S .M. Wani, P. P. Patil, P. M. Solanki, J. R. Chaudhari / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 3, Issue 1, January -February 2013, pp.1557-1564

"Failure of Underground Unplasticized Polyvinyl Chloride Plastic Sewer Chamber Cover when the Vehicle Passing Over"

[1*] S. M. Wani, [2] P. P. Patil, [3] P. M. Solanki, [4] J. R. Chaudhari.
[1*] Department of Mechanical Engineering, G. C. O. E, Jalgaon.
[2] Department of Mechanical Engineering, SGDCOE Jalgaon.
[3] Department of Mechanical Engineering, SSBTS COET Bambhori, Jalgaon.
[4] Department of Mechanical Engineering, SSBTS COET Bambhori, Jalgaon

ABSTRACT

This paper focuses on the strength of uPVC and FRP Materials. These material shows differ strength on same application. The uPVC inspection chamber ultra- 450 is used for light vehicle road traffic and it specifically facing or suffers from breakages when the vehicle passing over it. Whenever the light or small utility vehicle (SUV) about 14 to 16 tonne loaded passes over the underground uPVC chamber, it should not be failed or broken during functioning. Here , hence consider one wheel of vehicle when passes over uPVC chamber , it should be so designed to bare the ¼ th load of total load of SUV i.e. 3.5 ton . But actually, SUV passes it may be fail at central region or at corner of plate which is mounted at the top in chamber. Under the study it is proved that it is failed due to weak strength of the uPVC material. Its causes and influences. Therefore, From the experimental test and software verification trying to get find solution by altering the dimensions of chamber cover and testing it by software on same material for optimize solution. But even after dimension modified, it resulted completely failed. Hence material replacement options will more predominantly emphasis on those aspects which can be improving strength of chamber cover without altering the design parameter specifically improving sizes. For conclusion apporvence, the experimental test result of failure and analyzing & optimizing solution obtained from Pro-Mechanica software FEM analysis are verified.

KEY WORDS: uPVC, FRP or GRP, Von Mises stress, UTM, SUV,

1. Introduction

Aim of this paper as long as the recent trend development in 450 mm chamber's covers which are result in uPVC material that are effectively used in above applications like as a cover plate of chamber. Now a day most of manufacturers are particularly engages in design and Producing various types and ranges of ultra-chambers at large extent for India itself and for abroad. Out of these range the Ultra 450 mm chamber cover facing the problem when vehicle exert the load. It is failed as on vehicle when passing over it. It is safe below load of 3500 N. when the load exceeded than it resulting the breaking of the cover. The aim is that to search exact problem cause and focus on failure aspect by verifying it by physically or experimentally testing. Sort out only mechanical strengthening properties or aspect rather than other environmental, chemical or any other fact. Focus is made only at strength of material i.e. uPVC strength in way of poisons ratio effect, specific gravity etc. Effect is reviewing by software testing analysis.

Planning the sewer system is the most of the challenges in way to control and inspecting it. From long ago there are hierarchical developments made in the drainage system along with their component. Out of it, the chamber plays a very vital role that integrating the sewer water from various pipes lines deliver to next. These developments were started from soil to concrete and now in plastic. Plastic is one of optimize solution as per the reliable and durable efficient long life material. So there are very much trend in plastic to develops the chamber, recently the newest one development in plastic as the rigid plastic and popular by the name unplasticized polyvinyl chloridal plastic i.e. uPVC is the abbreviation.

The main objective of this paper is that the problem faced by the product of various company of uPVC material made cover of chamber of 450 mm. this size is safer unto 3500 N load of one wheel of SUV vehicle. But cover of chamber is failed when vehicle exert more load than specified i.e. 3600 N, it is failed at central region or may be at corner of plate of cover. So this paper try to review on the uPVC material incapability beyond certain strength. So there are modification made in inherent design by improving the sizes but that modification are failed and suggest that in uPVC material's Poisson's ratio is 0.41, it conclude that there are more deformation because of relation as per following.

$$\mu = {}^{\text{lateral strain}}/_{\text{linear strain}}$$

Above Certain boundary of uPVC material, it can bare the limited load due to its modulus ofelasticity and Poisson's ratio. Even going to or altering the dimension itself, no exact relation developed between the Von Mises stresses and change made in dimensions and as from following sensitivity graph it

can be proof that no lowered the stresses even if change rib and plate thickness as long. Therefore from software optimization the suggestions made as to replace the material which should have less difference in lateral to linear strain i.e. nearer poisson's ratio about 0.25. So the composite materials are most effective material which can contribute above aspect without altering the design. So that as per component category i.e. plastic category, it may suggest that the FRP or GRP material is most suitable for chamber cover at condition to fulfill the max. load exerting by the vehicle equal or above 5 tonne or 50000N.

