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Analysis of Pressure and Velocity Variation in T-shaped Channel at Micron Level

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***Abstract*- Micro-electromechanical systems (MEMS) are microscopic devices based technology mainly involving the moving parts. Bio-MEM is a particular affiliate of MEMS technology in general. This paper studies and analyzes variations of pressure and velocity inside the T-shaped channel at micron level. We have considered straight micro-channel for multi-field analysis among different types of micro-channels, i.e., sinusoidal, curved, straight, spiral and snake fang. The surface (inlet, outlet and walls) is defined for channel while water at 25C is to be assumed as working fluid. Moreover, parameters including diameter and length of channel are defined as well as meshing has been performed in 3-D formation. The fluid dynamics including pressure and velocity variation inside the channel are visualized using ANSYS CFX-solver.**

***Index Terms*-- ANSYS, Fluid Flow, MEMS, Micro-channel.**

I. INTRODUCTION

Micro-fluidic devices using MEMS technology have become much popular in the last decades in the field of biomedicine. Motion of fluid flow is primarily considered in micro-fluidic systems [1]. Manipulation mechanisms including mixers, filters and valves are mainly based on micro-fluidics and their implementation is the main goal for scientists and researchers [2]. Micro-fluidic devices generally involve; (i) micro-needle (ii) micro-pump (iii) micro-mixer and (iv) micro-channel. Some applications of the MEMS include; inkjet printers, accelerometers, displays devices, drug delivery, blood extraction, microsurgical tools, optical switching, fluid acceleration, mechanical, gas and chemical sensors, fuel cells, inter-ferometric modulator display, biomedical transducers, micro-scale based energy harvesting via piezoelectric and MEMS based gyroscope inside modern vehicles [3, 4]. According to the Technavio report, market segmentation of Bio-MEMS and the micro-systems applicability now exceeds US$ 7 billion with a projected growth rate of more than 25% by 2019 [5].

From aforementioned micro-fluidic devices, contribution of this study is mainly focused on the micro-channels and fluid flow analysis inside them. The novelty of the work involves transforming the straight micro-channel into new T-shaped channel geometry for multi-field analysis under certain conditions. From different types of fluids (methanol, silicon oil, gases, water), this study assumes water as a working fluid to visualize the flow pattern inside the T-shaped channel. The effect of parameters like pressure and velocity variation on fluid flow inside this newly designed geometry (T-shaped) of micro-channel has been studied.

II. ANALYTICAL FRAMEWORK

Micro-needle is a tiny glass needle employed in transdermal drug delivery system (TDDS) which is considered an emerging way of drug delivery since it has overcome the obstruction of outermost layer of the epidermis. Compact size and small length are the two factors which makes the micro-needle effective as compared to other hypodermic needles. The fabrication process of micro-needle involves poly silicon, metals, glass and polymers as fabricant materials while employed technology is the MEMS. With length of less than 1mm, micro-needle can be incorporated with multiple tiny devices like micro-pumps, micro-fluidic chips and biosensors in order to use it for versatile purposes.

Some applications of micro-needles involve; drug delivery, blood extraction, cancer therapy and dentistry. It is also considered a primary component in drug delivery systems. Actuation mechanism is provided by micro-pump to acquire the necessary volumes of therapeutic drugs. Micro-pump is comprised of; (i) chamber (ii) diaphragm (iii) actuator (iv) membrane and (v) micro-channel. Micro-pump is categorized in mechanical and non-mechanical parts, as shown in Figure 1.

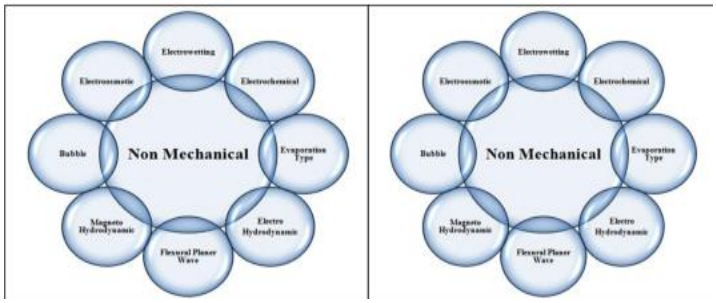

FIGURE 1. Types of micro-pump.

Micro-mixer is used in mixing the liquids featured to have the movement of micro parts. Two types of micro-mixer are (i) active and (ii) passive [6, 7]. The analysis of liquids flow and their characteristics is done through micro-fluidic devices extensively using micro-channels. Various types of micro-channel involve; straight, spiral, snake fang, curved and sinusoidal. The combination of multiple geometries with different radius is utilized in designing of micro-channels. By interfacing the configuration of curved micro-channel, double layer laminar liquid flow can be studied. The mathematical calculation of liquid flow as well as heat transfer could be done via periodic wavy channels.

Numerical analysis of liquid flow characteristics is carried out via Navier- Stokes (N-S) equation. The numerous formations of micro-channel including curved, sinusoidal, straight micro-channel, etc. are shown in Figure 2.

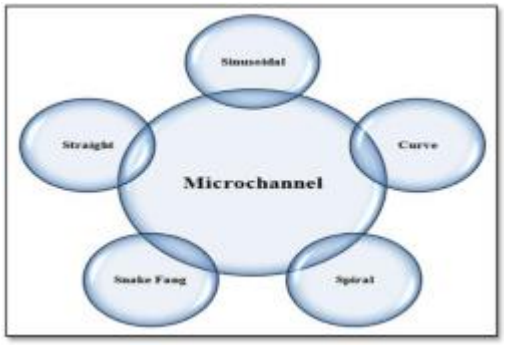

FIGURE 2. Types of micro-channel

In designing process, curve channels are fabricated on silicon substrate. The vital role during fabrication phase of channel is the physical characteristics of substrate [8-10, 11]. Dissipation effect (viscous) in laminar flow inside a curved channel is investigated when tow organic compounds (ethylene glycol, aniline) as working fluid using classical N-S equation [12].

Heat and flow transfer through sinusoidal passage has also been visualized. The selected flow was laminar in nature and the passage was wavy one. The aspect ratio of bounded wavy wall was 10:1 including length of 12-14m. Steady as well as unsteady behavior of fluid flow is considered. The phenomenon of mixing two or more fluids in homogenous form is based on two factors; (i) Reynolds number (ii) channel's geometry [12]. Two channels with dissimilar geometrical formation (i) arc shaped (ii) sinusoidal channels are employed to study the liquids flow features as well as heat transfer inside wavy shaped channel. Two forms of fluid flow which was 2-D steady and time dependent were considered. Value of Prandtl number (depends only on fluid and state of fluid) is 0.7. The channels having arc shaped geometry have the high friction parameter than sinusoidal [10].

The sinusoidal plate micro-channels which were symmetric in nature and organized in converging and diverging formation are discussed. The prescribed technique facilitates in controlling liquid flow traces during its motion in sinusoid channels. The liquid flow inside the channels is greatly affected by converging and diverging arrangement. Laser is used as visualization tool for fluid. 3-D heat transfer and laminar flow at low Reynolds number enhanced through sinusoidal channel has been investigated using CFD [5, 6]. The numerical study of convection (mode of heat transfer) and fluid dynamics in sinusoid shaped micro-channel is carried out to consider the effect of nano (small) particles inside the channels. Two parameters such as; (i) liquid flow at input inlet and (ii) walls, temperature of both taken into account. Nano scale liquid flow is observed for output analysis which includes copper-water [7].

Polymer electrolyte membrane (PEM) model of fuel cell was investigated in 3-D formation along with straight flow channel. Computational area of prescribed model comprised of anode as well as cathode liquid flow channel.

Different sorts of current density are applied showing shared characteristics of local current density. Distribution model is considered as comparatively deviating in nature at higher value of the current density and having an identical behavior at lower value of current density because of mass transfer restriction [8].

Dynamical behavior of liquid (water) transfer is analyzed in straight channel for PEM fuel cell cathode having manifolds. Gas channel definitely obstruct air/water in outflow manifold. Outflow manifold enhance the performance of fuel cell by enclosing large amount of water in a unit cell. Resistance (Ω) in membrane is mainly affected by water content [9].

Adaptive neuro fuzzy methodology is employed for the estimation of side weir discharging capacity that was triangular labyrinth in nature when kept on a straight micro-channel. Discharging coefficient is calculated using adaptive neuro fuzzy interference system (ANFIS) for triangular labyrinth side weirs. Numerous linear and nonlinear deterioration prototypes are the main parameters for comparison study between two; one is the radial basis neural networks (RBNN) and other one is feed forward neural networks (FFNN), when two different neural techniques are employed on straight micro-channel [2, 8-10]. Discharging coefficient of fluid flow is calculated for open channel which was straight in nature [12].

Electro-osmotic fluid flow inside a split channel which has been comprised of two parallel walls having zeta potential is studied. The working fluid is transient in nature. Partial differential equation is calculated by combining the momentum equation with Maxwell model to determine the velocity profile of fluid through the micro-channel. The resultant velocity profile shows symmetric, asymmetric formation and oscillatory behavior during the transient stage of fluid flow [12]. The diagnosis of disease for individuals and therapy using MEMS based technology is an innovative track for future medication. Implantable, programmable and refillable MEMS based chemotherapy drug transfer method is used for treatment of pancreatic cancer [2-6]. Flow phenomenon in parallel channel severely affecting the process of hot spot formation as well as distribution of temperature in micro devices.

The key purpose behind this work is to explore the factors (Reynolds number, hydraulic diameter, cross section area, number of channels) affecting prescribed phenomenon causing pressure decrease through the manifolds of parallel channel is employed for cooling of CPU [2-5]. Therapeutic magnetic micro-beads are used as navigable agents considered as progressive method of target drug delivery controlled by

magnetic gradients. The controllability and observability analysis is made for multiple micro-beads as well as linear control technique termed as linear quadratic employing integral function (LQI) that is applicable on magnetic micro-beads system. The process of precise transport of drug is perfectly done through micro-needle and micro-pump. Piezoelectric micro-pump having poly dimethysiloxane (PDMS) film and SU-8 hollow cavity micro-needle is used for finite element analysis. The fluid pattern observed in pump chamber is laminar in nature [2-7].

In this paper, a straight micro-channel is considered having the T-shaped geometry, through which micro-fluidic analysis has been examined to measure pressure and velocity variations inside the channel.

III. STRUCTURE DESIGNING OF T-SHAPED MICRO-CHANNEL

The straight channel having T-junction is discussed in this paper. Micro-channel in 3-D formation is designed using ANSYS. In designed geometry of the micro-channel, straight channel has length of 500µm, T-shape is 200 µm long and diameter of channel is 50 µm. Geometry of proposed channel is shown in Figure 3.

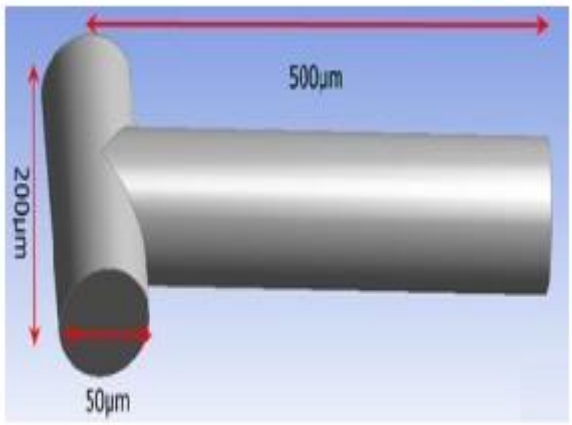

FIGURE 3. Designed T-shaped channel

IV. PRINCIPLE OF LIQUID FLOW

Channel is a closed shape medium through which any form of liquid can flow. It may comprises of formations including; large, small, artificial and natural containing of arteries and veins. It has been considered as base medium for transportation of liquids and gasses. The main constitutes of any channel are inlets and outlets. Two types of liquid flow is primarily considered through channels; (i) Turbulent flow (ii) Laminar flow. To know about the specific form of fluid flow, viscosity and inertial flow are the important parameters.

Motion of fluid (liquid) containing certain types of pressure and velocities varied on random basis is called turbulent flow. Turbulent flow is most commonly observed in non-viscous liquids having large velocities variations. The major categorizing parameters of turbulent flow are; diffusion, dissipation, irregularity and rationality. Turbulence is an unsteady parameter mainly caused by shear. When the shearing is large, turbulence become cohesive. Turbulent phenomenon of liquid flow take places having the Reynolds number value above 4000. Flow pattern for liquids will be changed from the laminar form into turbulence, when the value of Reynolds parameter is lying among 2000-4000 [2-8].

Steady, continuous and smooth motion of viscous fluid (liquid or gas) is termed as laminar flow. Pressure, velocity and other flow characteristics are remained constant in laminar flow, therefore also termed as streaming flow. The two main categorizing factors of laminar flow in fluid dynamics are; (i) lower values for momentum convection (ii) higher values for diffusing momentum. This type of fluid flow exists only, when having the value of Reynolds number lower than 2300 and at relatively higher velocities. Laminar is totally an opposite phenomenon to turbulent flow while considering the fluid dynamics [9]. The steady and smooth fluid behavior of laminar flow is shown in Figure 5. Reynolds number plays a vital role in turbulent and in laminar fluid flow. Inertia and viscous are the two main forces in fluid dynamics to distinguish the type of fluid flow whether it is laminar or turbulent in nature. Laminar type of liquid flow occurs only, when having inertial forces magnitude lower than viscous forces magnitude and turbulent type of flow exists only having greater value of inertial forces.

The numerical calculation of Reynolds number can only be done by division of kinematic viscosity during the stage of inertial forces for liquid flow.

V. SIMULATION ANALYSIS

In this paper, straight micro-channel having T-junction is to be taken for visualizing the multi-field analysis. The value of static pressure taken is the 100 KPa in magnitude is applied at input side (inlet) of straight channel. Value of pressure at output side (outlet) of channel is 0 Pa. While, water is used as working fluid at 25C. In the early stage of simulation, 3-D geometry of the T-shaped channel through ANSYS CFX-solver is designed as shown in Figure 4.

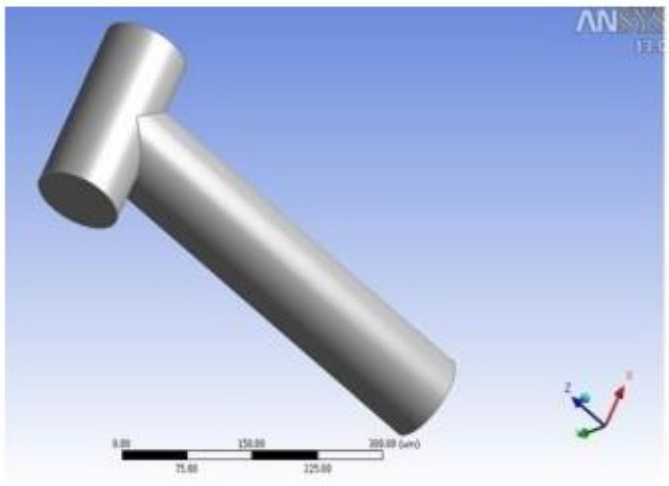

FIGURE 4. 3-D geometry of channel.

The main parts of 3-D formation of designed channel has been defined and termed as; (i) inlet (ii) outlet (iii) walls. After that meshing has to be performed for finite element analysis on the designed system model of micro-channel to acquire the appropriate and effective multi-field solution. In the next stage, meshed model is imported into CFX-Pre window. After that boundary, domain and initial conditions are defined.

To visualize the fluidic behavior inside the micro-channel, water which is a working fluid is entering the channel with an initial pressure of 100 KPa. After applying an initial high pressure with which fluid enter the micro-channel through inlet, the value of pressure then reduced to a value of 0 KPa. As a result, fluid will come out through the outlets of the channel. The roughness of inside walls of T-shaped micro-channel is assumed to be smooth for steady movement of fluid through channel.

VI. RESULTS AND DISCUSSION

Pressure and velocity are the main parameters which are affecting the fluid flow inside the T-shaped channel as well as their effect is analyzed at micron level.

A. Pressure changes inside the T-shaped channel

Initially, fluid (water) enters the T-shaped channel with an inlet pressure of 100 KPa. Since, water is viscous liquid with density of 1000 kg/m inside the straight channel, having viscosity of 0.00133 Pa. with a Reynolds number of R = 4511. As for the case of liquids, having Reynolds number greater than 4000 will exhibit turbulent flow inside the micro-channel. Turbulence is an unsteady flow pattern of liquid, therefore, after certain interval of time, collision of fluid with walls of channel resulting the periodic change of pressure values. The designed geometry (T-shaped) has smooth walls showing that roughness of the walls is ignored or assumed to be zero. We are considering an ideal case for working conditions of fluid; therefore, according to the prescribed conditions of working fluid, pressure value should also be the 100 KPa experimentally as well. It can be observed from the Figure 16 that how the above mentioned conditions are affecting fluid motion through T-shaped micro-channel and the graphical plotting of pressure variation along the channel length (chart count). When pressure value is reduced to zero at the inlet, working fluid will come out through the outlets of channel.

While outlet pressure is 0 KPa. Fig. 5 shows that maximum attained value of pressure is almost 100 KPa through the micro-channel, while motion of fluid flow inside the T-shaped channel. This maximum value of pressure is equivalent to the applied inlet pressure. The novelty of the work presented in this paper is that for an ideal case of fluid flow inside the T-shaped geometry of designed micro-channel, the applied inlet pressure of 100 KPa can be visualized during fluid flow through the micro-channel and it can be observed from Fig. 5 showing the pressure changes inside the T-shaped channel.

