



# Raising and Stabilization of the Concrete Slab by using Injected Polyurethane Foam

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## **ABSTRACT**

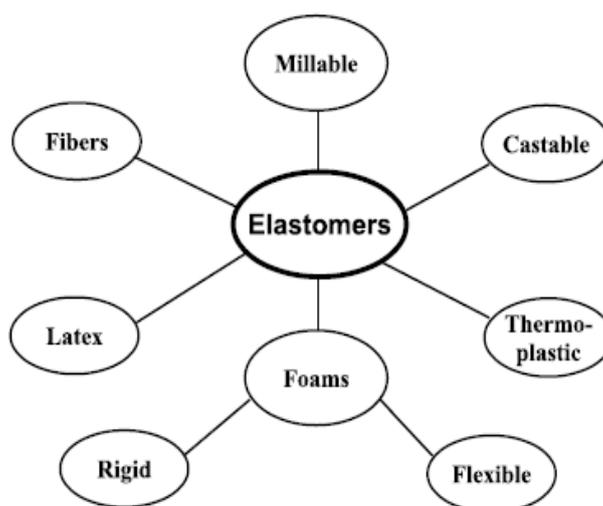
*The stability of a concrete slab is directly proportional to the quality of the base on which it is poured. Poor base conditions can be attributed to poor or improper compaction of the base, climate, erosion, machine/traffic, vibrations, slab curl/rocking slabs. Raising in-place concrete slabs to align roadway sections or to counteract subsidence may be done with traditional mud jacking or cementitious grouting. This process utilizes a hydraulically powered pump to install a slurry mix under the slab with enough pressure to compact weak soil underneath and raise the slab. Water, fly ash, top soil, sand, clay, agricultural lime, and cement are materials used to create these slurries. This method, when used on subgrade that has already settled, adds excessive weight and may lead to resettling.*

*The process of raising and stabilizing the concrete slab is carried out by drilling holes and pumping high density polyurethane foam (Polymer Foam) under the slab. This process is inexpensive compared to others options like replacement, grinding or traditional one. It is also exponentially faster than the replacement method. Repaired areas are ready within minutes to be utilized, as they were intended to be. Ease of process, material and clean up are advantages over traditional mud jacking repairs made with grout.*

**Keywords:** *Concrete Slab, Mud jacking, Polymer Foam, Polyurethane Foam*

## **I. INTRODUCTION**

It is hard to go a day without coming across some sort of polymer foam. Polymer foams are found virtually everywhere in our modern world and are used in a wide variety of applications such as disposable packaging of fast-food, the cushioning of furniture and insulation material. Polymer foams are made up of a solid and gas phase mixed together to form a foam. This generally happens by combining the two phases too fast for the system to respond in a smooth fashion. The resulting foam has a polymer matrix with either air bubbles or air tunnels incorporated in it, which is known as either closed-cell or open-cell structure. Polymer foams can be divided into either thermoplastics or thermosets, which are further divided into rigid or flexible foams (As shown in “fig. 1”). The thermoplastics can usually be broken down and recycled, while thermosets are harder to recycle because they are usually heavily crosslinked [1].

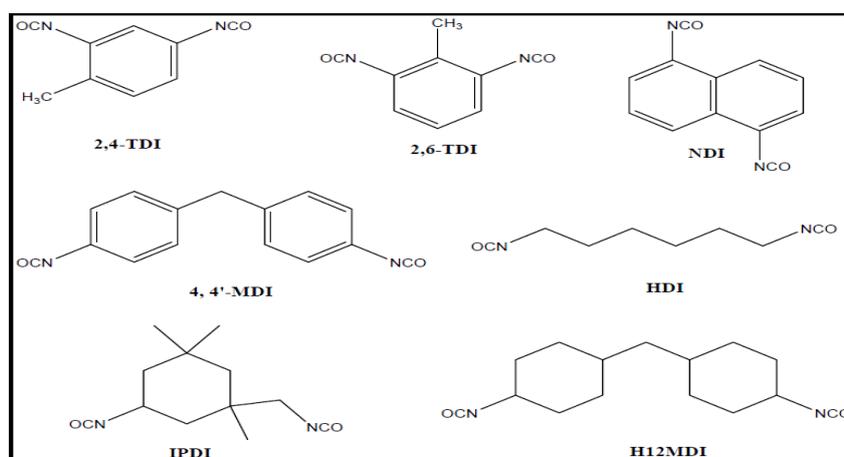


**Figure.1: Different forms of Polyurethane**

Polyurethane foams rely on an area of urethane chemistry different from that used in solid elastomers where in many cases maximum strength properties are required. Foams constitute one of the major segments of polyurethane use and tend to drive the search for different polyols. There are distinct segments of foam technology and types of foam include rigid foams, flexible foams, void filling and block stabilization. [2]

