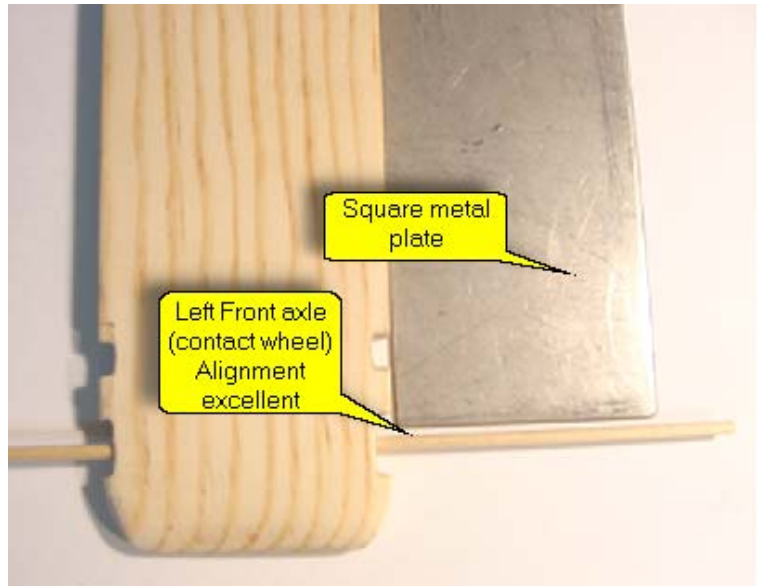


**Figure 19** - Body after final sanding. There should be no sharp edges or corners.



### 31. Wheel Align Check

- Use the mini dowels as shown with a nominal 3/32" diameter and insert them into the axle holes.
- Check toe-in toe-out of wheels by laying a right angle plate ( an index card or a business card would work) next to the dowel.
- As you can see in the photos the left front **Fig 20** and right rear **Fig 21** axles are perfectly parallel to the edge of the plate.
- The left rear axle dowel **Fig 22** may be just slightly towed-out, in that the right side of the plate is a tiny amount farther away from the dowel than it is next to the body.
- This is overall a satisfactory alignment. If the car doesn't roll straight, use pliers to rotate (carefully) the axle head of the touching front wheel 90 degrees.
- If an axle hole is really out of perpendicular alignment, plug with mini dowel and redrill as discussed in **Lecture 14**.