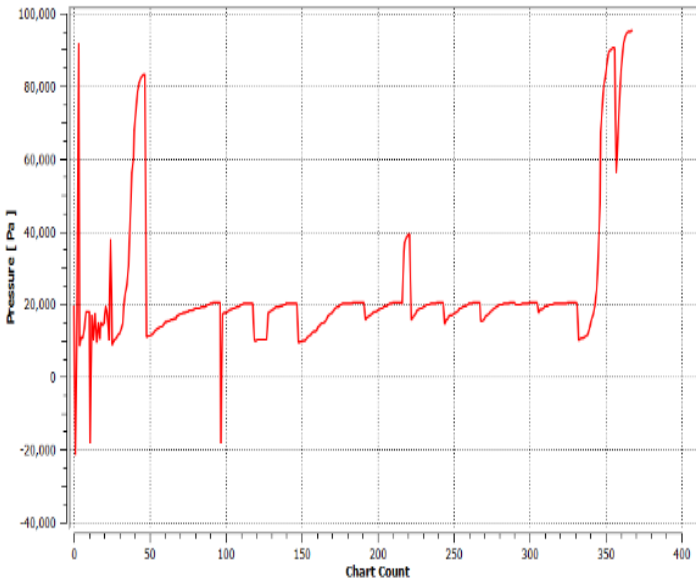

FIGURE 5. Pressure changes inside the channel.

B. Velocity changes inside the T-shaped channel

When fluid flow through the T-shaped micro-channel, there must be the changes in velocity value through the channel's length also termed as chart count which is presented in Figure 17. It can be seen that maximum value of velocity achieved while motion of fluid inside the channel is 13 m/s. From Fig. 6, it can be confirmed that for the inlet pressure of 100 KPa, maximum change in velocity value can be observed which is 13 m/s.

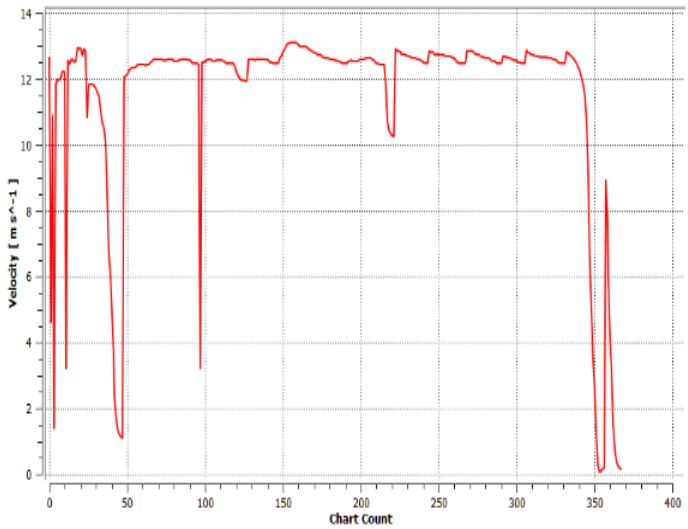

FIGURE 6. Velocity variation through channel

C. Simultenous analysis of pressure and velocity variation inside the T-shaped channel

To visualize pressure and velocity change inside the T-shaped micro-channel for provided input and output condition, a combine plot between pressure and velocity is shown in Fig. 7.

It can be observed from the resultant graph that pressure decreases with respect to velocity initially.

Since, fluid flow (water) is turbulent in nature, therefore, after colliding with the walls of T-junction of micro-channel, value of the pressure is significantly decreased again in comparison with velocity value which is increasing continuously, but now changes in pressure value is in opposite direction because of T-junction of micro-channel which is a unique feature of fluid flow inside this designed T-shaped channel as shown in Fig. 7.

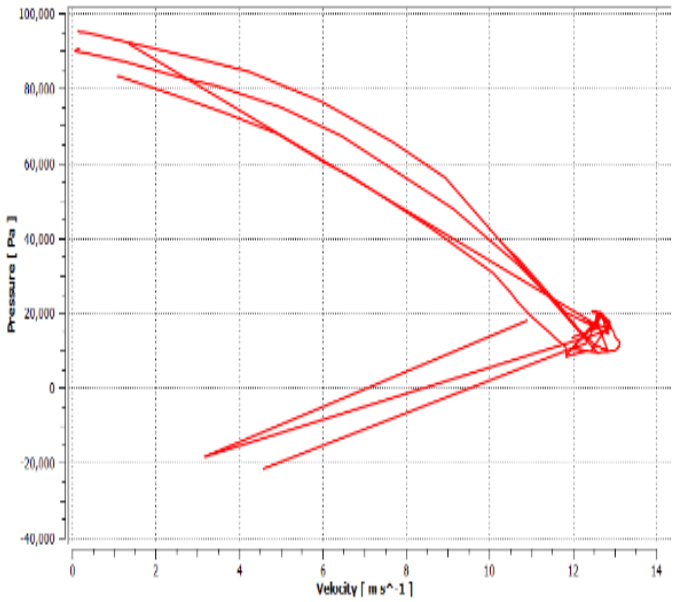

FIGURE 7. Pressure against velocity

VII. CONCLUSION

Micro-fluidic analysis of fluid flow (water) inside T-shaped micro-channel is visualized experimentally using the ANSYS CFX-solver. For the first time, straight channel having T-junction like geometry has been considered for multi-field investigation at such a micron level. The main purpose of the work is to design a unique geometry of micro-channel (straight channel having T-junction) and from numerous fluids (methanol, silicon oil, gases, water), water is considered as working fluid through designed channel. The effect of two basic parameters, pressure and velocity variation is analyzed during motion of working fluid via channel. In order to consider the effect of these varying factors (pressure and velocity), some conditions have been applied while geometry design, on inlet and outlets of the micro-channel. Static pressure having the magnitude 100 KPa is applied at inlet end and outlet pressure has the value of 0 KPa. While, water is taken as working C in an isothermal domain. Geometry of the designed micro-channel comprises of 500 µm fluid at 25 degree length of straight channel, having diameter of 50 µm and T-junction having length's value of 200µm. Surface parameters involving inlet, outlet and walls of 3-D model are defined initially.

After that brick meshing is performed via Solid_186 Element on 3-D model of micro-channel. Domain and boundary conditions are also defined for designed model. The results are obtained after running the ANSYS CFX-solver. The pressure and velocity variation is visualized by contour, vector and streamline flow. It can be observed that maximum velocity of 13 m/s is attained via micro-channel at an applied inlet pressure of 100 KPa. The novelty of work is shown in output results displaying significant decrease in pressure value in accordance with velocity, after collision with T-junction, pressure value is decreased again but in opposite direction because of T-junction of designed micro-channel.

References

[1] W. Wang; S.A. Soper. Bio-MEMS; Technologies and applications. CRC Press: ISBN: 978-0-8493-3532-7.

[2] G. S. Fiorini; D. T. Chiu. Fabrication and application of disposable microfluidic devices. Bio-techniques, 2005,38,429–446.

[3] C. Acar; A. M. Shkel. MEMS Vibratory Gyroscopes; Structural Approaches to Improve Robustness 2008,ISBN: 0-387-09535-7.

[4] A. Hajati; S. G. Kim. Ultra-wide bandwidth piezoelectric energy harvesting. Applied Physics Letters, 2011,doi: 10.1063/1.3629551.

[5] Technavio. Global Bio-MEMS and microsystems market in healthcare. September, 2015.

[6] N. T. Nguyen; S. T. Wereley. Fundamentals and Applications of Microfluidics. Artech House, ISBN: 978-1-58053-972-2.

[7] S. Hardt; F. Schönfeld. Microfluidic Technologies for Miniaturized Analysis Systems. ISBN: 978-0-387-28597-9.

[8] Y. Yamaguchi; F. Takagi, T. Watari; H. Maeda; Interface configuration of laminar (two layered flow) in curved microchannels. Chemical Engineering Journal, 101, 2004, 367-372.

[9] W. H. Yang; J. Z. Zhang; H. Cheng. Study of characteristics of flow in curve microchannels. Applied Thermal Eng., 25, 2005, 1894-1907.

[10] S. A. Khuri; Study of stokes flow in curve microchannels. Journal of Computational and Applied Mathematics, 187, 2006, 171-191.

[11] R. Mishra; T. K. Bhattacharyya; T. K. Maiti. Design and simulation of microfluidic components towards development of a controlled drug delivery platform. 29th International Conference on VLSI Design and 15th International Conference on Embedded Systems,2016.

[12] L. Mellal; D. Folio; K. Belharet; A. Ferreira. Optimal control of multiple magnetic microbeads navigating in microfluidic channels. IEEE International Conference on Robotics and Automation,2016.

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Ground Truth Annotation, Analysis and Release of Data set of Radiographic Images of Bone Fractures

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Abstract- **Bone is the tough, locomotive tissue of the body which is subjected to fractures very often. Advancements in Computer Aided Diagnosis (CAD) have leaded the researchers to develop robust algorithms to reduce human error in assessing different types of pathologies. This paper focuses on the data set release of the plain radiographic images of bone fractures which include both "Ground Truth Annotated" and "Non-Annotated Images". The data was collected from the Radiology Department of Pakistan Institute of Medical Sciences, Islamabad, Pakistan in the form of digital images which were 8,345 in number, out of them 735 images were of bone fracture. The bone fractures were annotated manually to provide "truth" for the spatial location of bone fracture. The type of bone affected, area affected of the bone fractured, type of fracture, potential laterality of the affected bone and x-ray projection had also been identified and reported in the form of a data sheet. These features are expected to help training classifiers for CAD analysis of bone fractures. Frequency analysis of essential features had been performed to accentuate the data. The data set will provide grounds for the research community to manipulate for various CAD operations which may include estimation of precision of the developed CAD operators.**

***Index Terms*-- Bone, Fracture, Ground truth, Annotation, CAD.**

I. INTRODUCTION

The human bone is tough, resilient and high stress and strain bearing anatomical structure, which provides site for articulation for various other bones to form movable and immovable joints. Bones also serves as the site for attachment of skeletal muscles. The normal adult human skeleton contains 206 bones [1-2]. The typical long bone is grossly divided into three regions; the epiphysis, which is the broad joint forming part of the bone (proximal and distal), the metaphysis, which is the narrow growth plate containing part of the bone and the diaphysis or the shaft of the bone. Short bones usually do not contain these parts specifically [3].

Bone is a dense connective tissue which is derived embryologically from mesoderm [4]. It is made up of an outer tough and hard cortical and inner soft and spongy medullary portion. It is composed of an outer periosteum and inner highly vascularized endosteum. The periosteum is further composed of fibrous and cellular layers. The endosteum lines the medullary cavity of the bone. The medullary cavity is composed of bone marrow and matrix made up of mainly hydroxyapatite, calcium carbonate and collagen fibers. It is the bone marrow where the synthesis and maturation of red and white blood cells take place [3].

At the articulation site (epiphysis), the typical bone is line with articular cartilage to provide friction free movement at the joint. The bones are held together in place by ligaments. The muscles are attached to the bone by tendons. Together this assembly provides mobility at the joint [5].

The bone serves as the locomotor, blood cell synthesizing house and protector for visceral organs by forming skeleton [3]. The medical condition which leads to loss of continuity in the bone is termed as a fracture. Certain bone fractures are treated as a medical emergency. Fracture can be traumatic, pathological and peri-prosthetic. Fracture results in disruption of periosteum or both periosteum and endosteum, the peri-fracture tissue edema, skin erythema and intense pain [6].

The major types of fractures are: *Closed Fracture:* The closed fracture is the type of fracture that does not lead to the fracture ends breaching the skin barrier. The fracture ends remain inside the body. *Open Fracture:* The open fracture is the type of fracture which causes one of the fracture ends to breach the skin barrier and become in contact with the body's external environment [6].

A bone fracture can also be classified on the basis of; mechanism of fracture, surrounding soft tissue involvement, extent of displacement of fracture ends, presence and amount of fragments, anatomical location and bone affected. There are several bone fracture classification mechanisms which include alphanumeric AO/OTA classification system for long bone fractures, Denis classification system for spinal injuries, Gustilo's classification system for open fractures [7], Allman's classification system for clavicular fractures [8] and classification of scapular [9].

The bone fractures can be detected clinically. The pathological fractures can be provisionally diagnosed by evaluating the patient's history, which may include osteoporosis, arthritis, bone tumors or osteogenesis imperfecta. There will be peri-fracture soft tissue swelling, erythema, and severe pain at the fracture site. The traumatic fractures can also be detected clinically in the same way. The history in the case of traumatic fractures may include fall, road side or vehicle accident. The peri-prosthetic fractures are caused by either Varus alignment of the implant or bone resorption as the result of inflammation at the implant site. The Varus alignment of implant results in fracture of the lateral aspect of the bone. The history of the patient is also very useful in formulating provisional diagnosis of the peri-prosthetic fracture [10]. The clinical evaluation is only helpful in making the provisional diagnosis of the fracture and does not give the absolute clue about the fracture. That is why some more advanced technique in fracture detection is required.

Radiology is the branch of medicine and physics which uses electromagnetic radiations to aid diagnosis for various pathologies which cannot be visualized otherwise.

Plain radiography is the primary diagnostic technique for bone fractures. It is most widely used technique in emergency and traumatic conditions. It has very high diagnostic accuracy for bone fractures. Computed tomography is shows very high sensitivity and specificity for subtle or occult fractures of cranium and short bones. Magnetic Resonance Imaging is found to be very accurate for detecting stress fractures of lower limb.

Despite of high contrast and spatial resolution of CT and MRI, conventional radiography is always a primary means of diagnosis of bone fractures in hospital settings because of certain advantages in terms of time required and expertise for diagnosis relatively apparent bone fractures [3-6].

Plain radiography, since the long time, uses screen film combination as the image detector. This conventional radiography method uses phosphor screens to convert x rays to light. This light is detected by the silver halide crystal containing radiographic films sandwiched between the screens inside the cassette. The latent image is formed on the radiographic film which is then processed in a darkroom which takes about one hour. The developed image is the readable image [5-9].

There is no film in the digital radiography, rather the image receptor is a cassette which is contains selenium, cesium iodide or gadolinium oxysulfide as a phosphor instead of screen. X rays are converted into light by detectors, converted to digital signal, subjected then to thin film detectors or CCDs which lead to the prompt formation of an image. The image does not need any developing chemistry. The conventional or plain radiographic image, once projected, cannot be altered in size, shape, contrast or saturation. The digital radiographs have an edge over conventional radiographs in this regard. The spatial resolution of conventional plain radiography is much better than the digital radiography [6-7].

The images of computed tomography, magnetic resonance imaging and ultrasound are always acquired in the digital format.

Image Processing refers to using various mathematical operations (algorithms) to extract desired information specifically and to manipulate the image generally, by altering its various parameters. The image processing techniques are usually applied on digital images but they can also be applied to analogue images. There are many tools available over the worldwide web for digital image processing. Some of them are listed as: Analyze, ANIMAL, Mango, MATLAB, OpenCV, and Openlab.

II. LITERATURE REVIEW

Most of the image data sets released in radiology are of CT scans and MRI. A 3D volume rendered CT image data set was released by Phillip *et al.* in 2002, featuring bone fractures. The 3D rendering of CT images allow better visualization of bone fractures specially the complex ones [11].

Another dataset of lung nodules was released under the banner of Lung Image Database Consortium by Armato Iii *et al.* in 2004. Six point criteria were introduced to set the inclusion and exclusion criteria for the release of dataset. The artifactual images were also catered to provide a comprehensive data resource to the medical research community [12].

An annotated dataset of lung nodules containing 157 CT images was released by Dolejsi*et al.* in 2009. The data was released in DICOM format and was annotated in XML format. Small nodules were marked by a point and voxels were marked for large nodules. Scanning parameters were also saved in each DICOM file as metadata [13].

A dataset containing cross-sectional high contrast to noise ratio MR images of young, middle age, older demented and non-demented adults was released by Marcus *et al.* in 2007which was composed of images from 416 different subjects. The brain volume was also calculated automatically and the effects of age and Alzheimer's were also reported. Similar study was conducted by releasing Longitudinal MR images of older adults in 2010 [14].

Certain annotated data sets of radiology are also available online such as; http://langlotzlab.stanford.edu/imaging-datasets/, http://www.radrounds.com/profiles/blogs/list-of-open-access-medical-imaging-datasets

None of the data has been found on the release of annotated plain radiographic images for bone fractures till now, up to the best of our knowledge.

III. MATERIALS AND METHODS

The identification of "truth" is very important for digital image analysis and computer aided diagnosis. The work presented in this paper focuses on the identification of the spatial location of the bone fractures. Several other factors are also important to identify, in order to support or accentuate the truth. Those factors include; the bone fractured, the area of the bone fractured, the type of fracture, the size of the fracture, orientation of radiograph and laterality of the affected bone.

Every bone has its unique radiographic anatomy which isolates it from other bones in terms of physical appearance, spatial location, distinctive features, size and articulations.

A typical bone is divided into three parts; proximal, diaphyseal and distal. These parts of a bone have distinctive shapes, sizes and articular facets, different types of fractures along with different dislocation patterns.

As described earlier there are multiple types of fractures. Each fracture has its own properties in terms of fragments, location, size and orientation, which distinguish it from other types.

Right and left bones are symmetrically located. This embryological alignment of bones does not allow the right and left counterparts to be interpreted interchangeably.

The radiographs for bone fractures must be taken into two orthogonal planes; Anteroposterior and Lateral typically. The bone appears differently in both of these planes. The fracture may be visible in one while obscure in another one.

Each of the features mentioned above can strengthen the imbecile CAD systems and can help in training classifiers for automated bone fracture detection.

This study was conducted retrospectively. Digital plain radiographs from September 2016 to June 2017 were collected from the Department of Radiology, Pakistan Institute of Medical Sciences (PIMS), Islamabad. A written approval was granted from the Head of the Department. A total of 8,345 images were obtained of which 735 images contained bone fractures. Since no record of a report was digitally available for these radiographs, presence of a fracture (and selection of a radiograph) was verified by two independent individuals.

Images containing bone fractures were included in the study regardless of the presence of an artifact. However, Images deficient in patient information, imaging parameters and collateral orthogonal scans were not excluded either.