Polyurethanes are broad class of materials used widely in many applications. Polyurethanes are also written as PU. PU are formed by chemical reaction between a di/poly isocyanate and a diol or polyol, forming repeating urethane groups, generally, in presence of a chain extender, catalyst and or other additives. Often ester, ether, urea and aromatic rings are also present along with urethane linkages in PU backbone. [2]

Isocyanates are essential components required for PU synthesis. These are di or polyfunctional isocyanates containing two or more than two -NCO groups per molecule. These can be aliphatic, cycloaliphatic, polycyclic or aromatic in nature such as TDI, MDI, Xylene Diisocyanate (XDI). Structures of common isocyanates are shown in “fig. 2”. [2]



**Figure 2: Some Common Isocyanates**

Substances bearing plurality of hydroxyl groups (shown in “Fig.3”) are termed as polyols. They may also contain ester, ether, amide, acrylic, metal, metalloid and other functionalities, along with hydroxyl groups. Polyester Polyols (PEP) consists of ester and hydroxylic groups in one backbone. They are generally prepared

by the condensation reaction between glycols, i.e; ethylene glycol, 1,4-butane diol, 1,6-hexane diol and a dicarboxylic acid/anhydride(aliphatic or aromatic). The properties of PU also depend upon the degree of crosslinking as well as molecular weight of the starting PEP. While highly branched PEP result in rigid PU with good heat and chemical resistance, less branched PEP give PU with good flexibility(at low temperature) and low chemical resistance. Similarly, low molecular weight polyols produce rigid PU while high molecular weight long chain polyols yield flexible PU. Along with polyols and isocyanate, some additives may also be required during PU production, primarily to control the reaction, modify the reaction conditions and also to finish or modify the final product. These include catalysts, chain extenders, crosslinkers, fillers, moisture scavengers, colorants and others. [3,4]



Figure 3: General Structure of Polyols [4]

**2. PU Syntheses:** PU microstructure and mechanical behavior are strongly dependent on the synthesis method employed. The various methods for producing PUs method can be differentiated according to the medium of preparation(bulk, solution, water) and addition sequence of reactants(one-step or prepolymer synthesis routes). The main difference between the materials prepared by the prepolymer and one-step methods involve the chain build-up. The PUs obtained by the prepolymer method are statistically more regular in the chain sequence whereas PU obtained by using one step method have more random sequence.[3,4]

**2.1 Pre Polymer Method:** Prepolymers are normally produced with a mole ratio of approximately two moles diisocyanate to one mole of polyol (as shown in “fig. 4”).This is the representation of a straight forward commercial prepolymer. One isocyanate groups (-NCO) reacts with hydroxyl group (-OH) of the polyol. Another isocyanate group reacts with the second OH group. The ratios are often varied to give enhanced different properties. The composition of the polyols is also varied for similar reasons. A very important features of this reaction is that there are no by-product formed. The resultant product has isocyanate groups on both ends with urethane bonds between the original polyurethane and the diisocyanate group.[3]

