“High-Performance, Flexible Fiber-Reinforced Concrete New Jersey Barrier with the Property of Absorbing the Energy from Crash to Protect Human Lives and Reduce Financial Losses during the Crash"

Summary of the Invention:

New Jersey is a type of concrete barrier that is made at different heights such as one, two and three meters and is used in highways in order to prevent detours and violations by drivers for providing security and preventing from crashes, and entry and exit in some cases and controlling the traffic and preventing from annoying headlights of cars on the opposite side.

Concrete New Jersey barriers are made of prefabricated concrete parts that can be connected together to direct the vehicles and put them in the route, when crashing with the side of the vehicle that act as a reversing guide due to the low angle of its edges and reduces the damages. It is also used to protect the pedestrians, protect the construction workers from vehicles, act as temporary barriers and anti-terrorist security barriers, as well as flood barriers, prevents from forest fires, directs the river and create several lanes in the roads.

This invention is the design and construction of a new generation of highway concrete New Jersey that will significantly prevent from financial and casualties due to traffic crash. This special type of New Jersey is made as a hollow shell of high-performance and high-strength fiber concretes using nanotechnology, which is filled with shock-absorbing earth materials, and at the same time its high resistance acts as an energy dump in the event of crash and reduces the effect of the impact and directs the vehicle in its route. This performance of New Jersey reduces the risk of casualties and deaths during the crashes.

The flexibility and the ability of creating a joint in the event of an crash is one of the efficiencies of New Jersey, and its function during the crash is to absorb the energy of impact and reduce its effects. This product has been successfully produced after several months of laboratory studies, software analysis, field tests and workshops tests and is can be presented in different facings.

Description of Appearance:

Hollow concrete modular parts are made of resistant concrete and strong fibers, the edges of which are curved with a slight angle and are made with the height of 100 cm and the standard length of 400cm and 600cm. This shell is filled with soft soil or earth materials (without rubbles) in order to increase the weight and also increase the softness and flexibility for absorbing the energy of impact. This New Jersey barrier has lateral fittings in order to be installed on longitudinal guardrails.

Report on Simulation of Vehicle Crash with New Designed Concrete Guardrail (New Jersey)

Assessing the value of the impact and strength of products produced by car manufacturers worldwide is one of the most important issues both in terms of advertising and in terms of the possibility of entering the markets of target countries and observing the minimums set forth in the relevant codes. Advanced companies and research units in different parts of the world deal with the issue of car crash and safety factors of passengers and their combination with economic issues, which is the most important issue for car manufacturers. In this regard, numerical analysis has been welcomed as a low-cost solution considering very high costs of conducting crash tests under different situations that have been discussed in international codes. This does not mean that there is no need for analysis on a laboratory and field scales; in fact, numerical analyses pave the way to reach the optimal answer and significantly reduces the costs.

In order to evaluate the accuracy of numerical analysis used in this study, the results of numerical analysis are compared with laboratory results. The vehicle has been tested under different conditions.

Simulation Software

Software used for analysis includes ESI VISUAL Environment and LS-DYNA.

ESI VISUAL Environment is used for preprocessing and production of finite element model and LS-DYNA software is used for processing.

An Introduction to LS-DYNA

Today, numerical methods beside the analytical and experimental methods help a lot to solve problems and identify physical phenomena. Phenomena that occur during high-speed dynamic processes are usually difficult to observe and record in experimental tests. However, in a numerical analysis, the whole process can usually be simulated. Hydro-Codes are computational tools from continuum mechanics that are used to simulate the response of solids and fluids to dynamic loads (impact and explosion). One of the famous Hydro-Codes is LS-Dyna software which has very high capabilities in solving nonlinear dynamic problems. The high ability of this code in analysis of detonation problems, propagation of shock waves, forming of metals with high deformations, crash of objects, projectile penetration in the target and… with approximately 200 types of material models and 13 types of equations of state and various surface contact methods, made it to be known as one of the most powerful engineering software that can be used in many explosion and impact issues.

It should be mentioned that despite these capabilities, this software, like other engineering software, cannot give an accurate knowledge of physical phenomena by itself. Selecting the type of material model and the appropriate state equation, having information about the properties of material and parameters required in the material model and the state equation, initial and boundary conditions, proper definition of contact surfaces and, …require that these numerical methods be used along with experimental results. The type of solution also has a considerable effect on the results. Lagrangian, Eulerian, Lagrangian-Eulerian coupling methods, MMALE, SMALE and SPH can be used, each of which has advantages and disadvantages. One of the efficient finite element software in simulating

of problems with high strain rate is LS-DYNA software. Finite element codes that have the distinctive capability of this type of simulation are known as Hydro-Codes because in this case, even the behavior of solid materials is similar to that of the fluids.