Images containing subtle fractures, which may be misdiagnosed due to absence of clinical correlation, of craniofacial bones, tarsals and carpals were not included in this study.

The data was available in DICOM format which was viewed using MicroDICOM viewer. The patient's data was embedded on the image and DICOM Viewer was unable to remove it. The DICOM image was then converted into JPEG through the inbuilt JPEG converter. In order to maintain patient privacy, the JPEG images were then cropped to remove patient information. The images were then randomly assigned numbers as the file name. To demarcate the fracture, it was annotated by manually drawing a red square around it. Both the annotated and non-annotated JPEG bone fracture radiographs are placed in the dataset for identification of truth and CAD analysis respectively. These labeled/annotated images along with their non-annotated counterparts were placed into respective folders shown in Fig. 1.

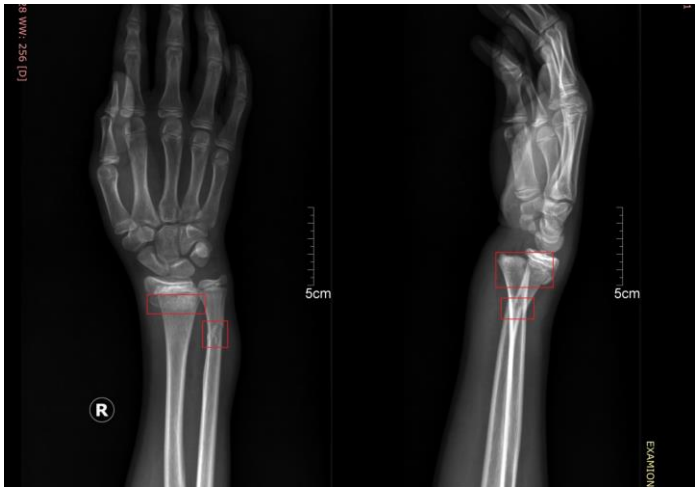

FIGURE 1. An Annotated Fracture of Distal Radius and Ulna of Right Forearm.

IV. RESULTS

Digital images of plain radiographs were collected from PIMS. The images containing bone fractures were separated and were annotated and an data file was created containing several labels including; Type of fracture, anatomical location of the fracture, bone affected, area of the bone affected, potential laterality of the affected bone, size of fracture, gender, age, presence of artifact and presence of implant/ prosthesis.

Transverse fractures were found to be most common types of fractures (34.04%), followed by comminuted fractures (17.36%). Diaphysis of a bone was found to be the most commonly affected area of the bone (53.03%). There were 90.14% of the images without any artifact while 71.69% images without any prosthetic implant. As there are significant images without the presence of any sort of artifact or implant, majority of the images are feasible for CAD operations. Further statistical analysis is not applicable because of the limited approach of the research paper.

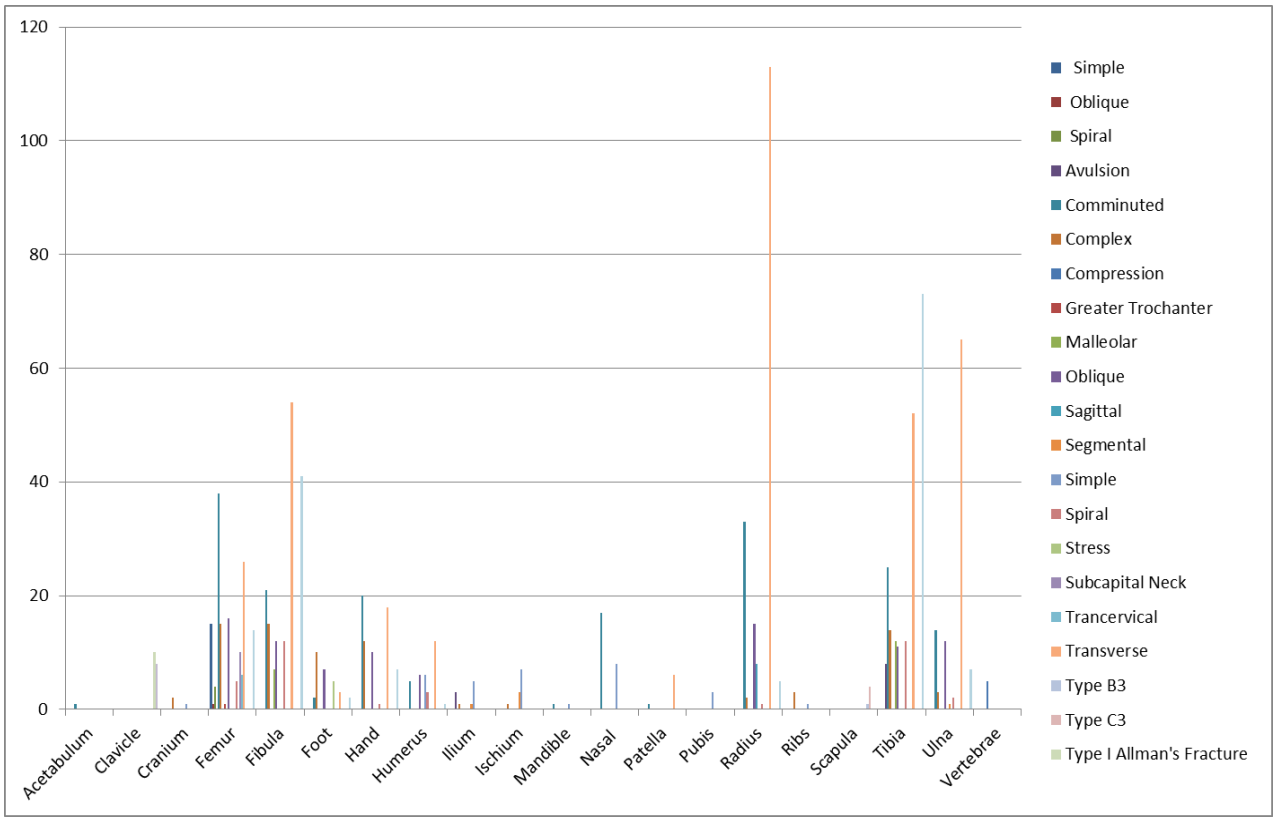

FIGURE 2. Frequency of Type of Fractures vs Affected Bone.

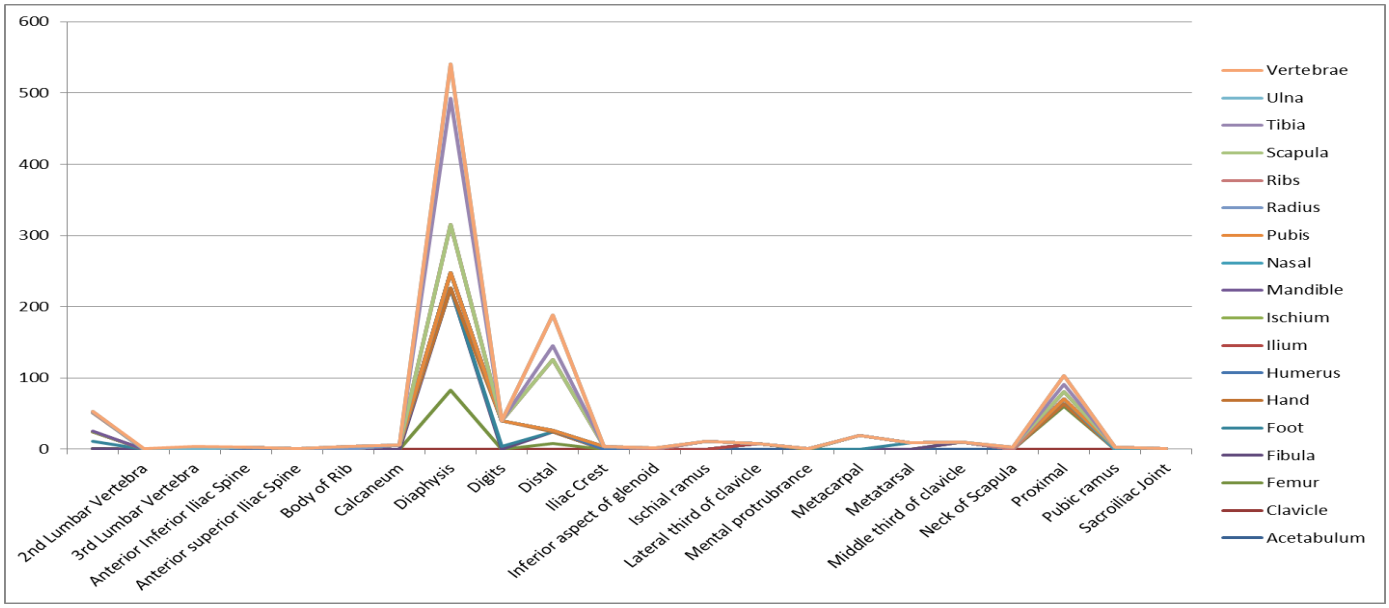

FIGURE 3. Frequency of Affected bone vs Affected Area of Bone

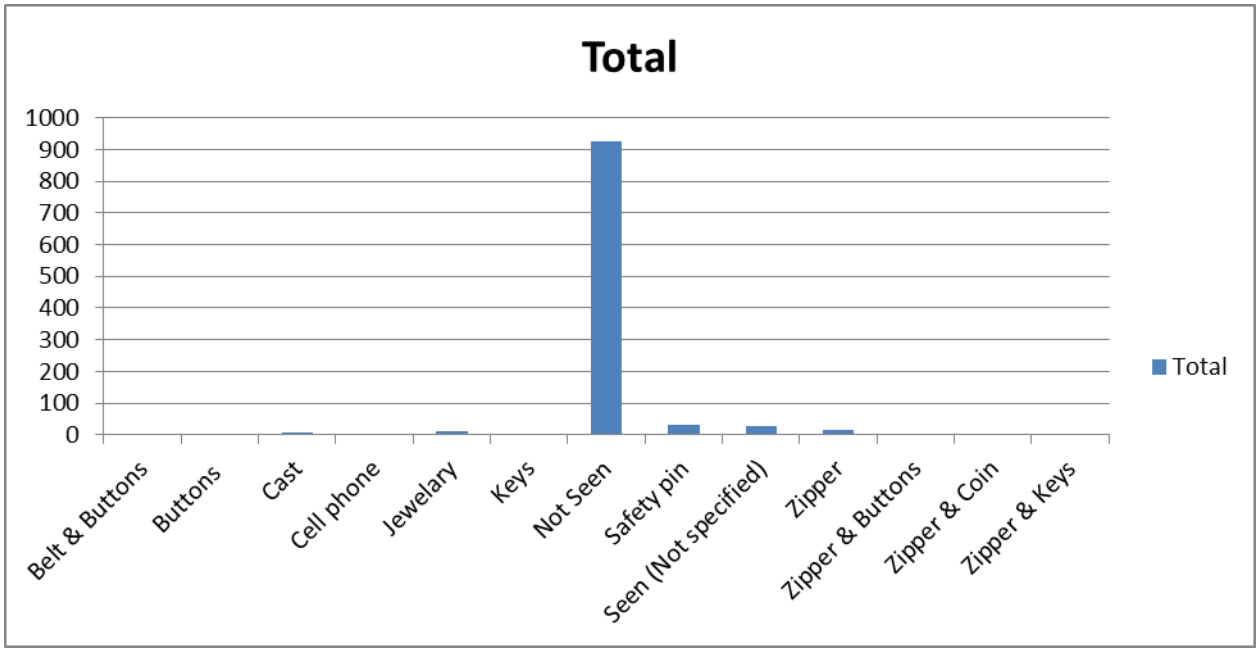

FIGURE 4. Frequency of Type of Artifacts found in radiographic Images

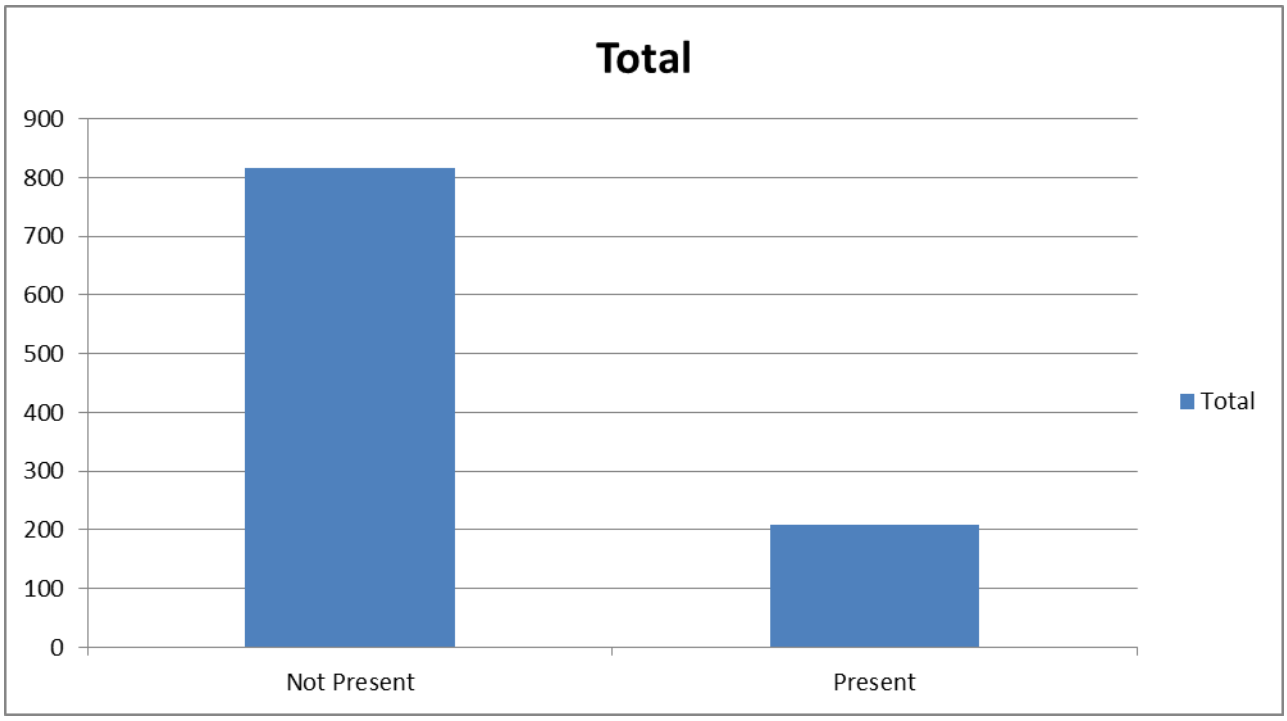

FIGURE 5. Frequency of Presence and Absence of Prosthetic Implant in Radiographic Images

V. DISCUSSIONS

The digital images were retrospectively acquired from Radiology Department of PIMS after the written consent of HOD Radiology. The collected images were then sorted out on the basis of presence of fractures. The DICOM images were then converted into JPEG, cropped to remove patient details, which was not possible otherwise and then were orientated properly. The images were renamed numerically randomly and then were placed into their respective folders, classified on the basis of bone type. Each of 735 images was then annotated manually to specify the fracture. The annotation indicates the "truth", which is the baseline for CAD analysis of digital images. Type of fracture, anatomical location of the fracture, bone affected, area of the bone affected, potential laterality of the affected bone, size of fracture, gender, age, presence of artifact and presence of implant/ prosthesis were explicitly mentioned in the data sheet created.

PIMS is one of busiest public sector hospitals in Pakistan. The department of radiology is equipped with the radiographic systems of Shimadzu and Toshiba, installed in two X Ray rooms. DR system has been purchased from Colenta which has inbuilt features of teleradiology and digital reporting. The problem arises when the quality of image is taken into consideration. The patient has not been positioned properly for most of the orthogonal scans either for screening or diagnostic purposes.

As mentioned earlier, the images were acquired in DICOM format and are not possible to be released as they contain embedded details of the patients which were irremovable. There were some of the images which did not specify the age, gender and proper imaging factors (kVp and mAs) of the scan. These factors were not possible to identify, even to best guess. Position markers indicating right and left side of the patient were also not present in some of the images. The potential laterality of each image was identified on the basis of best of knowledge of radiologist and author.

The important features to be identified manually, from the perspective CAD are the bone fractured, the area of the bone fractured, the type and size of the fracture and laterality of the affected bone. Each of these are features are expected to play an important role in training classifiers and machine learning in digital medical image analysis. Simulation results are shown in Fig. 2-5. The data can be accessed openly after peer review at the open access data base of National University of Sciences and Technology, Islamabad.

VI. CONCLUSION

JPEG images of bone fractures have been annotated to provide ground truth. Several data sets of medical images have been available online, no data set has been found for bone fractures up to best of our knowledge. The broadness of the subject restricts to analyze fine details during statistical analysis which could be taken into account individually in the future. The data set release along with the feature identification done in this study will prove a major contribution to the research community in the field of Medicine and Artificial intelligence to work upon CAD based diagnoses of digital medical images.

REFERENCES

[1] Mann, Robert W., and David R. Hunt. Photographic regional atlas of bone disease: a guide to pathologic and normal variation in the human skeleton. Charles C Thomas Publisher, 2013.

[2] Sutton, L., 2012. Bone tissue. In Body Composition in Sport, Exercise and Health (pp. 126-145). Routledge.

[3] Haynes, Gary. "Evidence of carnivore gnawing on Pleistocene and Recent mammalian bones." Paleobiology 6, no. 3 (1980): 341-351.

[4] Ogawa, Makio, Amanda C. LaRue, Patricia M. Watson, and Dennis K. Watson. "Hematopoietic stem cell origin of connective tissues." Experimental hematology 38, no. 7 (2010): 540-547.

[5] Hurtig, M., Sherril L. Green, H. Dobson, Y. Mikuni-Takagaki, and J. Choi. "Correlative study of defective cartilage and bone growth in foals fed a low-copper diet." Equine veterinary journal 25, no. S16 (1993): 66-73.