**Reaction:**

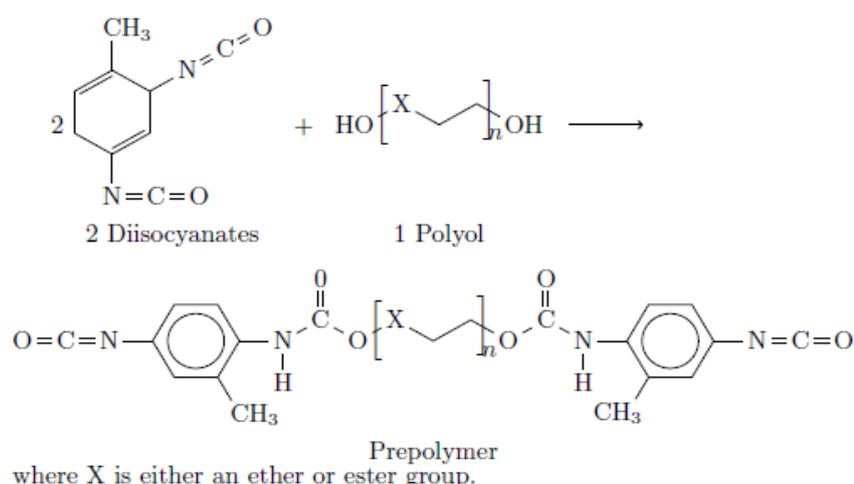


Figure. 4: Reaction between Diisocyanate and Polyol to form Prepolymer

### 3. Process Steps for Raising and Stabilization of Concrete Slab by Polyurethane Foam:

**3.1 Profiling:** An initial profile of the roadway is made to determine where the slab needs to be raised (As shown in “Fig. 5”).



**Figure 5: Uneven Leveling of Concrete Slab**

**3.2 Drilling:** Injection whole of definite diameters are drilled through the slab and in to the soil below.

**3.3 Injection:** Two components are injected simultaneously through drilled holes. The chemicals start reacting immediately to form rigid polyurethane foam in situ with carbon dioxide given off as a by-product. The volume of the foam is several times the volume of the reactant, the reaction produces an expansive force that lifts the slab.



**Figure 6: Raising of Concrete slab by Injection of Polyurethane Foam**

**3.4 Clean Up:** After each whole is injected, any excess foam is removed from the whole. The whole may be sealed with cementitious grout. Quite often the whole was not sealed because it is believed that polyurethane foam by itself creates an effective seal.[5]

#### IV. LABORATORY EXPERIMENT:

Foam was prepared using a standard hand mix procedure or cup foaming (as per shown in a “Fig. 7”).



**Figure. 7: Generation of Polyurethane Foam by Hand Mixing**

This method is also used to evaluate the foaming systems to compare raw materials and resulting foam properties. Equipment used were plastics measuring cups, and weighing balance. Foaming system was kept at constant temperature. Quantity of materials was taken in measuring cups in different proportions. Water was added as a catalyst but sufficient strength was not obtained. Apart from this no other additives were added. Only two reactants were used. Polyisocyanate was poured into the cup containing polyol and was mixed with stirring with spatula for definite time.

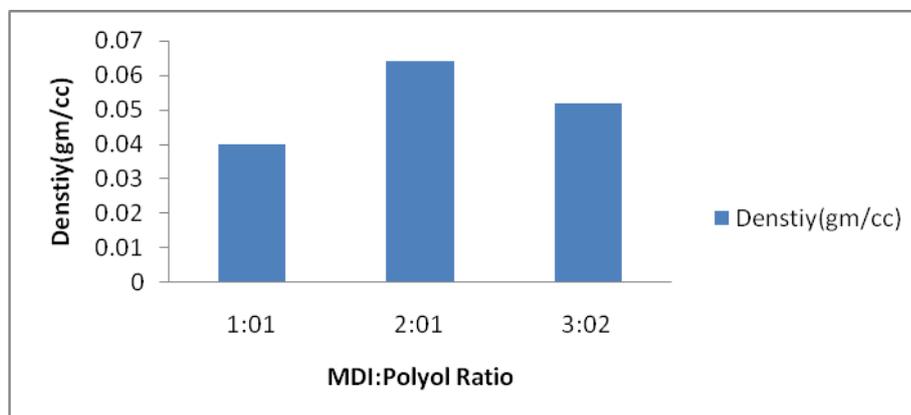
Because of chemical reaction, there was initiation of foaming. Foaming mixture was allowed to expand and rise in the same cup. Foam blocks were cured at room temperature overnight. Foam samples were cut for testing different properties. Different batches were prepared by changing the proportion of raw materials. “Table:1” shows the formulation used in different batches.

