Pedestrian Vaults

Humans Going Ballistic

The pedestrian vault: complicated and controversial – the perfect topic for examination. It sometimes seems that everyone involved with accident reconstruction has discovered a formula or formula variant computing pedestrian vault speed. At least a half-dozen computer programs deal primarily with pedestrian and/or bicycle vaults or that have a section containing multiple pedestrian vault formulae.

What distinguishes a pedestrian vault from a regular vault, and how do bicycles get included in the former? The point launch and the point of touchdown or landing define the regular vault. Within the field of accident investigation or reconstruction the vault formula is most often utilized with vaults involving launched vehicles that create easily discernible marks upon making contact with the struck surface. By contrast, a pedestrian vault is typically devoid of an easily discernible mark where the pedestrian made first contact with the surface. The difficulty in determining the point of first contact also holds true in the case of an operator of a bicycle or motorcycle. The undiscovered point of touchdown is the reason for including bicycle and motorcycle vaults with pedestrian vaults.

The terminology or language involved with the investigation of pedestrian vaults contains some terms that are unique and specific to the analysis of this type of vault. One of these terms is "throw" distance. In a regular vault, the distances involved in the analysis are the vertical and horizontal distances from the point of launch to the point of touchdown or first contact. As the point of first contact with the landing surface is normally not discernable when pedestrian vaults are investigated, the horizontal distance is unavailable. Instead, the investigator uses the throw distance.

Ideally, the throw distance should be measured from the point of release or separation of the pedestrian from the vehicle to the point of final rest of the pedestrian. The actual release point is almost impossible to determine, as it must account for the carry distance of the pedestrian by the vehicle and as such, the throw distance is usually measured from first contact or impact to the point of final rest of the pedestrian.

The throw distance covers not only the vault but also the sliding distance of the pedestrian. The inclusion of the sliding distance is the feature that best distinguishes pedestrian vault from the regular vault. The lack of demarcation between the vault and the slide dramatically complicates the analysis of the throw distance, the hallmark of the pedestrian vault.

No wonder pedestrian vaults seem so complicated. They involve both a vault over an undetermined distance and a slide over an undetermined distance. The word *undetermined* was precisely chosen. It may be undetermined, but it is not undeterminable.

Generally, vaults associated with accident reconstruction do not include corrections for air resistance, which is speed dependent. The mass of the object is so large in relation to its surface area and the distances and speeds are so small, that the corrections fall within the margin of error relative to the measurement of the variables involved.

Another common mistake made by the uninitiated is assuming that there are different formulae for different types of vaults. Publications from some training institutions have broken the vault into falls, vaults where the landing is above the point of takeoff, vaults where the landing is below the point of takeoff, vaults where the launch angle is limited to a few degrees above or below the horizontal, and the list goes on. To set the record straight, there is only one fundamental or basic vault equation and it is based on standard physics equations relating to distance, velocity and acceleration.

The analysis of a *regular* vault involves three primary variables that enable us to determine the fourth variable, the vault speed – usually the unknown. These primary variables are the horizontal and vertical distances from launch to contact (as previously discussed) and the launch angle of the vaulting vehicle or object.

As a rule, the analysis of a slide or skid involves a beginning speed, a final speed, a distance and the friction factor between the surface and the object. If three of the variables are known, the fourth variable or unknown is easily solved for using a relatively simple non-linear equation.

The unique feature of the pedestrian vault is that two of the components, the vault and the slide, are shared in an initially undetermined ratio. To help complicate matters, as is all too often true with the regular vault, the launch angle of the pedestrian vault is probably unknown.

Eating an Elephant

So how does one eat an elephant? One eats an elephant one bite at a time. If that works for elephants, it may also work for pedestrian vaults.

Pedestrian vaults deal with the pedestrian from the release or separation from the vehicle to the point of final rest, the throw distance. This throw distance involves both a vault and a slide. Since the vault and the slide are the essence of the pedestrian vault, why are they not the primary focus of the investigation into a pedestrian vault? Once separation occurs, the vehicle no longer has any influence on the pedestrian unless there is a secondary collision. The subsequent motion of the pedestrian as governed by the laws of physics should be the primary focus of our investigation.

The 600 Pound Gorilla

Current methodologies generally examine the vehicle-pedestrian geometry, assuming a ***non-reported*** launch angle to solve for the vault speed. The integration method examines the vault-slide relationship for the given throw distance using a narrow range of variables including appropriate ***input*** launch angles in determining the speed. The expert can then examine the effect and validity of all of the inputs, including the launch angle.

For any given launch angle and friction coefficient between the pedestrian and the surface over which the pedestrian is sliding, the vault and the slide components of the pedestrian vault are inexorably tied to each other. This tells us that if the launch angle and surface friction are known for any given throw distance, then solving for the vault speed of the pedestrian is simply a matter of doing the mathematics.

If the throw distance and height are kept constant, the only way the different currently published pedestrian formulae that use height, throw distance, friction and angle can arrive at their different solutions is by varying either the launch angle or the friction factor of the pedestrian.

As almost every pedestrian vault formula requires an input of the friction factor, the only remaining variable is the launch angle. Because of this fundamental relationship based on physics principles, the only real difference between most of the existing pedestrian formulae is the *assumed* launch angle except in cases where the author uses *constants* that are *empirically* derived.

Almost all of the pedestrian formulae are designed to handle one of two different types of problems: 1) the wrap or 2) the frontal projection. The foregoing statement is technically correct, but when examined closely, all that is usually at issue is the launch angle. Generally, a frontal projection will have a launch angle less than or slightly above zero. Launch angles much greater than zero are usually the result of a wrap. Again, it is simply a matter of the assumption made for the launch angle that is the difference in these two main types of formulae.

The Vault

How can we arrive at a solution for a known launch angle, throw distance, elevation change and friction coefficient?

There is almost enough information to use the regular vault formula to solve for a vault speed. Using the information at hand, a vault solution is possible but there is no distance remaining to dissipate the energy resulting from the horizontal speed of the pedestrian.

On the other hand, if the entire throw distance is used for the vault, there is no linear distance for the slide. The pedestrian would have landed at the final rest position with all of the horizontal speed still intact.