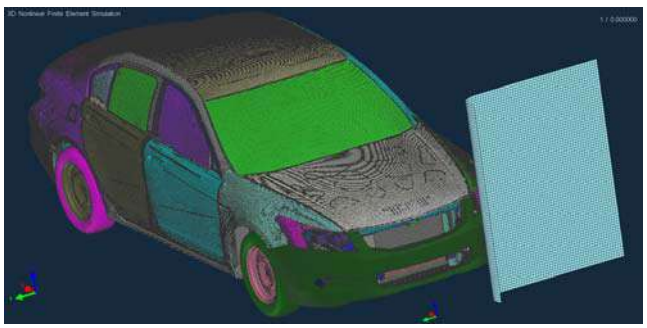
The problem-solving process, depending on its dimensions and complications, consists of two general steps:

- Validation
- Reviewing the designed model

Each of the general topics includes specific subsets and processes to achieve the goal; for example: in examining the designed model, several geometric parameters may be considered, each of which requires a finite element model based on simulation power of LS-DYNA software.

Specifications of Model

Weight (kg)	1661.0
Engine Type	2.4L 14
Tire Size	P215/60R16
Attitude (mm)	F - 684
	R-681
Wheelbase (mm)	2794
CG (mm) Rear of front	1175
wheel C/L	
Body type	4-Door Sedan

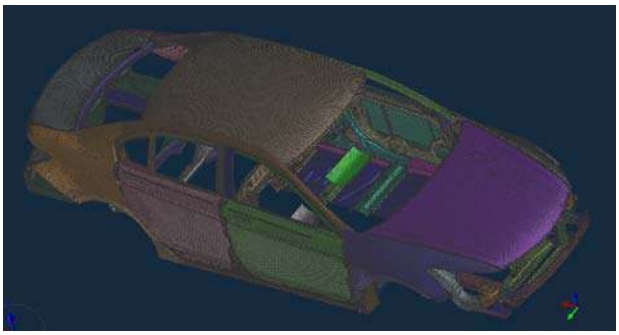


Used Specifications & Structural Equations

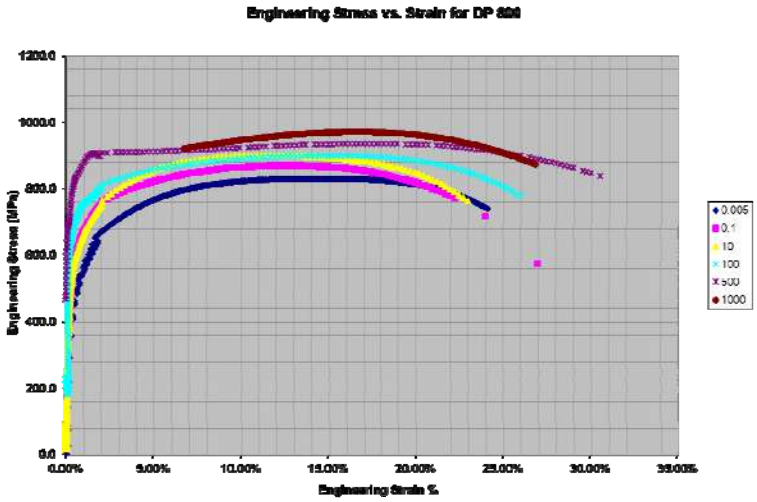
Considering the high number of materials used and also taking into account the corresponding structural equations used in in numerical analysis software, we express the general items considered in the structural equations.

For metal parts and considering the type of metal and depending on the alloy, cold rolled or hot rolled metal, in addition to the elastic properties and considering the high strain rate, plastic profiles depending on strain rate are considered.

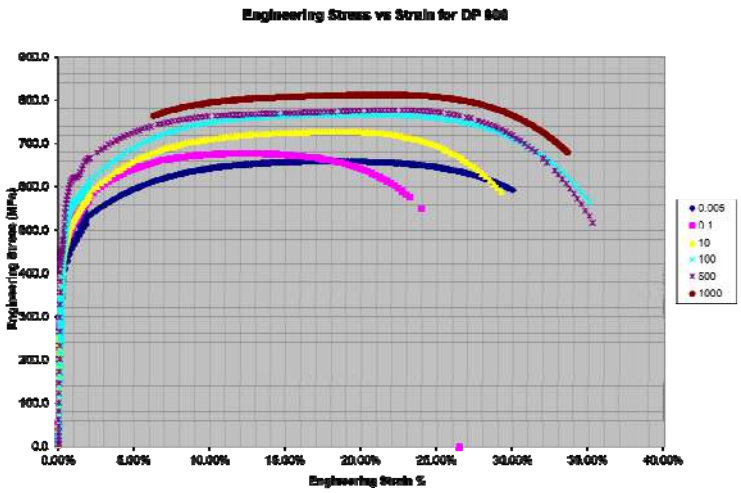
The following diagrams are some parts of such cases:



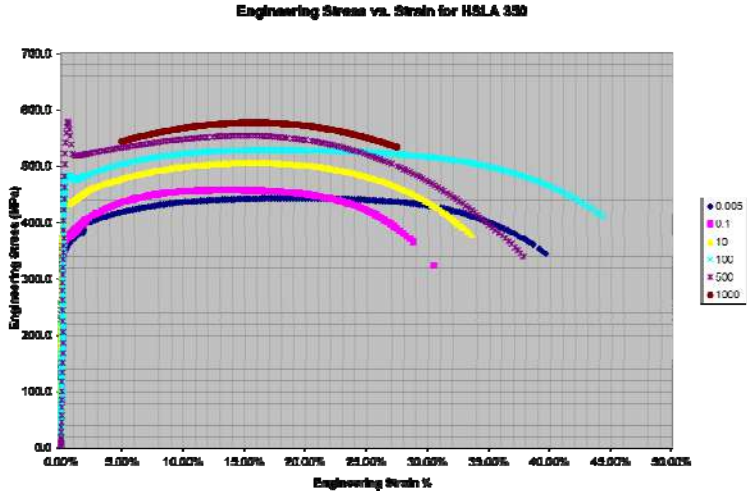
Used Specifications & Structural Equations



Stress & Strain Diagram in Different Strain Rates for DP800



Stress & Strain Diagram in Different Strain Rates for DP600



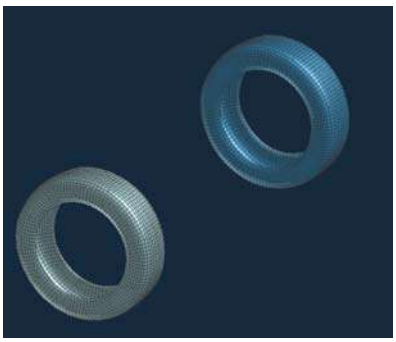
Stress & Strain Diagram in Different Strain Rates for HSLA 350

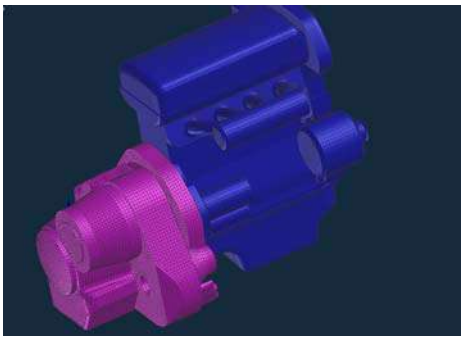
Used Specifications & Structural Equations

In addition to the cases mentioned above for brittle materials without the ability of energy absorption such as glass, the failure mechanism is considered using strain in order to reduce the computation time and high accuracy of the model at the same time.

The simple elastic model and also the air inside it is considered as a limited volume with internal pressure for tire modeling.

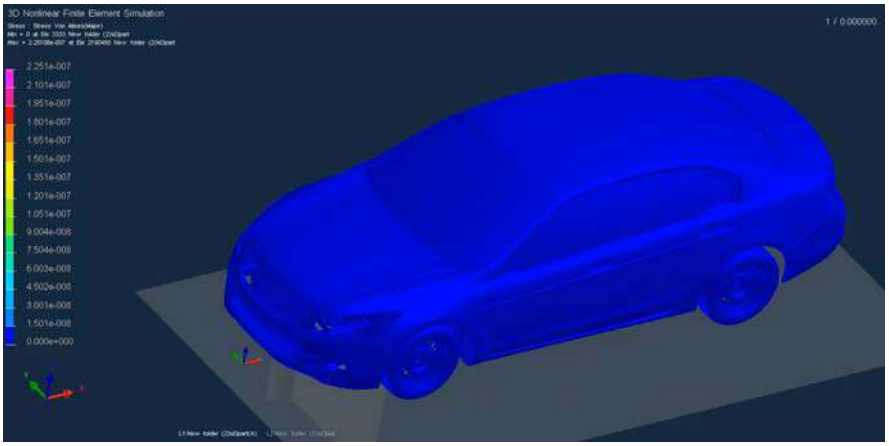
Some parts of the car, such as the engine, that have high stiffness and entering their details make analysis almost impossible in terms of model size, time and hardware required to process the model, and remain undamaged in high-speed crash are considered as a rigid body and the mass and inertia momentum in different directions have been introduced to the software accordingly