**V. RESULT AND DISCUSSION:**

**Table:01**

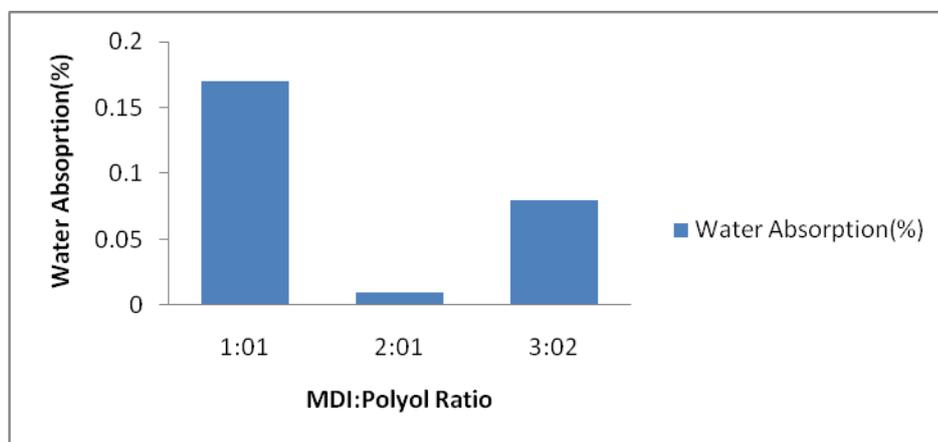
Ratio(MDI:Polyol)	Density(gm/cc)	Water Absorption(%)	Compressive Strength(Kg/Cm <sup>2</sup> )
1:1	0.04	0.17	2.158
2:1	0.0641	0.01	4.45
3:2	0.052	0.08	3.16

Density of polyurethane foam was measured by following ASTM D 1622. Comparison of different values of densities for the different samples of rigid foam is shown in the “fig. 8”. Among these 2:01 proportion shows the higher value compared to remaining two.



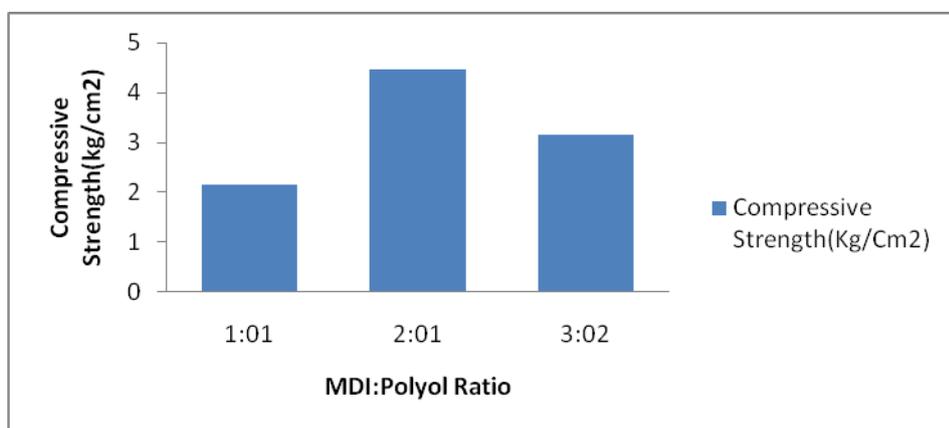
**Figure.8: Effect of MDI: Polyol Ratio on Density**

The ability of the polyurethane material to behave as a water barrier is important in preventing soil instability caused by water infiltration. One effort of this study was to measure the water absorption (%) by following ASTM D 2842. The results of the different composition are shown in “fig. 9”.The ratio 2:01 offers low water absorption among all.



**Figure.9: Effect of MDI: Polyol Ratio on Water Absorption**

One of the advantages of polyurethane is that it has excellent degradation resistance in many environments. In this work, compressive strength measurements were used to monitor the extent of degradation. Compressive Strength of samples were measure by following ASTM D 1621. The results of compressive stress are shown in “fig. 10”. Strength of all three compositions is comparatively good but 2:01 proportion is higher than remaining two.



**Figure.10: Effect of MDI: Polyol Ratio on Compressive Strength**

## VI. CONCLUSION

Among three compositions, the 2:01(MDI: Polyol) shows higher density, lower water absorption and higher compressive strength. Compressive Strength of polyurethane product does not appear to decrease after definite time of exposure to air and underground conditions. There are groups of chemicals like fillers, plasticizers, moisture scavenger, ultraviolet absorber, catalyst, nanoparticles used in definite proportion in polyurethane that have an influence on the physical properties of the final product but do not take part in chemical reaction which



makes polyurethane foam more rigid with increment in physical properties and make it usable for raising and stabilization of concrete slab.

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