[6] Castro, Alice Morais, Fernando Saraiva, Joaquim Polido Pereira, José Bravo Pimentão, and José Carlos Romeu. "Calcium Pyrophosphate Dihydrate Deposition in a Pseudarthrosis: A New Location for an Old Disease." JCR: Journal of Clinical Rheumatology 23, no. 3 (2017): 176-178.

[7] Kim, Paul H., and Seth S. Leopold. "Gustilo-Anderson Classification." (2012): 3270-3274.

[8] Smekal, Vinzenz, Juergen Oberladstaetter, Peter Struve, and Dietmar Krappinger. "Shaft fractures of the clavicle: current concepts." Archives of orthopaedic and trauma surgery 129, no. 6 (2009): 807-815.

[9] Holder, J., S. Kolla, and S. Lehto. "Clavicle fractures: Allman and Neer classification." J Adv Radiol Med Image 2, no. 1 (2017): 1ff.

[10] Jones, Christopher, Adeel Aqil, Susannah Clarke, and Justin P. Cobb. "Short uncemented stems allow greater femoral flexibility and may reduce peri-prosthetic fracture risk: a dry bone and cadaveric study." Journal of Orthopaedics and Traumatology 16, no. 3 (2015): 229-235.

[11] Phillips, Frank M., F. Todd Wetzel, Isadore Lieberman, and Marrion Campbell-Hupp. "An in vivo comparison of the potential for extravertebral cement leak after vertebroplasty and kyphoplasty." Spine 27, no. 19 (2002): 2173-2178.

[12] Armato III, Samuel G., Geoffrey McLennan, Michael F. McNitt-Gray, Charles R. Meyer, David Yankelevitz, Denise R. Aberle, Claudia I. Henschke et al. "Lung image database consortium: developing a resource for the medical imaging research community." Radiology 232, no. 3 (2004): 739-748.

[13] El-Regaily, Salsabil A., Mohammed A. Salem, Mohammed H. Abdel Aziz, and Mohammed I. Roushdy. "Survey of computer aided detection systems for lung cancer in computed tomography." Current Medical Imaging 14, no. 1 (2018): 3-18.

[14] Shen, Li, Sungeun Kim, Shannon L. Risacher, Kwangsik Nho, Shanker Swaminathan, John D. West, Tatiana Foroud et al. "Whole genome association study of brain-wide imaging phenotypes for identifying quantitative trait loci in MCI and AD: A study of the ADNI cohort." Neuroimage 53, no. 3 (2010): 1051-1063.

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Probability of Diabetes mellitus and Cardiometabolic Syndrome based on Facial Types

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Abstract- **With the advancement of technology it has been possible to detect diseases through non-invasive techniques. Previous studies showed us that diabetes mellitus and cardiometabolic syndrome are correlated disorders. Presence of one increased the possibility of existence of other. Efficient ways has been introduced to detect these disorders through facial image analysis using texture and color features. Furthermore, Human faces can be divided into three main categories based on the anatomical growth of their bones. Based on the knowledge the question arose that what could be the relation between facial types and these different categorical but linked disorders. Primary objective of this study is to analyze the facial types which have more probability of getting diabetes and cardiometabolic syndrome. Secondary objective includes the analysis of both genders i.e. male and female to detect which one of these genders are having more chances of these long lasting abnormalities. In the first step, data was acquired from four hospitals to make sure that it is accurate, both qualitatively and quantitatively. A few specifications were considered before capturing an image such as: frontal face, a distance of 3-4 feet between the camera and the subject, white background and neutral expressions. The age group of subjects was limited from of 30 to 80 years. The dataset consists of 198 participants including both male and female with equal number of subject in three groups namely diabetic, cardiometabolic and normal group. Facial index ratio was obtained after calculating the height and width of face using the anatomical landmarks described by researchers. After that each subject was classified into their respective group based on their facial ratio. Lastly, each group having different facial index ratio of project participant was analyzed statistically. Primary results showed that a large number of diabetic patients have wider and average faces also called mesofacial and brachifacial classes of face in medical terms. Further statistical analysis showed that there is a significant difference present between diabetic and normal group with P< 0.013 using CI of 95% and P<0.05. On the other hand, although large quantity of Cardiometabolic group belongs to mesofacial and brachifacial class but there was no concrete difference found between cardiometabolic and normal group using statistical analysis. Secondary results showed that in female there are more chances of these two disorders than male. The study concludes that rounder and average facial persons have more chances of diabetes mellitus and especially female are more affected by it. While there is no concrete result based showed that facial types have any relation with cardiometabolic syndrome.**

Index Terms-- **Facial Analysis; Facial Types; Diabetes Mellitus Detection; Cardiometabolic Syndrome Detection**.

I. INTRODUCTION

Cardiometabolic syndrome (CMS) or simply metabolic syndrome is a complex group of various abnormalities such as cardiovascular diseases (CVD), chronic kidney diseases (CKD), coronary heart diseases, stroke, inflammation and diabetes. Some of the vital factors which can induce CMS are obesity, hypertension, dyslipidemia and genetics [1-5] . Whereas diabetes mellitus is a metabolic disorder in which either the production of insulin is less than demand of the body or utilization of produced insulin cannot be used properly in the body [6-8] . Type-2 diabetes is the most common type and hypertensive patients have more chance to acquire it. Presently there is no proper cure for diabetes [2, 6, 9]. According to world health organization (WHO) estimation currently there are more than 171 million people suffering from diabetes and these numbers will increase to 366 million 2030 or 642 million by 2040 [7, 8]. Diabetes and cardiometabolic syndrome are correlated and any occurrence any of two will increase the risk factor for the other [1, 3-5]. There is a strong relation present between diabetes and edema, which is increment of bulk amount of body fluids in the tissue spaces between body cavities or cells. The change in the physical appearance is visible particularly on face[6]. A facial sign usually consists of color of skin, structure of bony zones, facial gesture and expressions and facial block analysis consists of two types of features such as texture and color[7, 8] . According to Chinese medicine cause, symptom, and origin of disease can be reflected through color changes.[8] Diabetes mellitus and cardiometabolic syndrome can be detected through non-invasive method using computer technology but there is no strong evidence present which showed that facial morphology is vital for cardiometabolic outcomes[2, 7, 10]. Facial asymmetry was observed in diabetic

patients such as dropping of brow ridge bugling of cheeks.[6] . Type-1 diabetic patients showed reduction of bone mineral density and decrement in skeletal mass which shows that changing in the craniofacial morphology due to reduction in muscle function.[11-14] Diabetic persons showed growth in zygomatic arch and those having hypertension have expansion in nasal region on the other hand, patients having both hypertension and diabetes Showed widening in the region of zygomatic arch and the jaw.[12]. Most common features of face can be detected through anthropometric measurements. Facial measurements include ratios, angles and landmarks detection. Due to advancement in computer technology various features of facial morphology can be detected with non-invasive, imaging technology techniques.[6, 15] some of the most common methods for analyzing faces of human are using imaging technology are face color blocks and facial texture features.[7, 8] Facial types can be divided into three basic types known as Dolicofacial, Mesofacial and Brachifacial. [16] For brachifacial skull is short in its anteroposterior where has dolicofacial have long cranial vault.[16] It was also observed that shape of diabetic patients was found to be rounder and less tapered.[15]. However there exist little or no knowledge in the facial analysis based on face types for determining the chances of diabetes or cardiometabolic syndrome. In this proposed study, Different types of faces have been examined using texture features of the face to determine the relation among facial type, diabetes and cardiometabolic syndrome.

II. METHODOLOGY

Entire project was divided into simple and concise steps for better understanding and less human error which could produce false results. Each Step from data acquisition to final results was done separately and critically examined before taking next step into consideration. Figure 1 show the steps involved in the whole project.

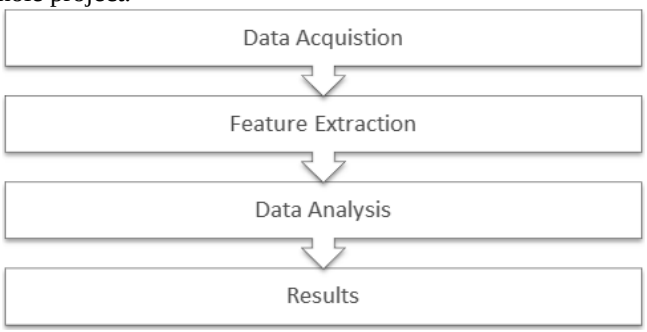

FIGURE 1. Graphical Methodology

A. Data Acquisition

Data was collected from four different hospitals due to two following reasons; one is the number of patients agreed to collect their facial images are low in numbers. Secondly, for quantitatively and qualitatively accuracy data from diverse regions were collected. Ethnic group of people belongs to Pakistan only. Both males and females were considered in this study. Three different groups were made for data acquisition namely Diabetic, cardiometabolic and normal group. Data was collected randomly without specifically targeting one group at a time. At the time of collection each participant was given a code which described the group in which a particular subject belongs. In last, each facial image was given code according to its group name while referring the code which was given during the time of acquisition.

A total 204 persons were included in this study and each group contains facial images of 68 participants. A written consent was signed from each participant who took part in this study. It was approved by each hospital's senior staff and home university ethical committee. Patient history related to diabetes and cardiometabolic syndrome was also noted down during data gathering. Table 1 provides an overview about the total subjects data collected from each hospital including patients from diabetic and cardiometabolic group. Table 2 showed the details about the data collected for each group from different hospitals. As the number participants were limited during data acquisition some of the males images have mustache and small beard, on the other hand females have accessions on their ears and nose. After careful consideration 6 images of male participants were discarded because they could produce variance in the results. Table 3 shows the specification and reason about rejection of images.

Table 1. Data Collection from four different Hospitals

Name of Hospitals	Number of Patients
Jinnah Postgraduate Medical Complex Karachi	111
Razia Diabetic Clinic Islamabad	26
Sidique Saddiq Memorial Trust Hospital Gujranwala	41
Major Shaheed Shaheed Sharif Hospital (THQ) Gujarat	26
Total Number of subjects	204

Table 2. Data Collection for each group from different hospitals

Name of Hospital	**Type of Subjects**		
	Cardiometabolic	Diabetic	Normal
Jinnah Postgraduate Medical Complex Karachi	25	42	44
Razia Diabetic Clinic Islamabad	Nil	26	Nil
Sidique Saddiq Memorial Trust Hospital Gujranwala	41	Nil	Nil
Major Shaheed Sharif Hospital (THQ) Gujarat	Nil	Nil	26

Table 3. Rejected Images

Number of subjects discarded	Reasons
6	Beard, Not in desired range of age

B. Data Specification

One of the vital parts of this study was data collection. The region of interest was face due to which some specific measure was taken into consideration before capturing images. View of face, background, facial expression and distance from camera were remained constant for the consistency in the obtaining data. These features of protocol allowed having good quality of dataset with some little variations. Table 4 showed the specifications of protocol used for acquiring data.

Table 4. Protocol used for acquiring data

Specification	Details
Background	White
View	Frontal Face
Expression	Neutral
Age group	30-80
Size of Image	2-3.4 MB
Pixels	5760 x 3840 & 4608 x 2592
Distance from Camera	3-4 feet
Camera and Lens	Cannon 24-105mm range

Before feature extraction the whole data was down-sampled and cropped to the size of 700X600 pixels due to limited processing power for batch processing. As the focal area was face in the image no part of face was cropped and images were having the same quality as can be seen in Figure 2. In addition to this brightness of each image from every group was maintained to one level for reducing the error which might be produced while capturing data from four different environments of hospitals.

FIGURE 2. Images of Subjects used in the study

C. Facial Index

The ratio between the morphological facial width to morphological facial height into hundred is called as facial index. It is also called as facial proportion. Mathematical expression for calculating facial index can be seen in (1).

$$Facial\ Index = \left(\frac{Morphological\ Facial\ Height}{Bizygomatic\ Width}\right) * 100 \qquad (1)$$

Facial height can be expressed as distance between anatomical points on face called Nathion (N) to Gathion (Gn) and facial width is defined as distance between byzygomatic widths staring from right zygion (Zyr) to left zygion (Zyl). Based on facial index facial types can be divided into three major types named as: Brachifacial, Mesofacial and Dolicofacial. Firstly, Brachifacial is the one in which width of the face is greater than the height of the face which can be calculated through facial index. Secondly, Mesofacial persons have on average height and width of the face. These faces are also called as normal or average faces. Lastly, Dolicofacial facial type is the one in which height of the face is greater than the width of the face. These faces are also referred as long or narrow faces. For categorizing any facial type a range of ratio was calculated by medical doctors [16]. Table 5, provides the details about the range of ratio for specifying the facial type.

Table 5. Ratio Range for each facial type

Facial Type	Ratio
Brachifacial	**X-84.9**
Mesofacial	**85.0-89.9**
Dolicofacial	**90.0-X**

D. Feature Extraction

The two vital parameters required for calculating the facial index were facial width and facial height. Facial type of each subject was predicted after calculating the facial index by using height and width as the features. Matlab image processing toolbox [17] was used for calculating the height and width of the face. Landmarks were pointed manually and straight line which is the distance between two landmarks for both height and width was drawn. This line provides the numerical value for width and height as shown in Figure 3. After calculation of these parameters facial index was calculated by using equation. 1. The whole process from width and height finding to calculation of index was repeated three times and an average values was taken for considering the facial type of the whole dataset.

FIGURE 3. Facial height and facial width calculation from anatomical landmarks

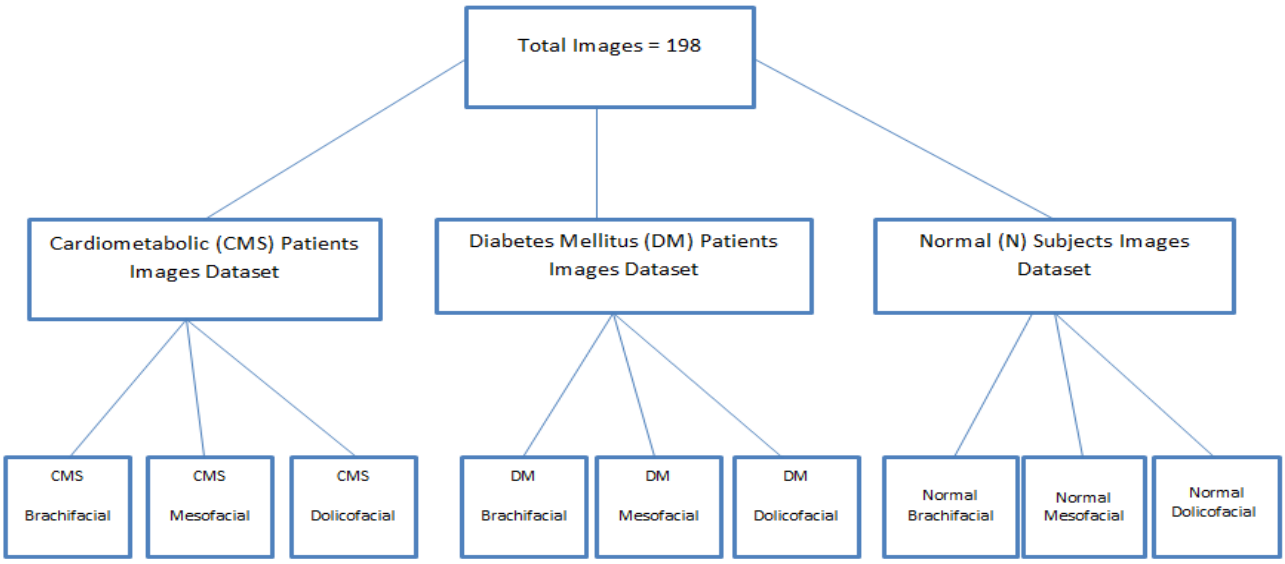

FIGURE 4. Division of Dataset based on Facial Type

III. RESULTS

This Dataset was separated based on the facial type by further dividing the groups into three relevant groups. Each group like cardiometabolic, diabetic and normal had had three of their own groups like Mesofacial, Brachifacial and Dolicofacial. A clear picture of this division can be seen in figure 4.

The finding showed that the diabetic group had most of the facial types which belonged to Brachifacial class whereas cardiometabolic group had on average an equal number of subjects laying in each class of facial types. On the other hand normal subjects have most the subjects who belonged to dolicofacial face type. Table 6, showed the details of subject belong to each class in all three groups

Table 6. Classification of subjects based on facial types in each group

Category	**Brachifacial**	**Mesofacial**	**Dolicofacial**
Cardiometabolic syndrome	26	16	24
Diabetic Patients	32	14	20
Normal Subjects	13	16	37

Gender based classification had also been done based on facial types. The finding showed that most of the female subjects in cardiometabolic group had brachifacial whereas most of the male had dolicofacial face type. In contrary to this diabetic group large number of male and female have brachifacial face type. For normal group the female had a large number of dolicofacial face type and male had a huge amount of faces contained in dolicofacial class. Table 7, and Table 8, provides the actual number of subjects both including male and female having facial type of particular class in the groups of cardiometabolic, normal and diabetes.