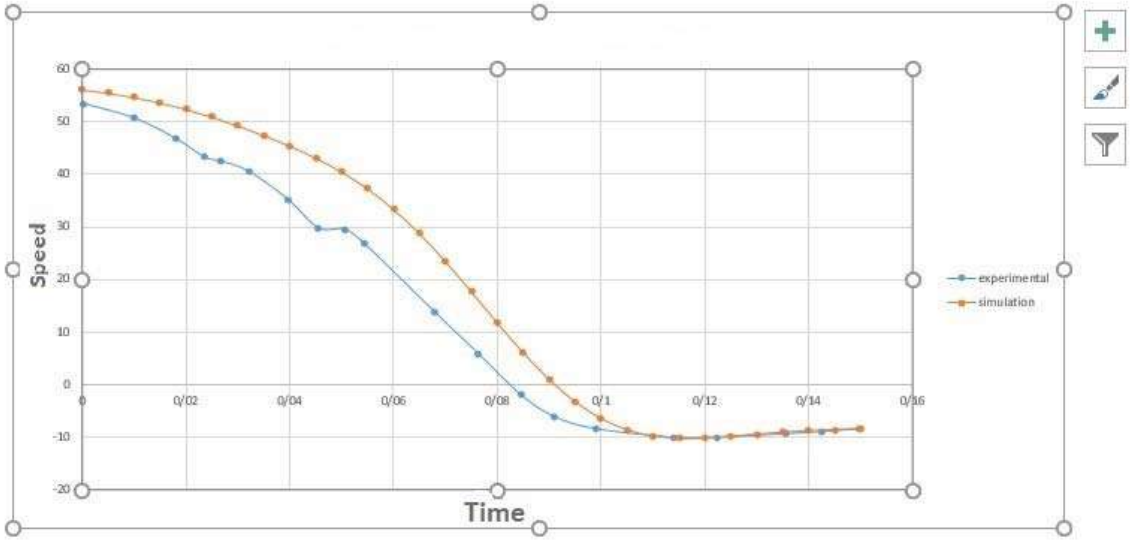
Validation

Since no experimental test was performed to test the structural system, we validate a crash model of a car in order to study the accuracy of the modeling and use this model to test the new structural system. The results of crash for the validation system are shown in the following video:



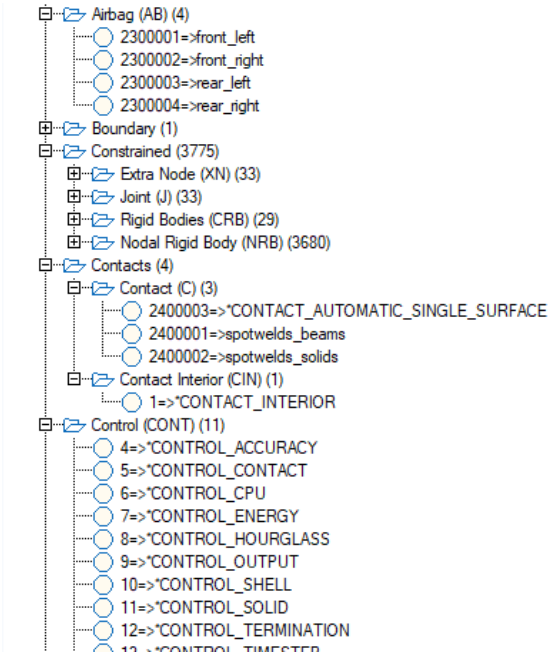
Crash Speed: 75-90 km/h

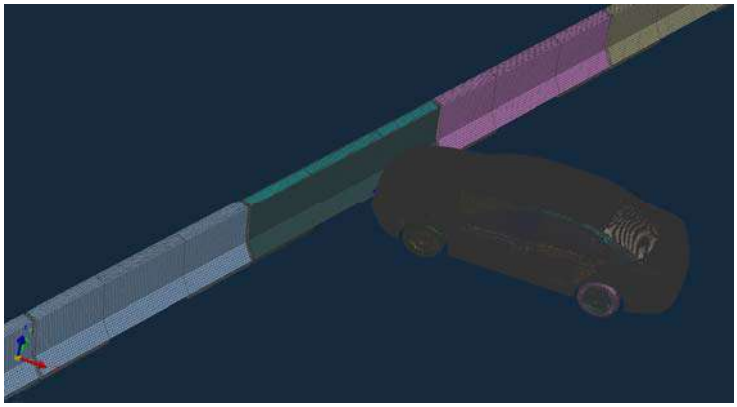
Compare vehicle speed in both simulation and actual test modes when testing speed



Crash Simulation in Designed New Jersey

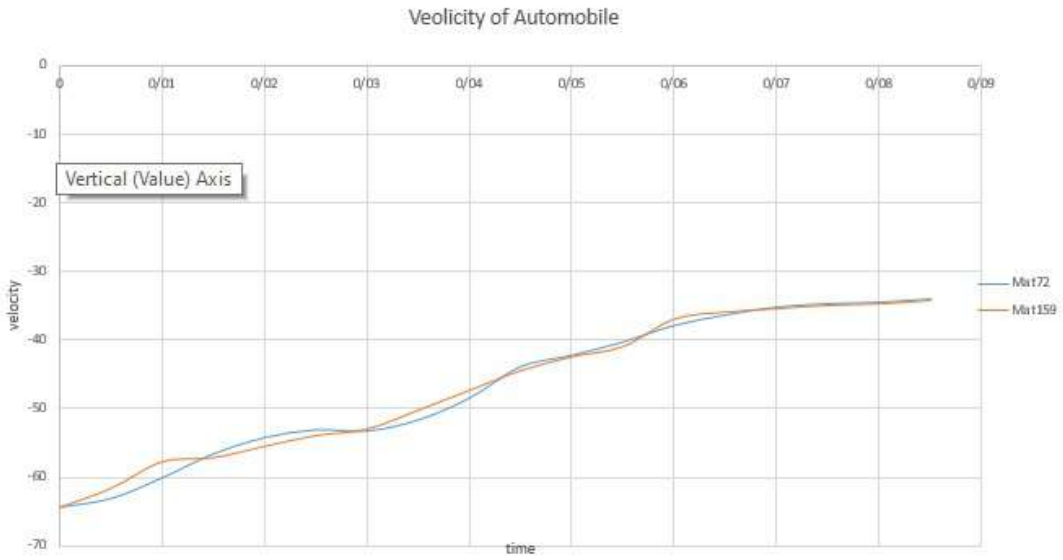
Considering the mechanics and structural equations for vehicle and its elements, which are briefly and generally presented in the previous section, we will explain the equations intended for concrete as the main energy absorbing material in this section:





Simulation of New Jersey

The results of crash for all structural equations show almost similar output:



Crash Simulation in Designed New Jersey

It is considered for convergence to solve the conditions related to the elimination of the element with a strain of 0.2 in LS-DYNA software for concrete.

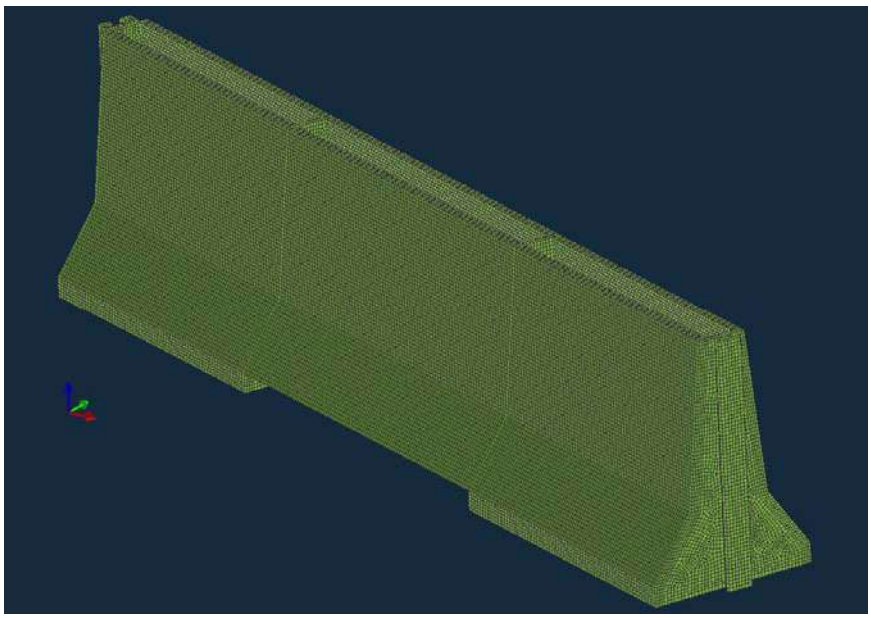
Behavioral models of LS-DYNA software accurately simulate the behavior of concrete under complex loading conditions. The behavior of concrete under tensile and compressive stresses are observed and related structural equations have been evaluated and validated according to tests performed by the US Road Department. Relying on a high number of studies and experimental tests performed by US research and military agencies, these structural equations are used as accepted equations for industrial and military purposes

Density (kg/m^3)	Young Modulus (Mpa)	Poisson Ration	Compressive Strength (Mpa)	Tensile Strength (Mpa)
2400	47000	0.22	96	12

Crash Simulation in Designed New Jersey

Solid elements are used to simulate the concrete structure. Four layers of elements are used in the thickness in order to strictly observe and investigate the stress in the thickness.

Number of elements used for each concrete block: 185171 Eight-node 3D elements



Part ID	Part Name	Type	E (C/S/O)	Mat ID	Section ID
1001	PART_1	SOLID	185171	2000514	100001

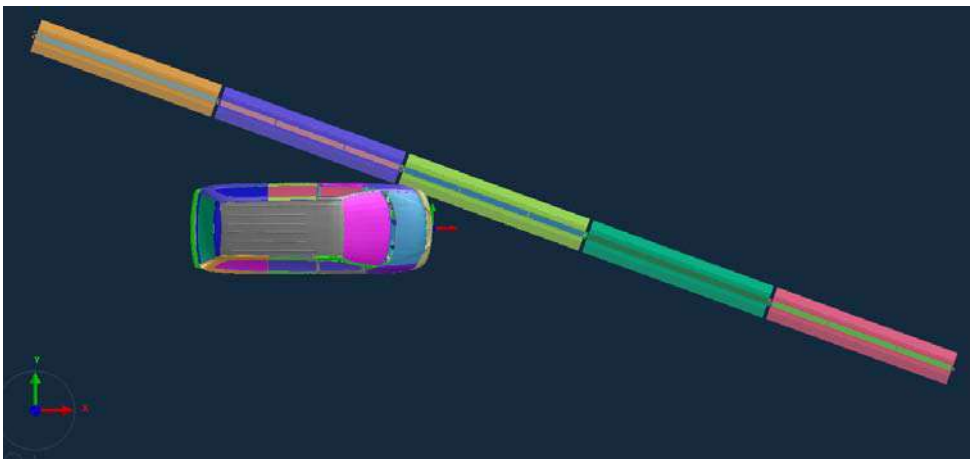
Geometrical Characteristcis of Each Concrete Newjersey : Length: mm Mass: MT