2. Objective of paper:-

The objective of paper work is that review design parameter of sewer chamber cover which suffers failure and focus on the weakness of material i.e. weakening strength. And also find out appropriate solution to control or eliminate it with very less changes made in dimensions. That will not disturb the inherent design, manufacturing and maintenance of chamber. If the cover will not bare the above load in any condition after just changes sizes, trying to find other compatible optimize solution through replacing the existing material and analyze and optimize it only through the software optimization (Pro Mechanica).

Finding the failure by software test along with the experiment test and Optimized solution by software:-

First recognize the needs of problem. Subsequently problem analyzed through various trials in sequenced phenomenon such as preprocessing, post processing and last solved in solver.

2.1 Problem definition:-

With the original model, first of all, with the same material all the result is calculated. Among that result, Von Mises stress is considered as a constraint. Means this Von Mises stress is to be lowered and thickness of plate and rib is taken as variable parameter. It means by feasibility and optimization it is to be checked whether by varying the thickness the value of stress lowers or not.

2.2 Solution: -

For software optimizing, first predominantly recognizes the main part/ section which are suffering more failure due to more stresses were induced that are in main sections/part of cover of chamber. These are referring from CAD drawing of chamber. And having properties and dimensions as follows

- Before going through optimization in the software first of all known specific properties are inputs in the Cad Modeled for further analyzing in ProMechanica. This properties given as Poisson's ratio =0.41, specific gravity=1.41gm/cc and UTS of material are 45-50 N/mm^2 , E= is 2971414950 MPa

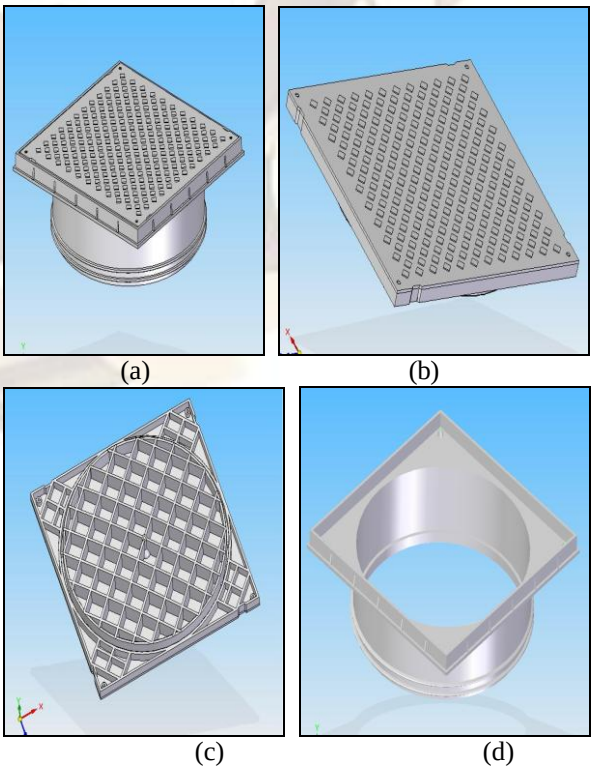
On the basis this of property to finding the failure of chamber 450 mm. therefore as per design the chamber can be designed by various considerations. But this paper is focus only about the strength aspect of material. As per the aspect above property is vital to solve and find out the failure with the optimum solution. This whole phenomenon is carried out through the software application. Such optimization is carried out through CAD and CAE software like as PRO-E, PRO MECHANICA.

- Top thick plate of following dimension 450 X 450 X 5.8 mm thick (variable constraint).
- Rib thickness = 4.7 mm at bottom side of above plate in cylindrical section (variable constraint).
- The boundary condition should be fixed i.e. constraining the bottom free surface of cover which is rest inside of frame that functioning like as a simply supported beam in frame of chamber (fixed constraint).

Evaluation by the software for optimize solution (find the safest point) of chamber should be made on following basis

1. Find the failure and analyze according to Changes or modification of dimensions only in cover plate.

Altering of dimension should be made in dimension of the rib, fillet at corner of adjacent of ribs and at bottom surface of plate thickness. Without disturbing the shape and other design parameter. It is necessary because of design and manufacturing constraint Testing and analyzing by Pro-E and Pro Mechanica.