Table 7. Facial types of female belong to different groups

Gender : Female			
Category	Brachifacial	Mesofacial	Dolicofacial
CMS	18	10	3
DB	14	11	5
Normal	5	6	10

Table 8. Facial types of Male belong to different groups

Gender : Male			
Category	Brachifacial	Mesofacial	Dolicofacial
CMS	8	6	21
DB	18	3	15
Normal	5	12	28

The index ratio of all subjects in every group was averaged for determining the mean face each class hold. Figure 5, each class average faces in the form of bar graph. It was found out that the average of all subjects facial index in each of the three groups i.e. cardiometabolic, diabetic and normal belongs to mesofacial type which is within the range of 85.0 to 89.9 [16]

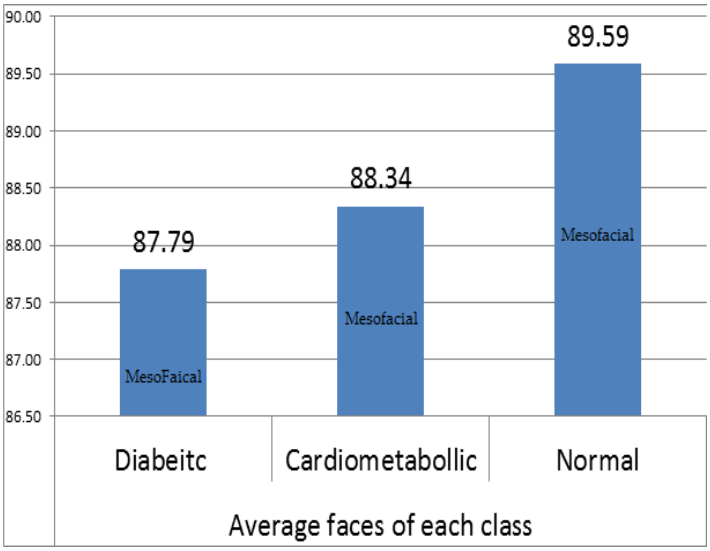

FIGURE 5. Average face of all subjects from each class 3.

Among all the groups, the diabetic group has (mean = 87.39, SD ± 7.87) whereas cardiometabolic group has (mean = 88.28, SD ± 8.50) and normal group has (mean = 90.64, SD ± 7.00). Data was found normal while checking with Shaprio-Wilk's W Test. Significance between groups had been checked using T-test independent sample at 95% CI with $P<0.05$. It was found out there is a significant difference present between diabetic group and normal group with $P<0.013$. On the other hand there was no significant difference present between cardiometabolic group and normal group.

IV. DISCUSSION

The results showed that almost 63.64 % of cardiometabolic patients are having facial types which are rounder and less tapered [15] including both brachifacial and mesofacial [16]. Both of these facial types are considered in the round face with wideness in the zygomatic arc. On the other hand only 36.36% of the patients in this class are dolicofacial [16] which belongs to the class of people having elongated face. For diabetic class patients 72.72% of the people belong to the mesofacial and brachifacial class combined which is validating the findings that diabetic persons have less tapered and rounder faces. Whereas only 27.28% of the data collected in this class have narrow faces. On the other hand in normal subject class only 43.9% have wider faces combing both mesofacial and brachifacial classes and 56.1% are dolicofacial persons. The classification based on gender provides different sort of results. In the category of female 90.32%, 83.33% and only 53.53% of cardiometabolic, diabetic and normal group subjects are having wider zygomatic arc [12] which are included in both brachifacial and mesofacial type. In contrary to this, male participants have only 40% of the cardiometabolic syndrome patients who belongs to brachifacial and mesofacial class. Whereas 58.3% are having rounder face and 52.38% of normal male participant have wider and average face. Based on these proportions the idea of diabetes for rounder persons is further strengthened while statistical analysis provides significant difference between normal group of facial index ratio of all three types of faces and the diabetic group facial index ratio. But for cardiometabolic syndrome there is contradiction present. The proportional data suggested that the are more chances present of cardiometabolic syndrome for those have wider and average facial types which is an alignment with the theory which states that facial signs are useful for predicting CMS [2]. On the other hand there is no statistical significant difference present between normal group and cardiometabolic group which is strengthen the results that [10] no strong evidence has been found on the basis of which one can surely say that facial morphology is vital for cardiometabolic syndrome. Further outcome based on gender showed us that there are more chances of diabetes and cardiometabolic syndrome in females while male data is not providing some convincing facts about the relation of facial type and the occurrence of diabetes and cardiometabolic syndrome. This study showed us that there are more chances of diabetes mellitus especially in female having the brachifacial and mesofacial type. For the relation of cardiometabolic syndrome it opens a new debate which provides the fact that whether there is a relation between any specific facial type and cardiometabolic syndrome.

There are some limitations present in the study. The first one is the participants are from same ethnic group, and therefore future studies have to include different ethnic groups for different findings. Secondly participants are from different cities and the lifestyles, culture and eating habits are variant that might affect the variation on the face. Lastly, the number of participants in terms of gender was not and equality in number of both participants can lead to different findings.

V. CONCLUSION

In recent years scientists had developed non-invasive techniques to detect various diseases which can be detected through facial analysis especially diabetes mellitus and cardiometabolic syndrome. In this study, we have analyzed the chances of

diabetes mellitus and cardiometabolic syndrome based on the types of the faces. Primary results showed us that those persons having brachifacial and mesofacial which means that their faces are rounder and wider in their form tend have more chances of diabetes mellitus while the risk of cardiometabolic syndrome to any specific facial type is still questionable as there was not significant results found related to this group. Secondary results showed that female are more prone to getting chances of diabetes and cardiometabolic syndrome as around 86.88% females both combining average and wider faces are having these disorders. For male participant there is no clear evidence and proportion on the basis of which any particular facial type considered as more prone to getting chances of these possible disorders.

References

[1] J. P. Castro, F. A. El-Atat, S. I. McFarlane, A. Aneja, and J. R. Sowers, "Cardiometabolic syndrome: pathophysiology and treatment," *Current hypertension reports*, vol. 5, pp. 393-401, 2003.

[2] S. Colantonio, D. Germanese, D. Moroni, D. Giorgi, M. Pascali, M. Righi, *et al.*, "Semeoticons-reading the face code of cardio-metabolic risk," in *Computational Intelligence for Multimedia Understanding (IWCIM), 2015 International Workshop on*, 2015, pp. 1-5.

[3] H. N. Ginsberg and P. R. MacCallum, "The obesity, metabolic syndrome, and type 2 diabetes mellitus pandemic: Part I. Increased cardiovascular disease risk and the importance of atherogenic dyslipidemia in persons with the metabolic syndrome and type 2 diabetes mellitus," *Journal of the cardiometabolic syndrome*, vol. 4, pp. 113-119, 2009.

[4] D. Leroith, "Pathophysiology of the metabolic syndrome: implications for the cardiometabolic risks associated with type 2 diabetes," *The American journal of the medical sciences*, vol. 343, pp. 13-16, 2012.

[5] B. H. Rice, C. J. Cifelli, M. A. Pikosky, and G. D. Miller, "Dairy components and risk factors for cardiometabolic syndrome: recent evidence and opportunities for future research," *Advances in nutrition*, vol. 2, pp. 396-407, 2011.

[6] C. Demayo, M. Torres, and V. Veña, "Face Shapes Of Diabetics And Non-Diabetics Described Using Geometric Morphometrics," *The Internet Journal of Endocrinology*, vol. 6, pp. 1-12, 2010.

[7] B. Zhang and D. Zhang, "Noninvasive diabetes mellitus detection using facial block color with a sparse representation classifier," *IEEE Transactions on Biomedical Engineering*, vol. 61, pp. 1027-1033, 2014.

[8] T. Shu, B. Zhang, and Y. Y. Tang, "An extensive analysis of various texture feature extractors to detect Diabetes Mellitus using facial specific regions," *Computers in biology and medicine*, vol. 83, pp. 69-83, 2017.

[9] L. A. R. Group, "Cardiovascular effects of intensive lifestyle intervention in type 2 diabetes," *New England journal of medicine*, vol. 369, pp. 145-154, 2013.

[10] J. Djordjevic, D. A. Lawlor, A. I. Zhurov, A. M. Toma, R. Playle, and S. Richmond, "A population-based cross-sectional study of the association between facial morphology and cardiometabolic risk factors in adolescence," *BMJ open*, vol. 3, p. e002910, 2013.

[11] M. E. Villarino, M. Lewicki, and A. M. Ubios, "Bone response to orthodontic forces in diabetic Wistar rats," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 139, pp. S76-S82, 2011.

[12] L. A. Nunes, A. S. de Jesus, C. A. Casotti, and E. D. de Araújo, "Geometric morphometrics and face shape characteristics associated with chronic disease in the elderly," *Bioscience Journal*, vol. 34, 2018.

[13] S. Kiliaridis, C. Mejersjö, and B. Thilander, "Muscle function and craniofacial morphology: a clinical study in patients with myotonic dystrophy," *The European Journal of Orthodontics*, vol. 11, pp. 131-138, 1989.

[14] M. A. Abbassy, I. Watari, A. S. Bakry, and T. Ono, "The Effect of Type 1 Diabetes Mellitus on the Dento-Craniofacial Complex," in *Type 1 Diabetes*, ed: InTech, 2013.

[15] D. S. K. Pavana S1, "Diabetes Mellitus Detection Based on Facial Texture Feature Using the GLCM,," *International Research Journal of Engineering and Technology (IRJET),*, vol. 04, 2017,.

[16] F. C. M. Franco, T. M. d. Araujo, C. J. Vogel, and C. C. A. Quintão, "Brachycephalic, dolichocephalic and mesocephalic: Is it appropriate to describe the face using skull patterns?," *Dental press journal of orthodontics*, vol. 18, pp. 159-163, 2013.

[17] MathWorks. (2018, 12 May). *Image Processing Toolbox*.

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Diabetes Millitus Control Exogenous Insulin Infusion: A Review

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Abstract- **Diabetes Millitus Control remains popular from the past years to explore for more investigations. Exogenous Insulin infusion is explored in the study for further analysis. Administration of Insulin delivery has been discussed for type-1 patients. These are some control challenges faced when Artificial Pancreas is developed. Different linear and non-linear schemes have also been discussed for Diabetes. PID Controller has been applied to control TIDM. Simulink Models has been explained and plotted. It's a control loop strategy which makes Artificial Pancreas reality.**

Index Terms-- **Diabetes, PID Controller, Exogenous Insulin infusion, TIDM.**

I. INTRODUCTION

Diabetes mellitus is a metabolic disease illustrated by high levels of blood glucose leading to chronic hyperglycemia either due to defect in insulin secretion or insulin action or both. Insulin is a hormone produced by specialized type of cells of the pancreas known as beta cells, which is necessary to exploit glucose as a source of energy from digested food. Chronic hyperglycemia is related to further complications such as microvascular and macrovascular damage leading to kidney disease, neuropathy, amputations, cardiac disease, stroke and retinopathy. Hence, diabetes includes a wide range of heterogeneous diseases [1].

Diabetes mellitus is the most common disorder of endocrine system and it has been classified in to two major types based on the presumed etiology; type 1 and type 2. Type 1 diabetes also known as insulin dependent diabetes mellitus (IDDM) or juvenile onset, the body is not capable of producing insulin and insulin inoculations are required on daily basis. Whereas, type 2 diabetes or maturity onset also known as non-insulin dependent diabetes mellitus (NIDDM) is characterized by defect in insulin secretion and insulin resistance. High levels of blood glucose are managed with reduced food intake, improved physical activity and ultimately oral medications or insulin [2]. Type 1 diabetes is further classified into two subgroups; immune mediated and idiopathic by American Diabetes Association in 2007.

Former accounts for the 5-10% and is autoimmune whereas later form of type-1 diabetes has no known etiologies and patients suffering from this type have permanent insulinopenia and are prone to ketoacidosis without any proof of autoimmunity. Morbidity and mortality rate of diabetes mellitus has increased throughout the world. Diabetes has influenced 246 million people worldwide and, of these, approximately 22 million adults and 0.4 million children have type-1 diabetes [3]. Type-1 diabetes is primarily characterized as an autoimmune disease resulting in damage of insulin-producing β-cells in the pancreas by T- cells (CD4+ and CD8+) and macrophages penetrating the islets. Both genetic as well as environmental factors yet unclear trigger the autoimmune responses against β-cells and destroy them, thus proliferating the disease [4].

The criteria of diagnosis for T1DM are the same for adults, children and young people i.e. fasting glycemia >126 mg/dl (>7.0 mmol/L) or postprandial glycemia > 200 mg/dl (>11.1 mmol/L). Other symptoms include polyuria, polydipsia, weight loss and polyphagia and blurry vision. Impaired growth and vulnerability to infections also increases. Clinical manifestations of diabetes differ from non-emergency appearances to severe dehydration, tremor and diabetic ketoacidosis [5].

Since, patients with type 1 diabetes have lost the ability to produce insulin hence such individuals depend on entirely externally administered insulin and it's the only treatment. However, daily dose of insulin required by the patient varies and depends on various factors including age, gender, daily exercise and physique. But an average daily dose is about 1 unit of insulin per kg weight per day [3].

Although, patients suffering from type-1 diabetes are dependent on regular dose of insulin either multiple injections daily or pump therapy but procedures and insulin administration to manage and control the disease varies as per the age. In neonatal diabetes insulin is initially administered through intravenous route with dose of 0.02 - 0.05 U/kg/hour, to be prolonged if possible before subcutaneous. In toddlers, it's difficult to manage the dose due to unpredictable energy consumption. School age children present stable age as they are following schematic daily routine. In adults, the need of insulin increases due to puberty. Behavior also presents a problem in adults influencing in a negative way hence affecting disease management. It is also present an inclination to disobedience and involving into activities like

smoking, alcohol and drugs as well as rebellious to insulin injection [6].

Insulin can be administered in several ways from basal-bolus approach to pump therapy depending on factors like age, diet, lifestyle, health, enthusiasm, self-management capability and availability/accessibility. While choosing, insulin type the most important that needs to be considered is the risk of hypoglycemia. Longer acting analogues of insulin (glargine and detemir) are preferred over intermediate-acting human insulin posing reduced risk of hypoglycemia Rapid-acting insulin analogues (lispro, aspart and glulisine) also preferred due greater improvements in HbA1c and with reduced risk of hypoglycemia over regular ones [7, 8]

II. PHYSIOLOGICAL METHOD OF INSULIN DELIVERY

It is important to go through how β-cell responds to glucose system in order to understand how an artificial system should behave [9]. There are two phases "first" and "second" phase responses of β- cell [9]. Significance of first phase insulin secretion. The immediate release of insulin after a meal is known as "First Phase Insulin Release". The first-phase insulin secretions have a major effect in extinguishing hepatic glucose production [10]. As shown in the figure [10]. Small change in the plasma insulin can have a significant effect on hepatic glucose output [10]. Normally , insulin production in an early phase is actually less than the total insulin needed to yield a similar area under the glucose curve [9] [11]. Improving first phase response has been related to glucose tolerance [12]. A person whose system is insulin resistant without the variation in insulin secretion becomes diabetic. While a person's system which maintains the required level of glucose tolerance by adopting the "control gain" is a non-diabetic individual [9].

After the First phase of insulin secretion if the blood sugar is not back at the level 100 mg/dl (5.5 mmol/L) then there is a second phase insulin secretion which brings back the glucose to its normal level. Second phase insulin secretion have major effect on glucose production as well as its utilization [10]. The importance of second phase insulin secretion cannot be ignored as it is necessary to maintain plasma glucose at set point [9].Insulin is not infused until blood glucose level is exceeds 180-200mg / dl . This condition is referred as hyperglycemia [13].The condition of hyperglycemia is found to be common in intensive care unit (ICU) [13]. According to surveys in [14], even a small level of hyperglycemia associated with increased rate of hospital mortality in ICU [14].

Sugar level control with insulin infusion has a risk of hypoglycaemia. Sugar level which is <50 mg/dl is the called hypoglycemia. Hypoglycemia can be diagonosed by Whipple's triad, with three steps. 1) neuroglycemia symptoms, 2) immediate glucose of < 40 mg/dl and 3) symptoms of relief after glucose intake [15].

III. OPEN LOOP ADMINISTRATION OF INSULIN

The requirement of an automated artificial pancreas has been there from 1921, the time insulin was discovered [9]. The production of insulin needs definition in terms of prehepatic insulin as well as portal insulin concentration in order to work as closely as a non-diabetic state [16]. With the increase in the demand of insulin infusion and its mechanism it is recommended to take the dose with almost every meal [17]. One major concern is the timing of insulin delivery [18]. Depending on the type of insulin, rapid-acting insulin should be infused 15 minutes before a meal. Short-acting or regular insulin can be infused 30 minutes before meal. Having food activity straight away after regular insulin can cause hypoglycemia (low sugar level) [18]. Changing the interval between insulin infusion and meal shows remarkable effect in Postprandial Hyperglycemia in insulin dependent patients. Recent studies show that near-normal glucose levels were achieved when patient had their insulin administered 60 minutes before meal [17]. Results infer that adjusting the time and the amount of insulin administered can be helpful in the management of diabetes [17]. As shown in (Fig. 1) delayed insulin infusion before meal can be linked to greater hyperglycemia up to 3 hours after meal [19].

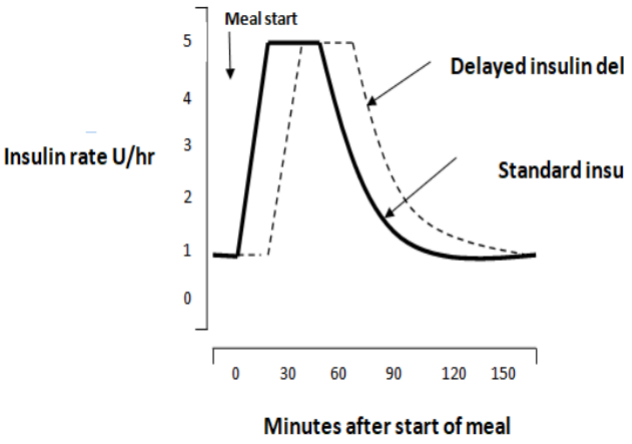

FIGURE 1. Comparison of delayed and standard insulin delivery with meal.

Injection technique is most common and early cure of a diabetic patient. Dosage is different for different individual. People with type 1 diabetes mellitus do not produce enough insulin to meet the glucose level of a normal person so they need external insulin. Most of the type 2 patients do not require external insulin. Timing of the injection depends on the glucose level and various other factors [18]. Injection site is important. Insulin can be injected into subcutaneous tissue of the upper arm and the anterior aspect of thighs and buttocks [18].