**Figure 20** - Checking alignment of front contact wheel.



**Figure 21** - Checking alignment of right rear.

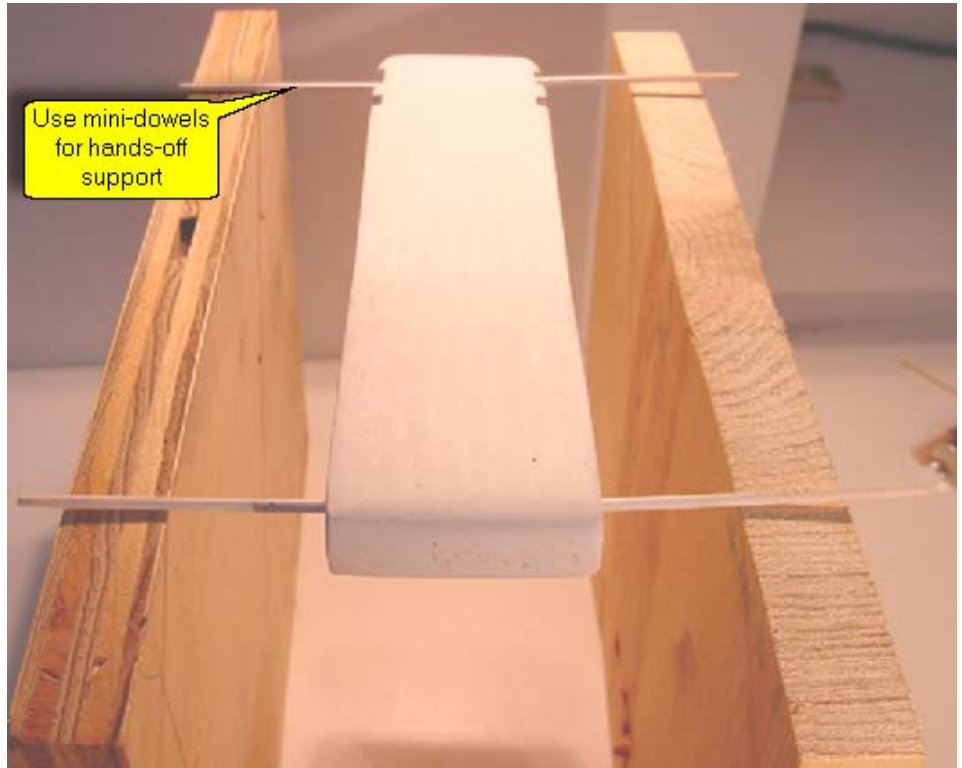


**Figure 22** - Checking alignment of left rear.



**32. Apply Primer**

- Leave the dowels in as they make excellent supports for painting. Here in **Fig 23** primer has just been applied..



**Figure 23** - Using mini dowels for support during primer application.

**33. Apply Paint**



**Figure 24** - Body after metallic paint and clear coat is applied.

- After sanding the primered body with 400 and/or 600 paper, the paint is applied still using the dowel supports.
- In this case a clear overcoat was also applied to add sheen to the paint job as in **Fig 24**.
- To bring car to a super gloss, spray with polyurethane and let dry until the 3<sup>rd</sup> day. Then sand lightly with No 600 paper and spray again. Let dry 2 days, sand again and spray again. After 3 or 4 coats of polyurethane the car finish will look like 10 or 12 laquer coats. Be sure to sand with No 600 after each coating dries well before spraying again. If you don't sand, the new layer may eventually peel off. You may spray polyurethane over wood, stained wood, or any color dry paint.

**34. Balance Car Parts 4**

- We are now ready for the 4th and final weighing as shown in **Figures 25** and **26**.
- The left side now requires for balance:

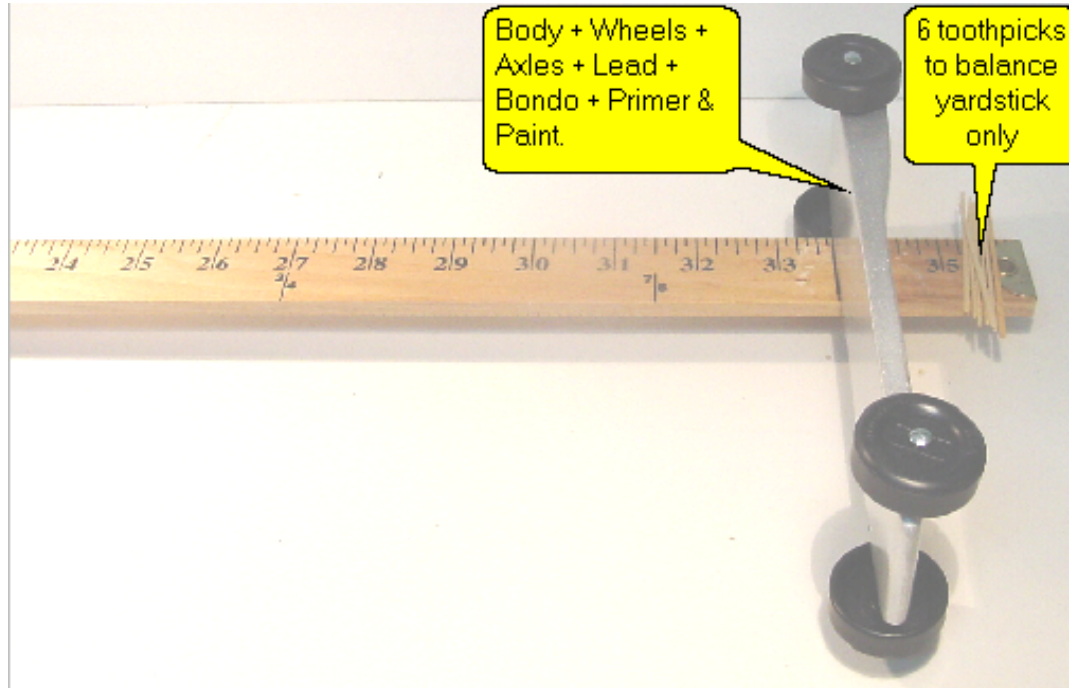
24 quarters + 1 penny = 138.592 g  
6 toothpicks x 0.06 g per toothpick = 0.360 g  
1 axle nail = 0.825 g