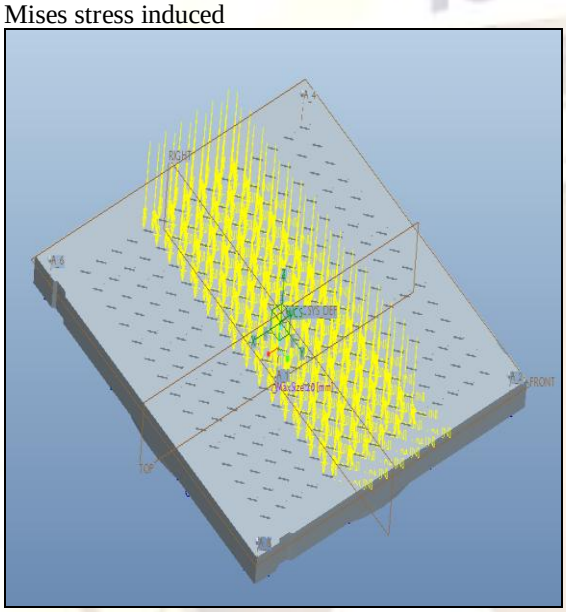
(a) (b) (c) (d)

Fig no.01 shows CAD modeled as (a) Assembly of Ultra 450mm chamber, (b) top surface of cover plate to be test,(c) ribs structure at bottom side of cover plate (d) frame for resting the cover plate.

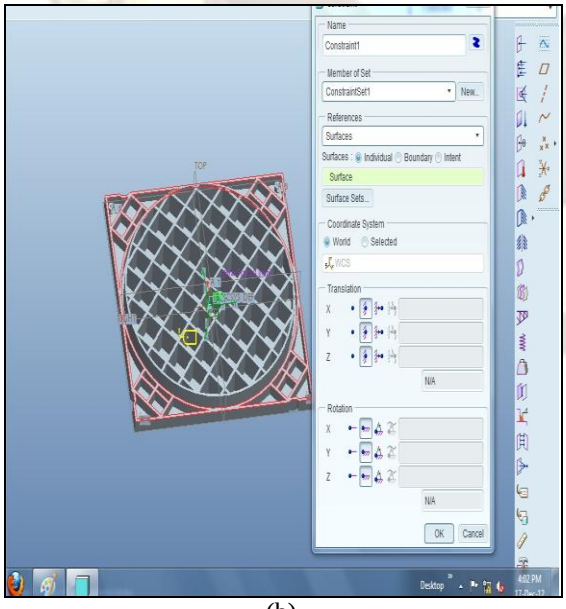
3. In first trial:-

The original dimensions as the rib thickness is 8 mm and plate thickness is 5.8 mm also ribs are modified by filleted of 2.5 mm radius to reduce stress concentration. Following steps carried out

1. Loading the component- 2.Then the model is constrained with lower end fixed. 3. The model is meshed with element size of 20mm.4.result of Von Mises stress induced



(a)



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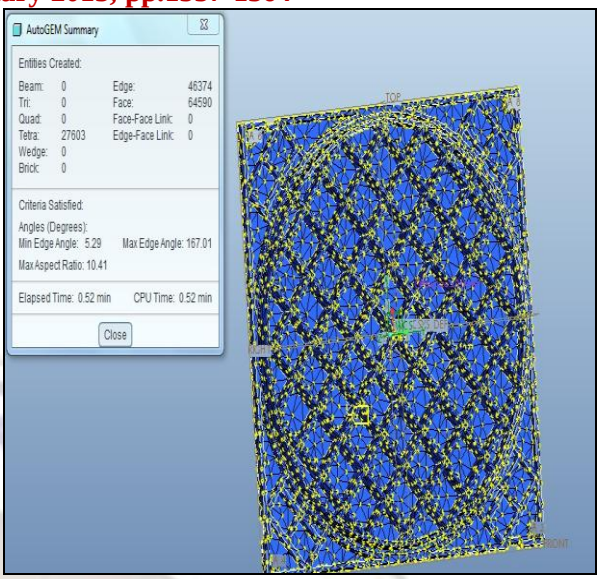
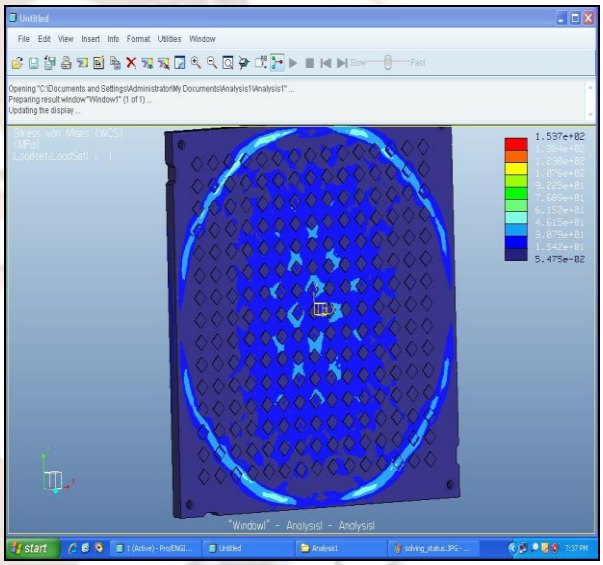


(c)



(d)

Fig.no.02 shows steps (a) Load apply on model (b) Restriction (boundary condition) in ProMechanica (c) Meshing of cover plate in Pro Mechanica (d) plot Von Mises stress

Result-

On exerting the load of 36 KN on top of surface of cover plate, the induced total Von Mises stress is 154 N/ mm^2 which are too high to cause the plate to break.