Inhaled insulin has been proven way more effective and reliable in Type 1 and Type 2 diabetes. Infusion of regular insulin through lungs by inhalation has shown insulin absorption and lowering of blood glucose [20]. As shown in(Figure 2), the maximum insulin concentration is more rapid in case of inhaled insulin as compared to SC injection [21] .

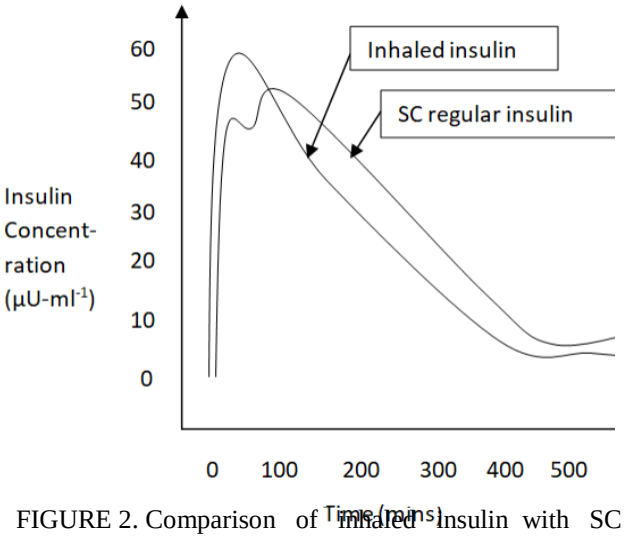

FIGURE 2. Comparison of inhaled insulin with SC injection.

It deals with the absorption and distribution process of insulin. Insulin gets absorbed into the directly into the stream [22]. Rate of absorption depends on the type of insulin , volume of injection, rate of flow. It has been observed that absorption s decreased with the increased in the ntration and the volume. Studies shows that d insulin is absorbed faster [23]. Insulin is uted with the help of circulating antibodies, e if they are present insulin is distributed as the plasma and other compartments [22]. This section deals with effect of insulin on the body. It is basically called the euglycaemic clamp study [24]. Glucose Infusion Rate (GIR) is used to represent pharmacodynamics of insulin [24].

IV. CLOSED LOOP ADMINISTRATION OF INSULIN

Current Treatment methods like SC injections and continuous delivery of insulin can result frequents glucose level variations due to their open- loop nature [25]. In order to keep a stable basal glycemia with continuous insulin infusion we require a feedback system [26] . The main aim of the feedback system is to maintain a set point which is predefined. Variable transfer functions like proportional integral or derivative terms are used to implement a feedback system [26]. Diabetes Control and Complications Trial (DCCT) published in 1993 showed how important it is to tight control the blood glucose [21]. The trial showed that there is an increased risk of hypoglycemia by combining the result of SC injections and insulin pumps [21]. A person with Type 1 diabetes has always in a long term risk related with hyperglycemia and short term risks of hypoglycemia, so they need to have a tight blood glucose control . Type-2 diabetic patients need an insulin treatment when oral antidiabetic agent and changing life style do not provide glucose control [25]. An artificial pancreas [Fig. 2] (Closed Loop) requires; Continuous Glucose Monitor (CGM) or Glucose sensor, An insulin pump. A control device that receives CGM and uses algorithm to convey signal to insulin pump [26].

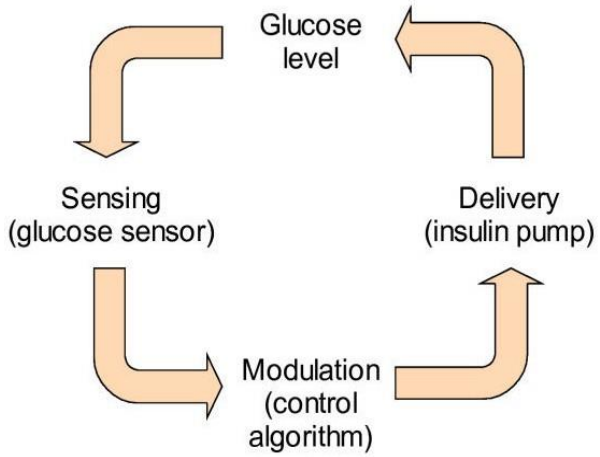

FIGURE 3 Example of Closed Loop Insulin Delivery System [29].

Different algorithms have been introduced so far but two of the most common are: Proportional integral control PID- regulates insulin by noticing variations from target glucose and Model Predictive Control MPC- regulates insulin by minimizing the difference of forecasted and target GL.

V. CONTROLLER CHALLENGES

Following are the different control challenges which need to be considered for artificial Pancreas:

- When there is closed loop system insulin is delivered when there is glucose deviation only without the information about meal size and timing.

- Hypoglycemia condition is also risky as it can cause coma, seizures and mental illness. Also hyperglycemia is not good as it causes cardiovascular disease and other chronic diseases. So these conditions must be considered.
- Different treatments have different requirements. Sometimes rapid and sometimes slow insulin delivery is required. Exercise can also create the hypoglycemia condition so all of these things are important to consider.
- When creating a rapid insulin delivery control algorithm mostly the maximum blood glucose lowering effect occur after up to 90–120 min. When designing control algorithm this time lag should be considered.

Sometimes there occurs noise in sensor measurements so different estimation techniques should be used for compensating this noise. In this paper glucose insulin system model is described. This is a simple model with few parameters. Another controller named design of Fuzzy and PID controller is described. The model is designed using Mamdani type Fuzzy structure. It has two input variables and one output variable. The inputs are error and rate of it and output is rate of insulin infusion.

PID Controller

A new device CMOS (complementary metal oxide semiconductor microprocessor) is presented which works on wakeup cycle each 2.86ms.CMOS operational amplifier and dc driver provides voltage to motor from 0 to 7.5 volt in 29.41 mV [1]. Feedback loop is used having three parts. (1) Blood glucose monitors (2) Control system (3) Insulin pump. The input of the control system is output of glucose sensor and output of the control system is the input to insulin pump. According to glucose concentration the control system instruct the insulin pump on how much insulin to be injected.

An expert PID controller is designed to regulate blood glucose level. It has clinical sliding table technique. Sliding table contains insulin concentration rates. PI controller is mostly used controller. PI stands for proportional integral. P and I controller are implemented for individual purpose. There are many methods to tune PI controller one of those is trial and error method. In this method the gains of proportional and integral were adjusted randomly to enhance the performance of insulin delivery system. Controller designers improved the steady and transient performance of PI controller by introducing fuzzy theory.

VI. LINEAR AND NON-LINEAR INSULIN INFUSION CONTROL SCHEMES

Self-Tuning Control. A self-tuning controller is basically a nonlinear control scheme which was made to implement on a micro-controller unit [21]. This scheme was checked using computer simulation and it was found that glycemia control is insensitive to changing patient behavior; also insulin concentration it produced was more physiological. Discrete-time model is assumed for the controlled system to implement a self-tuning controller. Self-Tuning uses estimator, coefficients are estimated by least-square method, it compares the true output of the model one and controlled system; so that estimation is sensitive to slow changes in patient response.

Sliding Mode Control (SMC). The advantages of sliding mode control is ultimate accuracy, insensitive to internal and external disturbances, robustness and convergence in finite time that are important characteristics of sliding mode control which are suitable choice for the control algorithms related to human body because it is important to get extreme precision [22]. Also the robustness against the parameter variation is better in SMC to that of PID. Sliding mode control is basically simple and robust procedure to synthesize controllers for both the linear and non-linear processes. The design problem of SMC consists of defining the switching logic and parameters tuning of each controller structure. The first step in SMC is to define a surface s(t), along which the process can slide to its desired final value. The sliding surface breaks the phase plane into regions where the switching function s(t) has different signs. The structure of the controller is intentionally altered as its state crosses the surface in accordance with a prescribed control law [23]. It was designed for T1DM.

Adaptive Control. It is a control method used by a controller which must adapt to a controlled system with varying parameters and which are uncertain initially. For adaptive modeling, *"Minimal Model of Bergman* [24]*"* is commonly used due to its simplicity. Most of the T1DM models are designed via model of Bergman. The model designed with it can be extended for the T2DM. The model has two inputs: glucose rate and the subcutaneously injected insulin flow; at the same time this input is the control input as well. The output of the model is plasma glucose level. The model has three state variables, which are connected to the blood plasm, these are: the blood glucose concentration, insulin-excitable tissue glucose uptake activity and the blood insulin concentration. The controller reacts promptly to large and rapid variations in insulin action [25].

Another Adaptive method used is Robust Fixed Point Transformation (RFPT) [24]. The RFPT method is an alternative for the model reduction techniques. Only the response of the system to the control signal is observed. Deformed input is used to calculate this signal to approximate the model for already defined "desired system response". "Purely kinematic terms" are used to determine the desired response without using any information on the system's dynamics. For the adaption of RFPT method route for control signal is elaborated which determines control actions and parameters. The control parameters can be set without any optimization. Controller is efficient to control blood glucose level very close to basal value for patient.

Model Predictive Control (MPC). Mostly work done in MPC is for the glucose control in T1DM. Flexibility to individually specify the critical parameters such as body weight, total insulin dose and control specifications are considered [36]. The feed forward ability of MPC that acts in anticipation of the future fluctuations due to disturbances is enhanced when considering a reference meal plan of specific size and time that is always given to the patient. Thus, the system is ready to provide the optimal insulin infusion to compensate for a small in size reference meal, in order to overcome the effect of long [26]

H∞ Control. When using LTI models H∞ is practical controller synthesis approach. There is an effective tradeoff between the strength of control action and the tracking error when considering low order robust controller characterized by H∞. This tradeoff is known as the mixed-sensitivity problem and the optimal solution in terms of the lowest gain between the input disturbance and the output errors is achieved by this optimal control procedure. The glucose-insulin response obtained by simulations shows that it got stabilized in a reasonable time interval [17]

State-Dependent Riccati Equation (SDRE). This technique is used to design blood glucose regulator for T1DM patients. There is a tracking problem defined so that blood glucose concentration tracks exponential decreasing desired trajectories. Hypoglycemia and hyperglycemic problems are limited by time- varying desired trajectory. Effects of uncertainties like meals and exercise have been investigated for ten different patients. Important advantages of this treatment are that for T1DM patients there are no hypoglycemia conditions and it has robustness against parametric uncertainties in glucose insulin system [38].

Proportional Integral Derivative (PID). It has three parts P,I and D. P is for proportional , I is for Integral and D is for Derivative. It may vary with requirements e.g. It may be P, PI , PD and PID. It calculates the error between set point and measured value.

Fuzzy Logic Control. The feedback FLC model is made. It is Mamdani-type fuzzy architecture which has two input and one output method. It is configured with PID.

VII. CONCLUSION

This review article discusses about Diabetes Millitus Control. Exogenous Insulin infusion term is briefly added. Administration of Insulin delivery has been discussed for type-1 patients. These are some control challenges faced when Artificial Pancreas is developed. Different linear and non-linear schemes have also been discussed for Diabetes. PID Controller has been applied to control TIDM. Simulink Models has been explained and plotted. It's a control loop strategy which makes Artificial Pancreas reality.

REFERENCES

[1] E. Loghmani, "Diabetes mellitus: type 1 and type 2," *Guidelines for adolescent nutrition services*, pp. 167-182, 2005.

[2] P. Zimmet, C. Cowie, J.-M. Ekoe and J.Shaw, "Classification of diabetes mellitus and other categories of glucose intolerance," *International Textbook of Diabetes Mellitus*, 2004.

[3] P. Aschner, E. Horton, L. Leiter, N. Munro and J. Skyler, "Practical steps to improving the management of type 1 diabetes: recommendations from the Global Partnership for Effective Diabetes Management," *International journal of clinical practice*, vol. 64, pp. 305-315, 2010.

[4] K. M. Gillespie, "Type 1 diabetes: pathogenesis and prevention," *Canadian Medical Association Journal*, vol. 175, pp. 165-170, 2006.

[5] J. Couper and K. C. Donaghue, "Phases of diabetes in children and adolescents," *Pediatric Diabetes*, vol. 10, pp. 13-16, 2009.

[6] H. Bangstad, T. Danne and L. Deeb,"Insulin treatment in children and adolescents with diabetes," *Pediatric diabetes*, vol. 10, pp. 82-99, 2009.

[7] P. Mullins and P. Sharplin, "Negative binomial meta-regression analysis of combined glycosylated hemoglobin and hypoglycemia outcomes across eleven Phase III and IV studies of insulin glargine compared with neutral protamine Hagedorn insulin in type 1 and type 2 diabetes mellitus," *Clinical therapeutics*, vol. 29, pp. 1607-1619, 2007.

[8] J. Plank, A. Siebenhofer and A. Berghold, "Systematic review and meta-analysis of short-acting insulin analogues in patients with diabetes mellitus," *Archives of Internal Medicine*, vol. 165, pp. 1337-1344, 2005.

[9] G. Steil, A. Panteleon and K. Rebrin, "Closed-loop insulin delivery—the path to physiological glucose control," *Advanced drug delivery reviews*, vol. 56, pp. 125-144, 2004.

[10] A. D. Cherrington, D. Sindela, D. Edgerton, K. Steine and O. P. McGuinness, "Physiological consequences of phasic insulin release in the normal animal," *Diabetes*, vol. 51, pp. S103-S108, 2002.

[11] R. N. Bergman, D. T. Finegood and M. Ade, "Assessment of insulin sensitivity in vivo," *Endocrine reviews*, vol. 6, pp. 45-86, 1985.

[12] R. E. Pratley, J. E. Foley and B. E. Dunning, "Rapid acting insulinotropic agents: restoration of early insulin secretion as a physiologic approach to improve glucose control," *Current pharmaceutical design*, vol. 7, pp. 1375-1397, 2001.

[13] G. Van den Berghe, "First do no harm Hypoglycemia or hyperglycemia?," *Critical care medicine*, vol. 34, pp. 2843-2844, 2006.

[14] J. S. Krinsley, "Association between hyperglycemia and increased hospital mortality in a heterogeneous population of critically ill patients," in *Mayo Clinic Proceedings*, vol. 78, 2003, pp. 1471-1478.

[15] E. Kraegen, D. Chisholm and M. E. McNamara, "Timing of insulin delivery with meals," *Hormone and Metabolic Research*, vol. 13, pp. 365-367, 1981.

[16] R. P. Eaton, R. C. Allen, D. S. Schade and J. C. Standefer, ""Normal" insulin secretion: the goal of artificial insulin delivery systems?," *Diabetes Care*, vol. 3, pp. 270-273, 1980.

[17] G. D. Dimitriadis and J. E. Gerich, "Importance of timing of preprandial subcutaneous insulin administration in the management of diabetes mellitus," *Diabetes Care*, vol. 6, pp. 374-377, 1983.

[18] A. D. Association and otthers, "Insulin administration," *Diabetes care*, vol. 26, pp. s121-s124, 2003.

[19] E. Kraegen, D. Chisholm and M. E. McNamara, "iming of insulin delivery with meals," *Hormone and Metabolic Research*, vol. 13, pp. 365-367, 1981.

[20] J. S. a. B. J. a. N. S. Patton, "Inhaled insulin," *Advanced drug delivery reviews*, vol. 35, pp. 235-247, 1999.

[21] K. Rave, S. Bott, L. Heinemann, S. Sha, R. H. Becker, S. A. Willavize and T. Heise, "Time-action profile of inhaled insulin in comparison with subcutaneously injected insulin lispro and regular human insulin," *Diabetes Care*, vol. 28, pp. 1077-1082, 2005.

[22] C. Binder, T. Lauritzen, O. Faber and S. Pramming, "Insulin pharmacokinetics," *Diabetes Car*, vol. 7, pp. 188-199, 1984.

[23] J. S. Patton, J. G. Bukar and M. A. Eldon, "Clinical pharmacokinetics and pharmacodynamics of inhaled insulin," *Clinical pharmacokinetics*, vol. 43, pp. 781-801, 2004.

[24] R. H. Becker and A. D. Frick, "Clinical pharmacokinetics and pharmacodynamics of insulin glulisine," *Clinical pharmacokinetics*, vol. 47, pp. 7-20, 2008.

[25] R. S. Parker, F. J. Doyle and N. A. Peppas, "A model-based algorithm for blood glucose control in type I diabetic patients," *IEEE Transactions on biomedical engineering*, vol. 46, pp. 148-157, 1999.

[26] B. Candas and J. Radziuk, "An adaptive plasma glucose controller based on a nonlinear insulin/glucose model," *IEEE Transactions on Biomedical Engineering*, vol. 41, pp. 116-124, 1994.

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Use of Waste Material for Sustainable Self-Compacting Concrete

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Abstract- **This paper explores one of the major environmental concerns which is disposal or recycling of the waste materials . Marble processing plants produce millions of tons of waste dust in the powder form every year . Having a considerable high degree of fineness in comparison to cement, marble powder may be utilized as filler for the production of Self-Compacting Concrete (SCC) . This research paper aimed at developing an eco-friendly and workable self-compacting concrete with the maximum amount of marble powder . For this, a control mix and four other mixes with varying amounts of marble powder as 5%, 10%, 15%, and 20% are prepared. These mixes are then tested for their new properties by slump flow, j-ring, and V-funnel at T 5minutes. Compressive strength is used to evaluate the hardened concrete. It was found that up to 15 % marble powder addition, the fresh and hardened properties of the concrete mix did not vary considerably. However, it was also found that with the addition of marble powder, the compressive strength decreased.**

Index Terms—**Waste Material, Sustainable, Marble Powder, Compressive Strength, Slump Flow, J Ring, V Funnel.**

I. INTRODUCTION

Concrete composite human-made material is the most widely used building material in the construction industry. It consists of a rationally chosen mixture of binding material such as cement, well-graded fine and coarse aggregates, water, and admixtures. **[1]**

The most crucial benefit of concrete is its ability to conform to any shape that we want it. However, ordinary concrete requires compaction to fulfill this ability. The compaction is provided by either external or internal vibrators. The use of vibrator requires skill and time, which increases the cost and high chances of uncertainty in the uniform placement of concrete, resulting in a decrease in the strength of a particular member. When the construction industry in Japan experienced a decline in the availability of skilled labor in the 1980s. That is need was felt for concrete that could overcome the problems of defective artistry. This led to the development of self-compacting concrete, primarily through the work by Okamura **[2]** . The first usable version of self-compacting concrete was completed in 1988 . It was named "High-Performance Concrete", and later proposed as "Self-Compacting High-Performance Concrete".