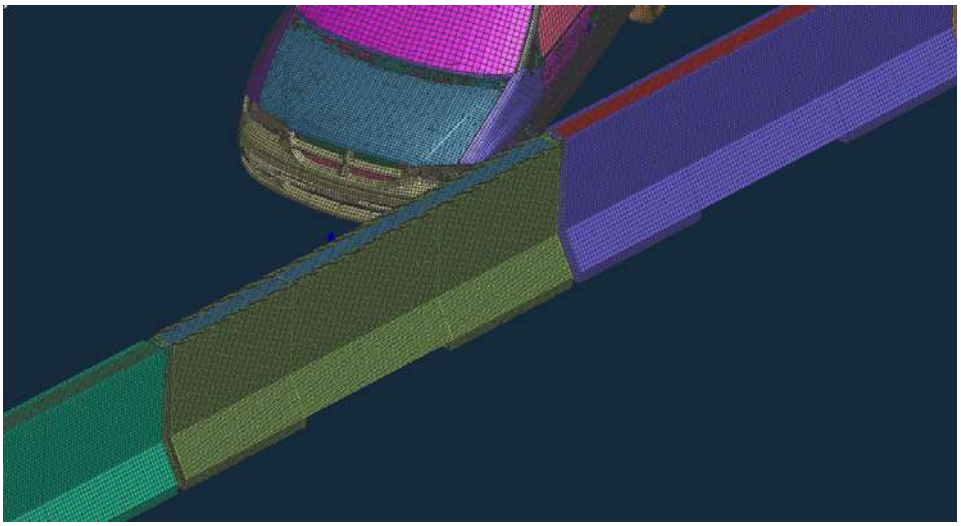
Mass	Xcg	Ycg	Zcg	Ixx	Iyy	Izz	Ixy	Iyx	Izx
1.05173	1277.12	556.745	408.885	315891	1.51E+06	1.62E+06	499451	-302.142	830.262

Arrangement of Concrete Newjersey

Crash Simulation in Designed New Jersey

Considering the crash conditions including the speed of 75 to 90 km/h and crash angle of 30', the final arrangement of the finite element model in Visual Environment for processing in LS-SYNA software is as follows.



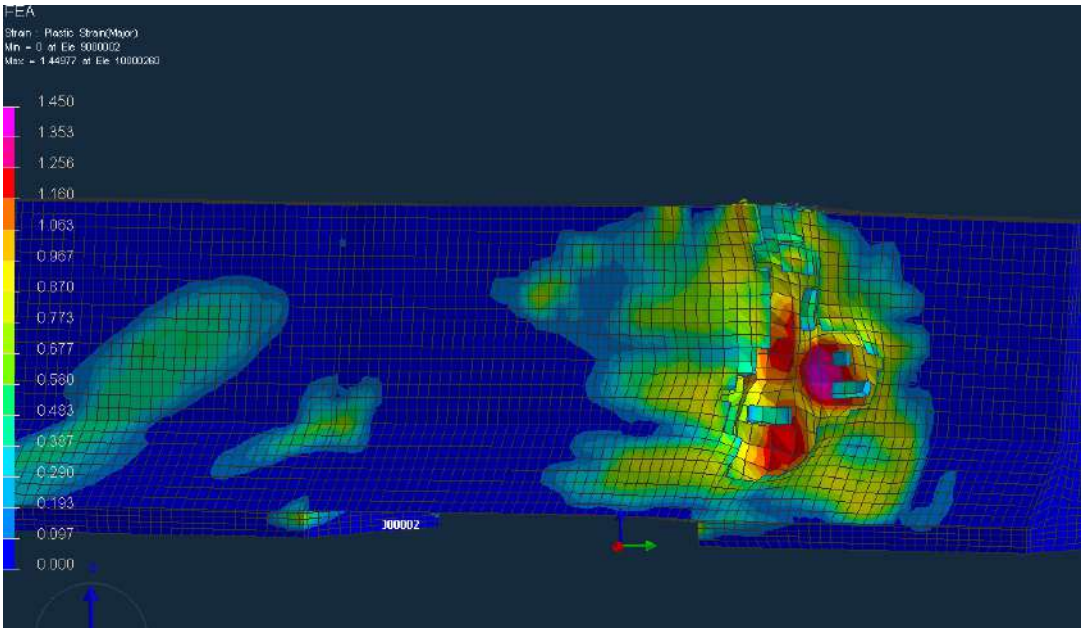


Crash Simulation in Designed New Jersey

By increasing the thickness of the concrete layer, the possibility of improving and modifying the design was investigated.