-The very first original model, the Von Mises stress value was 154 N/ mm^2 which was nearer 3 times more than that of the UTS of the material uPVC =45-50N/mm^2. Hence, on first modification it is not safe. It is a farthest from 30 N/mm^2 that to attain target an under limit of stress for safety of design. Now, find same failure by Experiments that it was failed as per above result.

4. Experimentally check the failure of uPVC cover of Chamber:-

The concept of failure is shown by following fig. no.1whenever the light or small utility vehicle (SUV) weighs about 14 to 16 ton or approx. of 1400 N to 1600 N loaded passes over the underground uPVC chamber. One wheel of front or rare pair of vehicles when passing over the surface of top cover. It is exerting the ¼th load of total load of vehicle on the top of cover which is causing to breaking of plate at central region or at corner i.e. 35 KN or 3500 N.

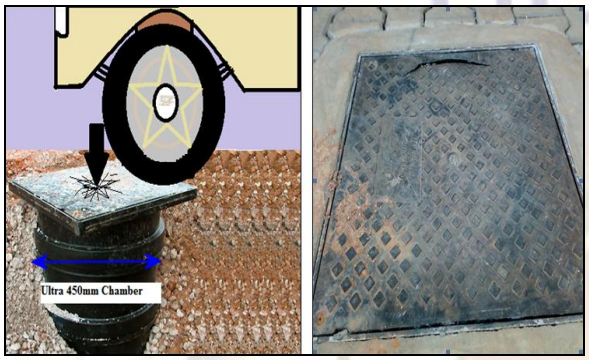


Fig no.03Broken of the uPVC cover plate under load exerting by vehicle when it passes.

The ultra 450 chamber requires focusing on details for experimenting on the UTM (universal tensile test machine) machine. These are the most important technical parameter is playing key role in existing above same chamber. Which are tabulated in following table no. 1. Ultra 450 mm chamber suffers failure at cover plate which is made up of uPVC material and fitted in frame of chamber, the plate having strength to sustain load of a wheel exert as 35 KN or 3.5 tonne.

4.1 Experiment for find the failure at different loads:-

(a) (b)

(c) (d)

Fig no.04 (a) shows concrete mould (b) set up of testing on UTM machine, (c) Reading on assignment of gradual loads and (d) braking of the chamber at extreme load application.

As from the shape of the chamber, reinforced concrete mould casted for the testing purpose which is shown in above picture no.2 (a). The chamber placed under above moulded or casted concrete and seated on the table of UTM machine. As well as the circular disc of steel plate of dia. 205 mm and 25 mm thick placed at the top surface of the cover of chamber. This plate should be located exact at central region for purpose of the even distribution of stress among whole surface of 450 X 450mm.of cover as like seen in fig. 2(B). Load is subjected on surface gradually. Readings noted on gradually increased load. After load application as 36kN the cover plate broken, this is illustrated in above fig. 2 (d). This proofed here that the existing materials' compressive strength is not suitable for more application of load than 35 KN i.e. it having sustain compressive strength below of 35 KN. Reading shown in following table No.01.

Table No.01 Reading of assigning gradual load on cover of chamber by compressive test on UTM.

Component/ concrete mould	Range of Load in N of machine settled	Actual load bearing capacity (compressive strength) in N	Compressive load given on chamber cover in N	Remark or test result
uPVC cover with chamber assembly	100 to 40000	Maximum 35000 N(company designed)	100 to 35000	Not any component braked
			35000 to 36000	Cover plate Broken on 36000N at above & below side central region (top surface & rib broken). No failure of rest other component seen

4.2 Result of Experiment -

As from table no.1 of above experiment, it is results that the material sustains 3.5 Tonne or 35 KN compressive load exerted by one wheel of SUV (small utility Vehicle). but broken just by above it i.e. at