Total = 139.777 g

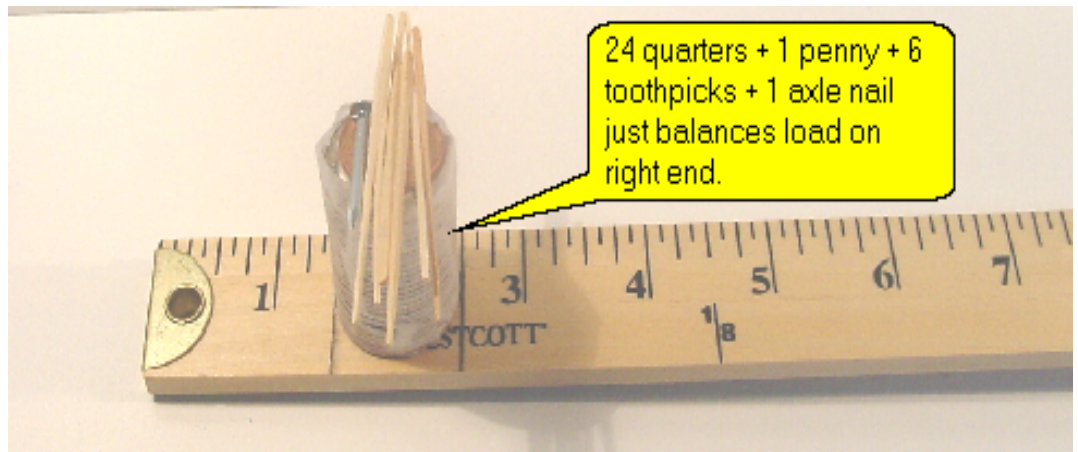
- Actual weight by electronic balance = 139.948 g

- A final decal will add about 0.6 g for an overall weight of 140.38 g

- This is about 1.4 g under the limit of 141.75 but you can't tell the difference at the finish line. See **Lecture 1a**.



**Figure 25** - Putting finished car on balance.



**Figure 26** - Just slightly over target by weight of 6 toothpicks and 1 axle nail.



### 35. Loose Axle Tighten

- It should take firm thumb pressure on the nail head to push the axle head into the hole.
- It should also take firm pulling pressure to remove the wheel from the body. Use the index and middle fingers on each side of the axle under the wheel and pull straight up to remove the axle from the body.
- If the axles are not tight enough add a little wood glue to coat the inside walls of the axle hole using a toothpick and let dry overnight. See **Fig 27**.



**Figure 27** - Adding slight glue to tighten axle hole/axle fit..



### 36. Final Car

- In **Fig 28** is a photo of this SBF (simple but fast ) car. Your first one may take a little time but they can be built in a 2 hour time frame. Some builders spend perhaps a hundred hours on a car, usually of a more advanced type.
- To bring car to a super gloss, spray with polyurethane as explained under **Item 33**.
- Next, in **Lecture 16**, we can go into lubrication because the axles and wheels need to be worked on to reduce the coefficient of friction for the SBF car.

NOW TO MAKE THIS CAR REALLY GO FAST, DO THE POLISHING AND APPLY THE LUBRICANTS IN THE [SPEED PACKAGE](#) AS EXPLAINED IN THE NEXT LECTURE 16.



**Figure 28** - The final SBF car...