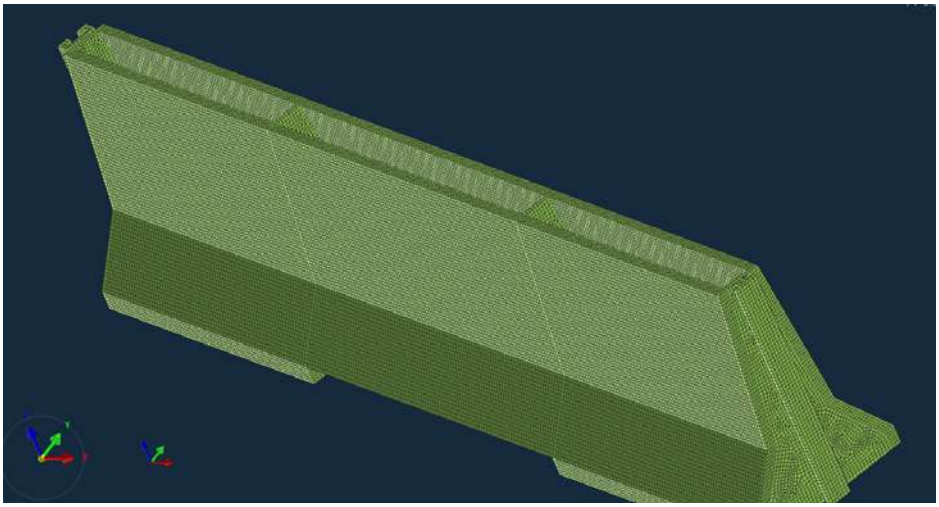
The results of the analysis show that by .05 cm increasing of the thickness, the design has significantly improved. But this improvement cannot guarantee the efficiency lever of the structure.

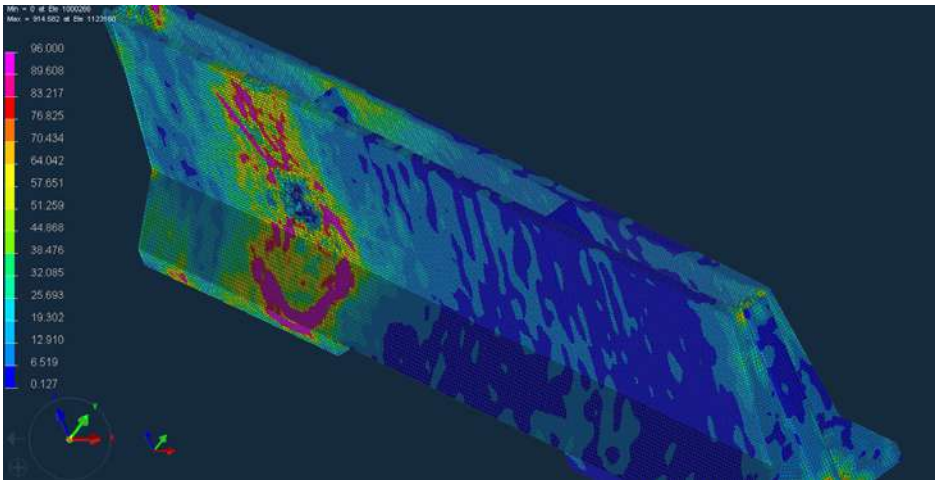
For this purpose, considering the level of damage and the trend of changes in the stress and damage field in the concrete layer, the thickness of 4cm will be studied in the next step.

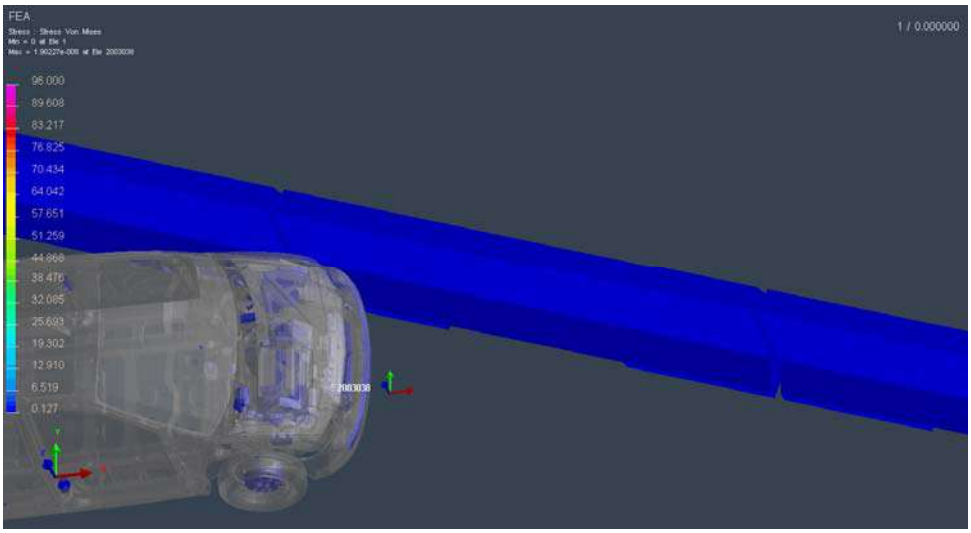


Simulation of New Jersey

The thickness of the concrete layer is increased and examined in order to increase the capacity of the designed structural system. To estimate the appropriate parameter for the thickness of concrete based on the level of damage to the concrete, a thickness of 4cm is used for simulation and the whole process of geometric simulation and finite elements are made based on this parameter.