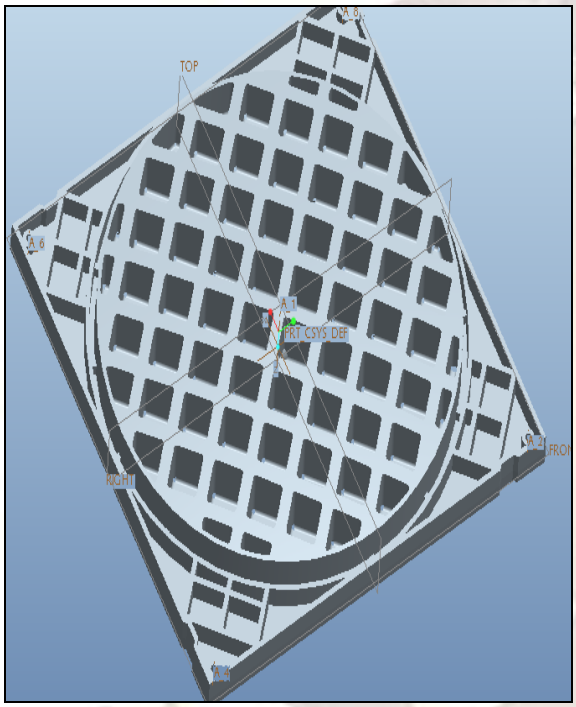
3600N or 36 KN. Thereby, required to modify the design i.e. dimensions of chamber cover OR may be require to search alternate material, if exiting material will be fail even after modifying in the design.

5. Last trial : -

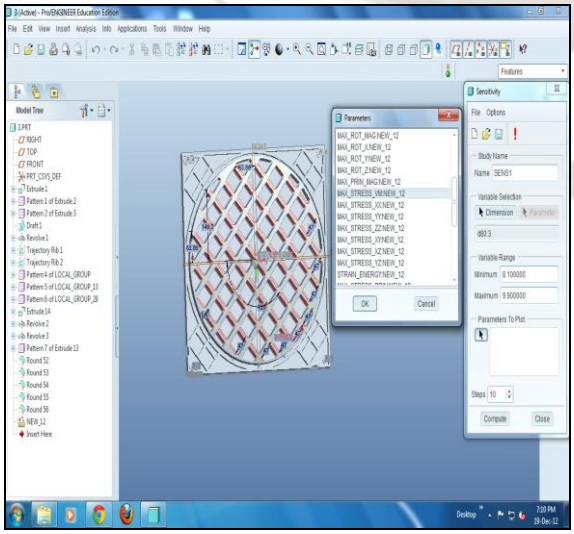
Again the rib thickness is increase upto 12mm and plate thickness is increase upto 12 mm, also ribs are filleted by 2.5 mm radius to reduce stress concentration.

-once again increased plate thickness upto 12 mm. In this case the Von Mises stress is 64 N/mm^2 which value is more higher than that of 30N/mm^2 (UTS =50N/mm^2 of uPVC material). Therefore, again this is still not safer.

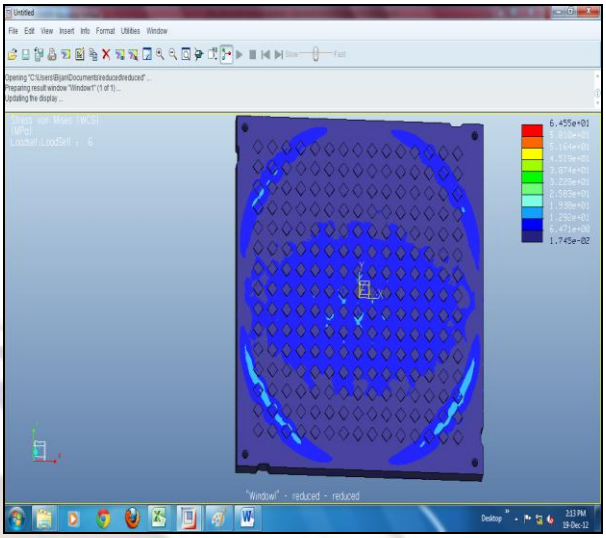
UTS of this material is 45-50 N/mm^2.



(a)



(b)



(c)

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    in global Z direction: -4.000000e+04

 Measures:

 max_beam_bending:    0.000000e+00
 max_beam_tensile:    0.000000e+00
 max_beam_torsion:    0.000000e+00
 max_beam_total:      0.000000e+00
 max_disp_mag:        2.357220e+00
 max_disp_x:         -4.680565e-01
 max_disp_y:         -5.037752e-01
 max_disp_z:         -2.357220e+00
 max_prin_mag*:      -1.133533e+02
 max_rot_mag:         0.000000e+00
 max_rot_x:           0.000000e+00
 max_rot_y:           0.000000e+00
 max_rot_z:           0.000000e+00
 max_stress_prin:     4.194033e+01
 max_stress_vm*:      6.455176e+01
 max_stress_xx*:     -7.036118e+01
 max_stress_xy*:     -2.761434e+01
 max_stress_xz*:     -3.488712e+01
 max_stress_yy*:     -6.169547e+01
 max_stress_yz*:     -2.051615e+01
 max_stress_zz*:     -8.334025e+01
 min_stress_prin*:   -1.133533e+02
 strain_energy:       3.218785e+04
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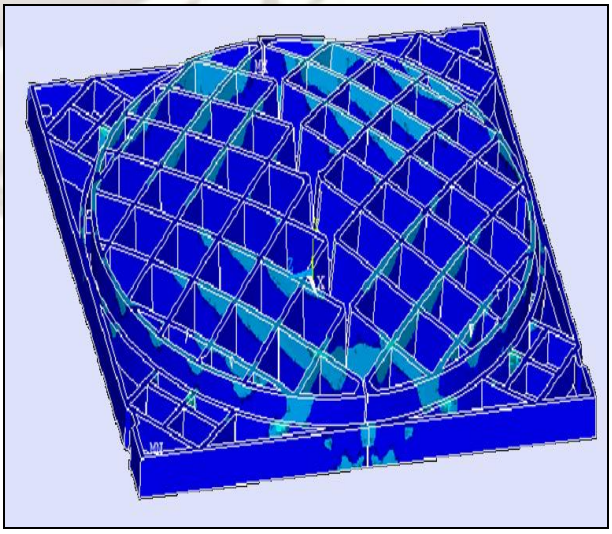
(d)



(e)

Fig. no.05 shows step are carried at last trial as (a) Modified dimensions of rib, filleting all over in rib structure and plate of cover (b) Sensitive segments or elements under stresses (c) Von Mises stress Plot on last Trial (d) Result of last trial (e) cover plate failed at last modification.

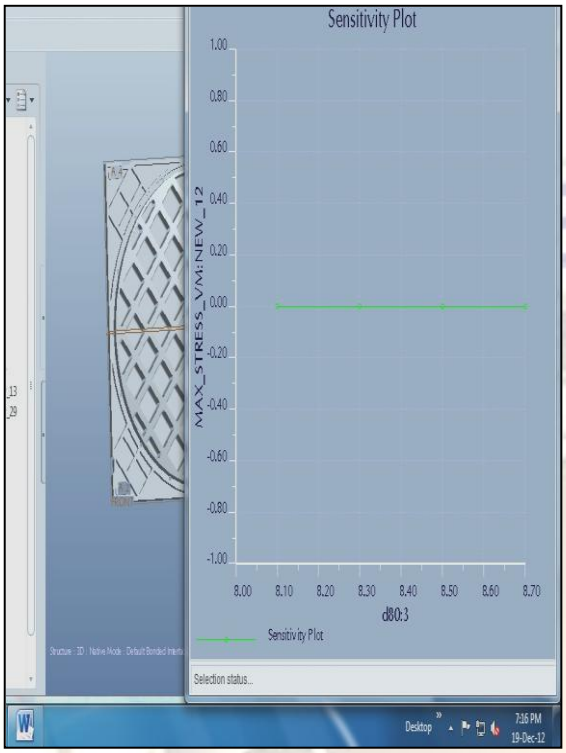


Fig no.06 Feasibility Graph

VON MISES PLOT. (Value is still greater than UTS)
RESULT = COMPONENT IS FAIL.

6. Feasibility graph:-

It is observed that the feasibility graph what we obtained has a very sharp straight which tends to zero. From this graph it is also clear that by varying the dimensions of rib & plates, the stress value cannot be lowered. Or in other words there is no feasible relation between the thickness and the Von Mises stress. The relation shown in above Fig no. 06.