Self-compacting concrete (SCC) is a unique, very liquid concrete type that can settle into the heavily reinforced, narrow and deep sections by its weight, and can consolidate itself without necessitating internal or external vibration, and while providing with these features can keep its cohesion (stability) without leading segregation and bleeding **[3]**. Especially, the developments in superplasticizer technology have contributed considerably to the formation and progression of the self-compacting concrete **[2]**.

From the definition given by Okamura, it is concluded that SCC must exhibit three characteristics:

- Passing Ability.
- Filling Ability.
- Segregation Resistance.

Passing ability is the ability of SCC to flow through tight openings such as spaces between steel reinforcing bars without segregation or blocking. Filling ability is the ability of SCC to flow into and fill all spaces within the formwork completely under its weight. Segregation resistance is the ability of SCC to remain homogeneous in composition during transport and placing.

These characteristics are obtained by careful proportioning of the mix. Some guidelines were set for the proportioning of the SCC including the reduction of water/powder ratio, increasing paste volume, controlling the total amount of coarse aggregates and its maximum particle size, and using a powerful superplasticizer along with the vast quantities of powders and

viscosity modifying admixtures (VMA) to fine-tune the balance between deformability and stability **[4]**.

The reduced size and content of coarse aggregates decrease the frequency of collision between the aggregate particles, thus reducing the internal friction. In this way, it helps provide passing and flowing abilities. The higher amount of fines with lower exceptional ratios and use of admixtures create a cohesive mix that avoids segregation; thereby, segregation resistant concrete will be useful in passing and flowing abilities. The amounts of coarse and fine aggregates, fines, water, and admixture are to be adjusted to achieve the required properties. In case of insufficient segregation, resistance blockage can occur. If concrete is highly flowing able, it may be prone to isolation, and less flowability can cause a blockage. It is the balance of the above-discussed factors which are responsible for right SCC.

The fines can be either pozzolanic additions such as silica fume, fly ash, ground granulated blast furnace slag or inert fillers like crushed limestone and sandstone, etc. The composition of the blend of cement and fines is significant in SCC, as the high amount of pozzolans with lower water contents may cause autogenous shrinkage. Pozzolanic additions can significantly improve the long term performance of the concrete.

II. LITERATURE REVIEW

Sustainable development is the organizing principle for meeting human development goals while at the same time sustaining the ability of natural systems to provide the natural resources and ecosystem services upon which the economy and society depend. The desired result is a state of society where living conditions and resource use continue to meet human needs without undermining the integrity and stability of the natural system. Sustainable development can be classified as development that meets the needs of the present without compromising the ability of future generations **[5]**.

Environment sustainability concerns the natural environment and how it endures and remains diverse and productive. Since natural resources are derived from the environment, the state of air, water, and the climate is of particular concern. Environmental sustainability requires society to design activities to meet human needs while preserving the life support system of the planet. For example, it entails using water sustainably, utilizing renewable energy, and sustainable material supplies **[6]**.

Sustainable construction is attracting more attention lately. Sustainable development means designing, renovating, or converting a building in compliance with the environmental rule and energy-saving method. In particular, it aims to promote environmentally friendly materials and the companies that use them. And therefore, it significantly contributes to the well-being and sustainability of buildings **[7].**

In Europe, the construction industry is responsible for 34.7 percent of the continent's total waste. Green buildings minimize waste with their lower environmental impact and use of renewable sources and materials. Products such as demolition debris, sand, and burnt coal can be used with excellent aesthetic and ecological results **[8]**. Recycled materials used during the construction process are contributing significantly to the protection of the environment and the reduction of waste. Traditional materials like cement, concrete, bricks, and tiles are broadly used significant construction material. Theses construction materials consume natural resources for their production, and this further causes environmental damage. Most of the building materials production processes such as lime decomposition, calcium carbonate, and binding material cement manufacturing emit a large amount of carbon monoxide and oxides of Nitrogen and Sulphur. The release of these toxic gases into the environment leads to severe air, soil, and water pollution and gravely affects human health **[9]**. Carbon dioxide emissions from such materials can be controlled by replacing cement or proportion of cement with waste material such as marble powder that potentially improves the specifications.

The environmental impact of marble wastes recycling towards sustainable construction materials has great practical significance. The mineral powder, such as marble powder. Galetakis and Soultana reviewed thirty-eight articles in which the usage of marble powders as waste material in the construction sector was investigated, and it was found that the marble powder has a positive effect on the mechanical and durability properties of the concrete

III. RESEARCH METHODOLOGY

To investigate the properties of fresh and hardened SCC using waste marble powder, a control self-compacting concrete mix was prepared to keep in view the (EFNARC, 2002) **[10]** guidelines. The effect of waste marble powder (WMP) was studied by replacing the cement content by varying amounts of marble powder. Locally available materials have been used in the preparation of these concrete mixes. The properties that have been used in the development of concrete mixes are as follows:

a. Fine Aggregates

Lawerancepur sand was used in the preparation of mixes. Some physical properties are as under:

Table 1: Properties of Lawerancpur Sand

Property	**Value**
Bulk Density	1617.41 kg/m^3
Specific Gravity (SSD)	2.68
Water Absorption	2.01 %

Moisture content was also found out while taking into account water requirements.

b. Coarse Aggregates

Sargodha crush was used as a coarse aggregate. It was selected due to local availability. The collected crush then passed through a 19 mm sieve, and the rest of the material is discarded. The fraction passing 19 mm sieve then separated into two fractions: one 19 mm down and one 13 mm down. 30% of total aggregates with particle range from 19 mm to 13 mm and 70% of total sums 13 mm down was used in the preparation of the mixes

Figure 1: Sieving of Coarse Aggregates

Table 2: Properties of Sargodha Crush

Property	**Value**
Bulk Density	1465.69 kg/m^3
Specific Gravity (SSD)	2.64
Water Absorption	1.16 %

c. Cement

Ordinary Portland cement type-1 was used. Cement under the brand name of "Maple leaf" was used in the preparation of the mixes.

d. Marble Powder

Marble powder was collected from marble cutting and sawing workshops located near Icchra on Ferozepur road, Lahore. Per bag cost containing non-sieved marble powder of approximately 20 kg weight was 60 rupees. Sieved marble powder obtained from one such bag approximately 3 to 4 kg. Fraction passing sieve no. 100 was used to sieve the material. This fraction was used keeping in view the fineness requirements of powder content.

Figure 2: Sieving of Marble Powder

e. Admixture

Chemrite 303 SP manufactured by Imporient Chemicals (Pvt.) Ltd. was used as a superplasticizer. Its density is 1.06 ± 0.01 kg/liter at 25°C.

f. MIX PROPORTIONING

A control mix was prepared following the (EFNARC, 2002) guidelines. A total of 4 different mixes were made. The mixes were designated as SCC-1, SCC-5, SCC-10, and SCC-15 and SCC-20. Cement was replaced in these mixes as 0%, 5%, 10%, 15%, and 20%, respectively, with 100μm sieved marble powder. The dosage of the admixture was kept constant for all replacement mixes concerning the weight of cement. Initially, the work was started to look into a point where the addition of marble powder ceases to give acceptable fresh properties. The mix design calculations and summary is presented in table 3.3 and 3.4, respectively

Table 3: Mix Design Calculations

Quantity	SCC-1	SCC-5	SCC-10	SCC-15	SCC-20
	(kg/m^3)				
Cement	525	500	475	450	425
Marble Powder	0	25	50	75	100
Total Powder	525	525	525	525	525
Water	185	187.5	189.75	191.55	195.4
Fine Aggregates	825	830	840	850	850
Coarse Aggregates 13 mm retained	225.225	225.225	225.225	225.225	225.225
Coarse Aggregates 13 mm down	525.525	525.525	525.525	525.525	525.525
Super plasticizer	7.875	7.875	7.875	7.875	7.875

Quantity	SCC-1	SCC-5	SCC-10	SCC-15	SCC-20
	(m^3/ m^3)				
Volume of cement	0.1672	0.1592	0.1512	0.1433	0.1353
Volume of Marble Powder	0	0.0096	0.0192	0.0288	0.0384
Volume of Powder	0.1672	0.1688	0.1705	0.1721	0.1738
Volume of Water	0.185	0.1875	0.1897	0.1915	0.1954
Volume of Paste	0.3522	0.3563	0.3602	0.3637	0.3692
Volume of Coarse Aggregates	0.2843	0.2843	0.2843	0.2843	0.2843
Volume of Fine Aggregates	0.3078	0.3097	0.3134	0.3171	0.3171
Volume of Mortar	0.6600	0.6660	0.6736	0.6808	0.6863
W/C (weight)	0.3523	0.375	0.3994	0.4256	0.4597
W/P (weight)	0.352	0.357	0.36143	0.36486	0.37219

Table 4: Mix Design Summary

Quantity	SCC-1	SCC-5	SCC-10	SCC-15	SCC-20
	(Per Batch in kgs)				
Cement	13.90	13.24	12.58	11.92	11.25
Marble Powder	0	0.66	1.32	1.98	2.64
Total Powder	13.90	13.90	13.90	13.90	13.90
Water	3.76	3.96	4.01	4.06	4.16
Fine Aggregates	23.45	23.45	23.45	23.45	23.45
Coarse Aggregates (total)	19.92	19.92	19.92	19.92	19.92
Super plasticizer	0.21	0.21	0.21	0.21	0.21

Mixing was done in a high-speed mixer, with a speed of 300 rev/min. Mixing of ingredients was initiated with preparation if paste i.e., mixing of water, cement, and fillers in two-thirds of water. After the preparation of paste, the aggregates were added to the mixer and admixtures were also added to the mixer. Total Mixing was done in nearly less than 5 minutes.

The water was added in two rounds by pouring two-thirds part of water during paste preparation, and the left one third was used in the development of an aqueous solution of a blend of admixtures, which was added after right after the aggregates were poured in the mixer.

IV. RESULTS

1. TESTS FOR FRESH PROPERTIES

As already mentioned, SCC has three workability parameters i.e. passing ability, filling ability and segregation resistance. The results obtained from these properties may then be used to evaluate the possible cause of the defect in the concrete mix and similarly by identifying the correct cause possible corrective actions can be applied. (EFNARC, 2002) Guidelines ANNEX C contains the troubleshooting guide which can be used to find the faults and their corrective measures to be done in the design mix.

a. Slump Flow Test

Table 5: Slump Flow Test Results

Identity	Slump Flow	VSI	Range	
			Min.	Max.
	(mm)		(mm)	(mm)
SCC-1	672	0	650	800
SCC-5	670	0	650	800
SCC-10	683	0	650	800
SCC-15	690	0	650	800
SCC-20	615	0	650	800

Figure 3:Slump Flow Test (EFNARC, 2002)

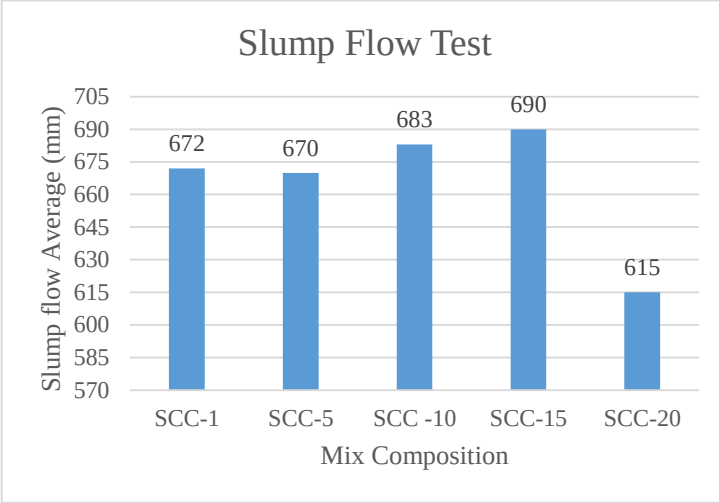

Figure 4: Slump Flow Results (Graphical)

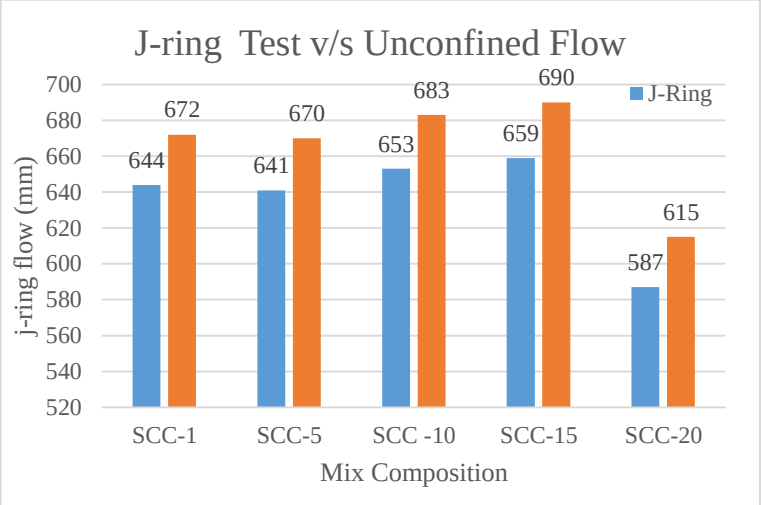

Figure 6: Comparison of J-Ring & Unconfined flow

b. J-Ring Test

Table 6: J-Ring Test Results

Identity	J-Ring Flow	Height difference	Range for height difference	
			Min.	Max.
	(mm)	(mm)	(mm)	(mm)
SCC-1	644	8	0	10
SCC-5	641	9	0	10
SCC-10	653	9	0	10
SCC-15	659	11	0	10
SCC-20	587	13	0	10

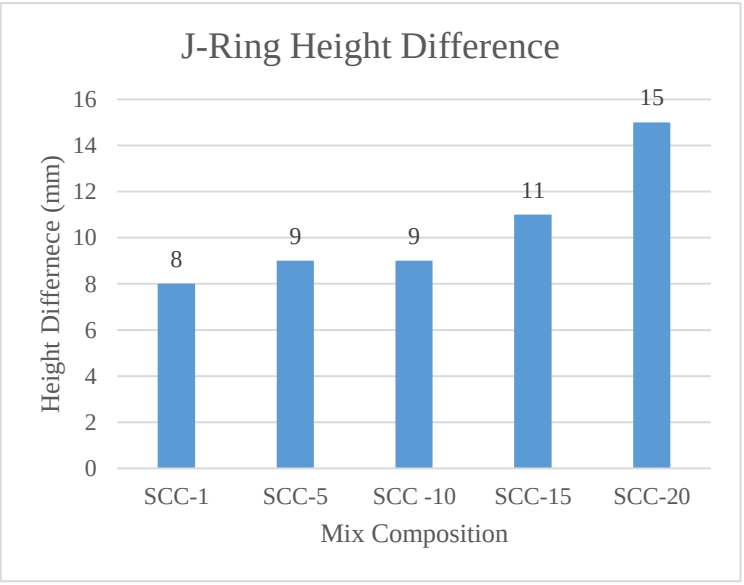

Figure 7: J-Ring Test Results (Graphical)

Figure 5: J-ring Test (EFNARC, 2002)

c. V-funnel at T 5 minutes

Table 7: V-funnel Test Results

Identity	V-funnel	V-funnel at T 5 minutes	V-funnel		V-funnel at T_{5min}	
			Min.	Max.	Min.	Max.
	(sec)	(sec)	(sec)	(sec)	(sec)	(sec)
SCC-1	8.4	8.7	6	12	0	+3
SCC-5	10	11.3	6	12	0	+3
SCC-10	9.2	10.1	6	12	0	+3
SCC-15	9	9.8	6	12	0	+3
SCC-20	9.2	10.7	6	12	0	+3

Figure 8: V-Funnel Test (EFNARC, 2002)

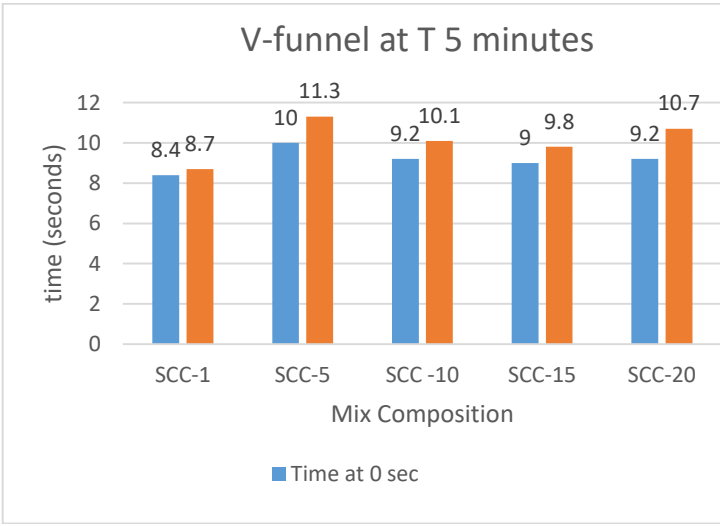

Figure 9: V-funnel at 0 sec & 5 min Results

1. *TESTS ON HARDENED CONCRETE*

Cylinders having a diameter of 150 mm and 300 mm height were cast to evaluate the compressive strength of the concrete mix at the age of 7 and 28 days, respectively.