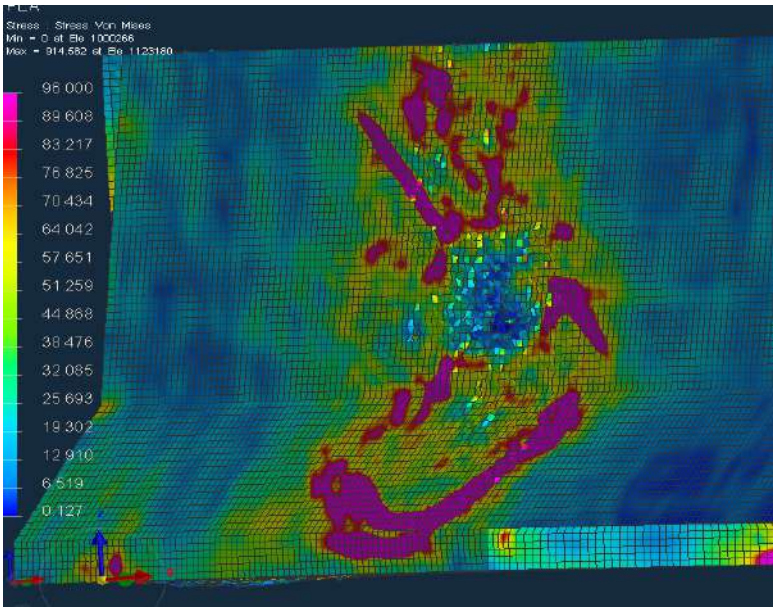

96.000
89.608
83.217
76.825
70.434
64.042
57.651
51.259
44.868
38.476
32.085
25.693
19.302
12.910
6.519
0.127



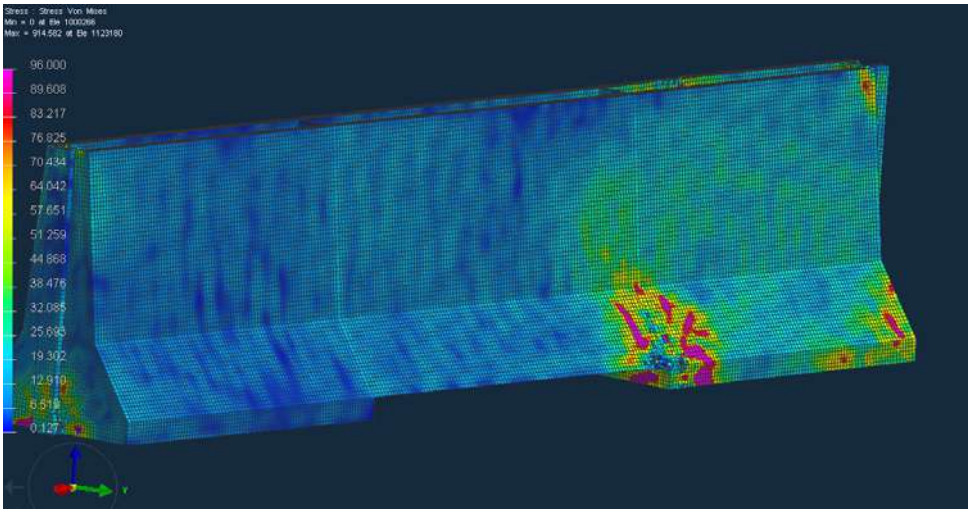
Study of the results of this simulation shows that this design has the necessary strength and efficiency against the applied load and according to the type of crash, the vehicle deviates from the direction of motion. Changing the angle of motion of the vehicle is the final demand of the design and at the same time the level of damage in the designed structural system should be acceptable.

A part of New Jersey that absorbs a significant part of the energy and changes the angle of motion and is there in the very first moments of the crash is damaged and this damage is transferred to adjacent parts according to the structural equations and failure mechanics defined for concrete.

More detailed studies in this area show that although the central area of damage, which is highly distorted with even low level of stress due to finite elements, the adjacent area, despite being involved in the failure process, can still withstand the stress. The reason for the low level of stress in the center of this area is the general damage in this small area due to the crash.



Another damaged area, as shown in the figure, is the area behind the crash surface and the heel area involved in the first moment of crash. This part is responsible for transmitting the energy of crash in a very small fraction of time and therefore the probability of damage in this area is high. Despite this fact, the level of damage in this area is very low and the designed structure can withstand the load.



It is concluded that New Jersey, which is an invented and innovative concrete and hollow concrete with a shell of high-strength concrete and very special fibers with a thickness of 4 cm, made with nanotechnology, is fully responsive to tests, modeling and simulation, and can be used. It has highways, freeways and roads.