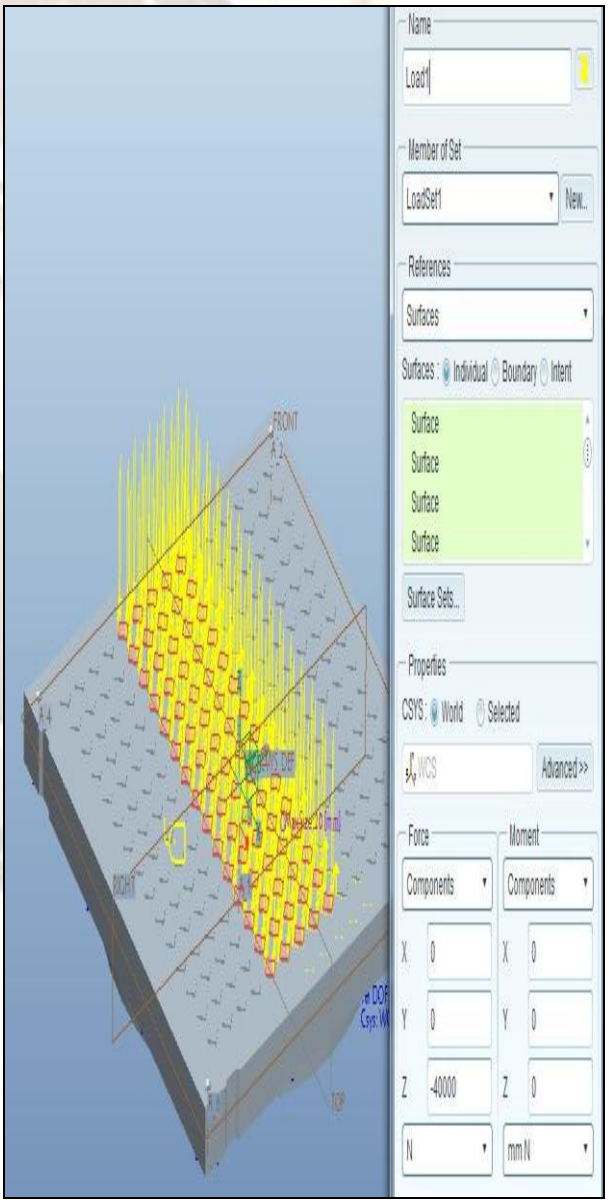
Conclusion -

After lots of trials (even after increasing the rib and plate thickness by nearer 03 times of original) the Von Mises stress value is still more than the Ultimate Tensile Stress 45-50 N/mm^2). Hence the component didn't satisfy the design criteria. So alternate material is requires for this component.

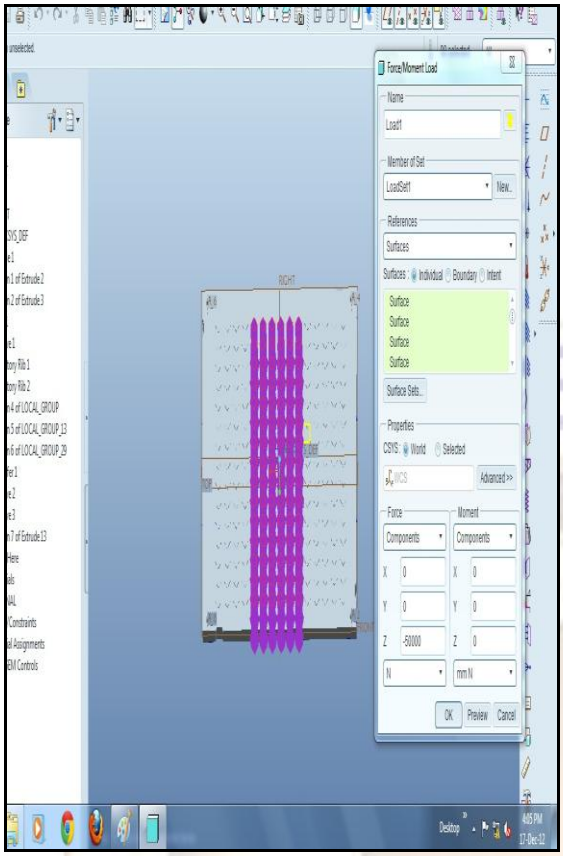
7. Find the failure and analyze according to Altering material type or changing the material:-

The above modification not satisfied the design safest point, there are only and one solution to change material i.e. composite material, which should have being to confirms following belong to plastics category, fulfilling physical, mechanical, chemical and non-electrical property for good strength, availability of raw material resources, easy to manufacturing most of component, least time to be require to shaping, easy to inspection & maintenances, aesthetically good appearance, less in weight and most important to be with less cost for manufacturing and selling. As from above all points, the composite materials are suitable for the cover plate. The one of composite material which is belonging to plastic category is FRP OR GRP. Chooses one FRP material with specific properties as poison's ratio =0.25, specific gravity =1.7 gm /cc, Compressive Strength=1000N/mm^2. Young's Modulus= 3000 N/mm^2 with this data analyzed the failure problem through the following analyzed step.

7.1 final trial for Optimization of original model on replacement of uPVC material by FRP –



(a)



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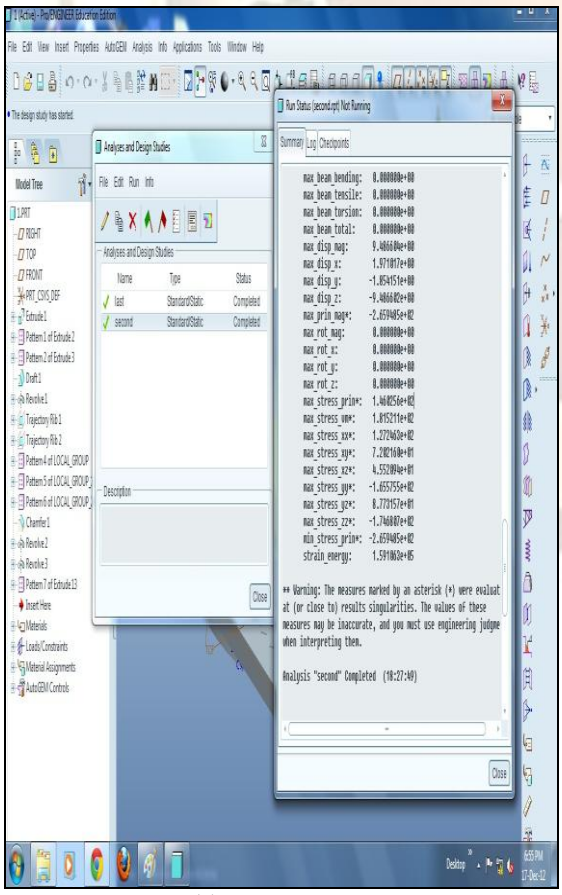

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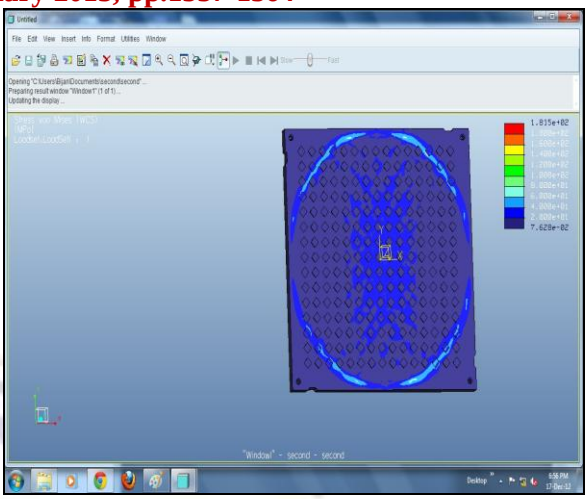
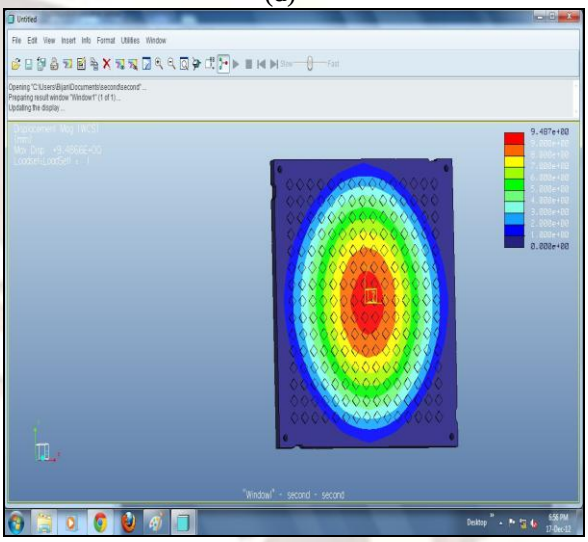


(d)



(e)

Fig. no.07 Shows (a) loading condition on FRP Material (b) force / moment loading at maximum (c) The Von Mises plot result (d) Von Mises stress under permissible range stress (e) displacement of plate surface at max load condition and seen safer.

Von Mises stress are 182 N/mm^2 which lesser than 1000 N/mm2. Hence, **component is safe**.

8. Final Result:-

Since the material bearing stress is 1000N/mm2 and the value of generated stress in the plate of cover is 182 N/mm2. This baring stress value is much greater than the material bearing capacity. Hence, the design is safe. These results indicate that our modifications regarding to FRP material to the cover plate utilize better (the stress is distributed more evenly than it was in the original designed for uPVC material).

9. Conclusion:-

From the above research, it may concluding that the existing material uPVC of cover having weak strength to withstand against the compressive force more than 35 KN. Even changes was made in rib

thickness with filleting and plate thickness, but not seen the lowered the stress value below the UTS. Thus, uPVC material having no exact any relationship with deformation against change of size i.e. not lowered Von Mises stresses on changes of size. Therefore, the uPVC material having a limited strength and is not sufficient from point of safe design. This is suitable for only light and medium loading applications.

Remedies for problem is that Replacing the existing uPVC material by composite material like as the Fiber Reinforced Plastics because it is familiar to plastic and having high strength and reinforcement to withstand against the compressive load of 35 KN to 50 KN. This material lowers the stresses induced. That's why it is compatible to various above range of load application. So it is quiet and most appropriate solution for cover of chamber in condition of fulfilling exerting heavy loads when the vehicles passing over it which is the actual requirement.

Final conclusion as, Fiber Reinforced Plastics is the Optimal solution for the failed sewerage chamber when the heavy vehicles passing over it.

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