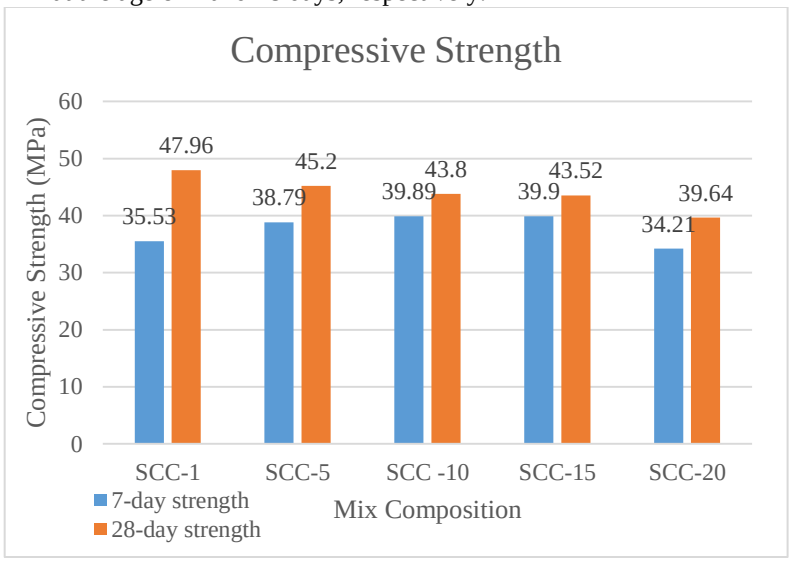

Figure 10: Compressive

Strength Test Results

Figure 11: Performance of Compression Test

V. CONCLUSIONS

1. WMP can be effective filler for SCC concrete.
2. When the fresh properties such as flowability, passing ability, and segregation resistance are considered, 15 % of marble powder replacement has given good results.
3. Marble powder can be used up to 15 % without much affecting the strength. Up to 15% by weight of cement can be said as the most favorable amount of WMP with particle size below 100 μm as filler in producing good quality SCC.
4. It has been observed that marble powder increases the early age strength of the concrete.

VI. RECOMMENDATIONS

1. The effect of WMP on autogenous and drying shrinkage needs to be examined.
2. The effects on durability properties such as corrosion resistance, alkali-aggregate reaction, sulfate attack, and freezing and thawing, etc. need to be studied.
3. Present researches can incorporate 50 % of marble powder in the preparation of SCC while fulfilling its all requirements.
4. The SCC may be studied with different powders e.g. fly ash, ground blast furnace slag, and crushed sandstone, etc.

REFERENCES

[1] Duggal, S., 2008. *building materials.* New Delhi: NEW AGE INTERNATIONAL (P) LIMITED, PUBLISHERS.

[2] K. Maekawa, K. Ozawa & H. Okamura, 1989. *Development of High Performance Concrete.* s.l., s.n., pp. 699-704.

[3] M. Ouchi, K. Ozawa & H. Okamura, 1996. Development of a simple self- compactibility test method for acceptance at job site. Cario, s.n.

[4] Al-Mishhadani, S.A., Al-Rubaie & M.F., 2009. A Database for Self- Compacting Concrete in Iraq. *Eng. Technol. J.,* pp. 1203-1218.

[5] Shaker, R. R., 2015. The spatial distribution of development in Europe and its underlying sustainability cor-relations . In: *Applied Geography.* s.l.:s.n., p. 35.

[6] Barbier, E. B., 2006. *Natural resources and economic development.* s.l.:Cambridge University Press.

[7] Chausee, C. d., n.d. *Ecobuild Brussels.* [Online]
Available at:
https://www.ecobuild.brussels/en/professional/what-meant-sustainable-construction
[Accessed 14 January 2019].

[8] Pinch, L. & Masterson, J., n.d. *Construction Executive.* [Online]
Available at: http://www.constructionexec.com/article/ten-benefits-of-sustainable-construction
[Accessed 14 January 2019].

[9] Saxena, M., Mehrotra, P. & Asokan, P., 2011. Innovative building materials from natura fibre and industrial waste. In: *Land Contam Reclamant.* s.l.:s.n., pp. 355-363.

[10] EFNARC, 2002. *Specifications and Guidelines for Self-Compacting Concrete,* s.l.: s.n.

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Effect of Grain Size Distribution on Geotechnical Properties of Alluvial Soils

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Abstract- **This research work concerns the analysis of the impact of changes in size of grain on the geotechnical characteristics of alluvial soils. So, collected soil samples from The University of Lahore, Lahore, Pakistan. In this research work, special experiments performed moisture, strainer analysis, hydrometer analysis, Atterberg limit (liquid limit and plastic limit), direct shear testing, and unspecified compression testing on our models. After these experiments, it is observed that as the density increases, the internal friction angle of the soil and the unknown force of the soil also increases. It has been observed that moisture content does not greatly affect silt and sand properties, as in the case of clay.**

Index Terms-- **Analysis, Alluvial Soil, Clayey, Compressive Strength, Geotechnical, Soil, Silt, Sand, Unconfined**

I. INTRODUCTION

The importance of soil in development cannot be ignored because no structure is formed in the air. Each construct has direct or indirect contact with the soil. The floor is an internal fabric with a variety of textures depending on the place and the source. Therefore, it is important to properly appreciate soil ecosystems for safe and sustainable growth. There is a great deal of research and a variety of research to understand soil engineering properties. As our turn, we interact with soil clay with the center needed to focus on the properties of these soils with changes in grain size. Alluvial soil fashion occurs when a soil drain slows its carrying capacity more slowly. Slowly, a river does not have enough power to prevent heavy mud; these cells are located along the river bank. To minimize the causes of the movement, remove small cells [1].

The river slows and slows down (its gradient becomes smaller in the lowlands), which contains only unusually beautiful particles of suspension. These cells accumulate at the mouth of the river, where they form a delta of stacked soil. Aluminum (as opposed to Latin, aluminum, sabs, wash) is loose, thick (not strong stone cement) soil and rain, and is re-distributed in some form by water and reproduced in the marine context. [2]. Alluvial sediments are large particles of clay and clay and large particles of sand and gravel. When this loose mixture is deposited in the lithological unit, cemented or stabilized, it is called an alluvial deposit.

The "aluminum" length is not normally used for moisture conditions for another geological method. These include (but are no longer prohibited): lake sediment, river basin (liquefaction) or glacier-derived debris (glaciers). Permanent circulation and / or accumulation in a river is called a specific 'nautical mile'. Since alluvial clay is part of our research work, the primary factor is the grain measurement variable [3].

The size of the grain is also called particle size, and the nature of the residue refers to the grain diameter of the particles in the classic rocks. The term can also be used for other granular materials. It differs from the crystalline form in that it is the same crystal shape in particles or grains. There may be very few crystals in a single grain. Clay materials range from very small impact cells to rocks through clay, sand, sand, and gravel. Most countries and groups categorize soils and measure specific types of soils to estimate their grain size [13].

II. LITERATURE REVIEW

Sand soil flow potential with specific grain compositions. In this research, SPT was performed to obtain results on in-situ parameters. Door inspection clothes have good sand. The end result of the research suggests that the sand structure strongly influences the granular structure and the presence of fine. This increase is attributable to the increase in the proportions of sandy soil volatiles that can be achieved by the drainage-free flow. Therefore, good sand has a wide range of densities and pressures, which are wetter than soft sand.[14].

The flow with two zero residual forces is limited to deposits with very low SPT shocks, which implies that such conditions do not enter the field regularly [4]. Difficulty - Granular country variables and silt sand are difficult. Silt sand samples were used in this search work. In this research, new inter-granular state parameters (and, f) and (e s, e f) are added as country variables to classify silt sand. Using these country variables, these researchers demonstrated the stress-strain electrical behavior of host sand assessments [5]. Reconstructed versus speed reconstructed sand and fine sand models. In this search, we consider the convergence and triangle validation used. Differences in Un-Drain Stresses - Research shows that stress behavior is also dramatic between specimens that are not specified and reproduced in the same space ratio. In all cases, constrained models confirmed weak and elastic behavior, whereas in all cases reconstructed models confirmed compressive behavior [6].

Therefore, variation and stability analysis based on the results of the reconstructed models is very misleading. Although the relative density is greater than 73% (E = 0.73), all the reconstructed models confirm very low altitude and fragile behavior. On the other hand, undefined samples were diluted even though their relative density was only 66% (E = 0.81). In order for the reconstructed moisture model to function similarly to the neutralized model, the reconstructed model undergoes an 80% relative density increase over the cutoff (e.g., 0.66). The next failure is geometry. This finding is demonstrated by incorporating failure in physics and predicting the geometry before failure. The kinetics of failure is assumed to be related to shear force collected during melting, known as flow failure [8]. The strength and hardness of sandy sand. Storage of a three-axis probe and the use of silt sand samples in the bender lookup process is an issue. Research contributions determine how non-plastic fines affect small-stress viscosity and shear strength. The inclusion of a small percentage of sand for cleaning significantly increases the elevation process at each initial density and critical-state friction angle [9].

Failure of the Merispruit Sewing Dam. His research was carried out in February 1994 to detect the failures of a 31-meter golden tail near the village of Merisprat in South Africa. They carried out a UN-verified tri-axial test on samples obtained from the surrounding area. Failure [10]. He concluded that in a meta-stable country, there were once large piercings and that Foxwell's exposure to erosion and erosion contributed to the constant erosion and consequent fracture. Static liquefaction is the purpose of a once pulsed glide slide [11][15]. Monotonic and cyclic decomposition of most sandstone sandstones with high silt content. The samples used in this test are Nevada sand, which has a high content of silt-free plastic. These models include drought and non-drought tri-axis testing, rainfall pre-cyclic triaxial testing and drought/drought instability testing. Researchers have found a significant amount of sand in different amounts than previously published checks [12]. They claim that increased silt content provides greater sensory feedback under pressure - the strain curve.

Monotonic un-drain tests show that `ancestor 'behavior, such as static lubrication, occurs at low turbulent pressures and simultaneously detects a tendency to change volume as the boundary pressure increases[16]. Reduced resistance to sand-silt alloys: An experimental. NS Impact Research. In this invention, the cyclic quarterly experiment was combined with a moderate saturation quality using a non-plastic treatment amount [17].

The international vacuum ratio SNS material, compared to the thread, can reduce and expand the liquefaction resistance of the sand - a non-plastic alloy NS alloy - to increase the lower vacuum content values. Management value. According to the results of the present study, the FC rate is approximately 44%. It should be noted that the threshold value is not FC specific, it depends on the properties of the hard and granular grains and adds E (14) to the global void ratio [18].

III. RESEARCH METHODOLOGY

This research is concerned with the study of alluvial soils with varying grain sizes. Collected three samples of soil from The University of Lahore, Lahore-Pakistan. After the collection of samples, all the research work has been done in UOL Lahore and the following test is performed.

- Moisture content Determination of samples
- Sieve analysis of samples
- Hydrometer analysis of samples
- Atterberg limits of samples
- Direct shear test of samples
- Unconfined compression test of samples

IV. RESULTS

Table 1: Summary of Moisture Content

Sample	Moisture Content (%)
Silt	0.577
Sand	0.499
Clay	1.335

Table 2: Summary of Sieve Analysis (Sand)

Sample Distribution	Percentage (%)
Fine Gravel	0
Coarse Sand	0.006
Medium Sand	0.149
Fine Sand	97.23
Silt And Clay	2.76

Table 3: Summary of Sieve Analysis (Silt)

Sample Distribution	Percentage (%)
Fine Gravel	0
Coarse Sand	0.179
Medium Sand	0.298
Fine Sand	70.25
Silt And Clay	28.82

Table 4: Summary of Sieve Analysis (Clay)

Sample Distribution	Percentage (%)
Fine Gravel	0.588
Coarse Sand	1.61
Medium Sand	1.69
Fine Sand	0.98
Silt And Clay	96.10

Table 5: Summary of Hydrometer Analysis (Silt)

Sample Distribution	Percentage (%)
Fine Gravel	0
Coarse Sand	0.178
Medium Sand	0.29
Fine Sand	70.20
Silt And Clay	28.83
Silt	27.52
Clay	1.53

Table 6: Summary of Hydrometer Analysis (Clay)

Sample Distribution	Percentage (%)
Fine Gravel	0.556
Coarse Sand	1.60
Medium Sand	1.55
Fine Sand	0.94
Silt And Clay	95.10
Silt	51.09
Clay	44.2

Table 7: Summary of Direct Shear Test (Sand)

Density(KN/m^3)	Angle Of Internal Friction (Φ)
15	31.413
16	33.01
17	34.02

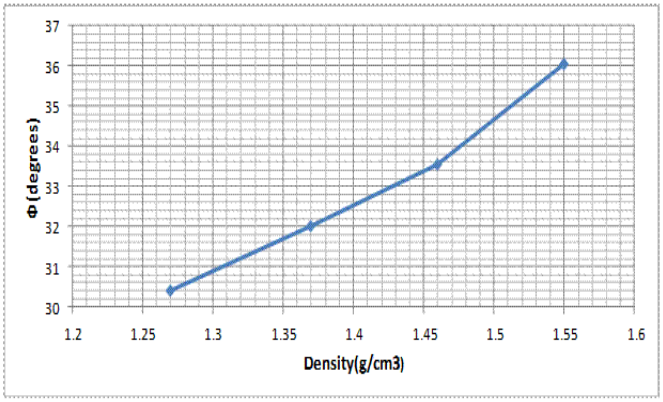

Figure 1: Relation between Density and Internal Angle of Friction

Table 8: Summary of Direct Shear Test (Silt)

Density(KN/m^3)	Angle Of Internal Friction (Φ)
15	27.02
16	29.04
17	30.47

Figure 2: Relation between Density and Internal Angle of Friction

Table 9: Summary of Unconfined compression test (Silt)

Density(KN/m^3)	Cohesion, C (lb/In^2)
17	6.98
18	25.33
19	32.11
20	41.51

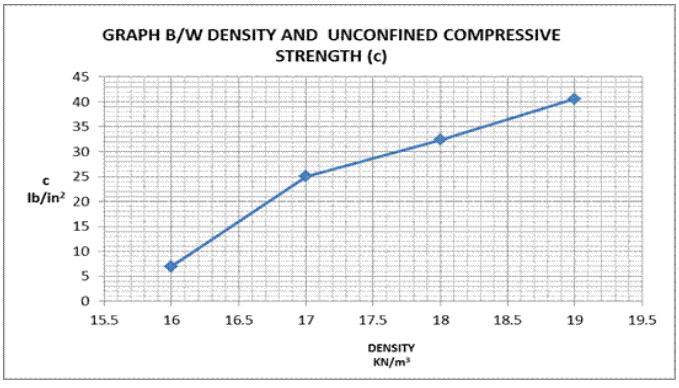

Figure 3: Relation between Density and unconfined Compressive strength

V. CONCLUSIONS

From the results of direct shear research for each sand and silt, it is concluded that the amount of friction inside increases with the density expansion . In the performance of direct shear tests, we found that concentrations of up to 17 kN / m3 can be easily obtained by applying them manually . Obtaining concentrations larger than 17 kN / m3 is very challenging. As the size of the silt increases, the silt is released from the sand, which increases the internal friction system. The difference between the policy values of friction within sand and silt is not so great now. The reason behind this is that our silt contains a large amount of sand (up to 72%). Soil classification results indicate that our silt sample is actually silt sand. The moisture content version does not significantly affect the internal friction attitude of the sand and silt. Immediate deposits of samples in the shear zone will not yield high-quality results. An excellent design is to first compact the pattern into the cutter and then transfer it to the cutting box. This is because we can get the desired density in the cutter. The stress version is not very large in our direct shear test; Therefore, the greater the difference between the pressures used, the greater the results. From the uncontrolled test, it can be concluded that the unspecified compressive stress increases with the expansion of the density. The variation of moisture has a great effect on undefined compressive strength. The results of unconfirmed compression tests show the excellent appearance of molding of the same specimen due to differences in extraction effort. Below are some suggestions to help in future related research work. UUDS (Un-Disturbed Model) is preferred for direct incision tests to get better and reliable results. The compression effort by compact compression applies more than manual compression so that both direct shear evaluation and infinite compression testing can achieve effective results. In addition to the above assumptions, to better understand the effects of grain dispersal on alluvial soils, we have strengthened the search function to perform the following tests. Permeability Test, Triaxial Compression Test, Modified Proctor Test, Resonance Column Test, and Soil Mineralogy.

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REFERENCES

[1] Cubrinovski, M. and Ishihara, K. (2000) "Flow potential of sandy soils with different grain compositions", Soils and Foundations 40(4): 103-119.

[2] Thevanayagam, S. and Mohan, S.(2000) "Inter-granular state variables and stress-strain behaviour of silty sands", Géotechnique 50(1): 1-23.

[3] Høeg, K., Dyvik, R. and Sandbækken, G. (2000) "Strength of undisturbed versus reconstituted silt and silty sand specimens", Journal of Geotechnical and Geo-environmental Engineering 126(7): 606-617.

[4] Olson SM, Stark TD, Walton WH, Castro G. Olson et al. (2000) "1907 static liquefaction flow failure of the north dike of Wachusett Dam", Journal of Geotechnical and Geo-environmental Engineering 126(12): 1184-1193.

[5] Salgado, R., Bandini, P. and Karim, A. (2000) "Shear strength and stiffness of silty sand" Journal of Geotechnical and Geo-environmental Engineering 126(5): 451-462.

[6] Fourie, A.B., Blight, G.E. and Papageorgiou, G. (2001) "Static liquefaction as a possible explanation for the Merriespruit tailings dam failure", Canadian Geotechnical Journal 38(4): 707-719.

[7] Yamamuro, J.A. and Covert, K.M. (2001) "Monotonic and cyclic liquefaction of very loose sands with high silt content" Journal of Geotechnical and Geo environmental Engineering 127(4): 314-324.

[8] Xenaki,V.C. and Athanasopoulo, G.A. (2002) "Liquefaction resistance of sand–silt mixtures: an experimental investigation of the effect of fines", Soil Dynamics and Earthquake Engineering 23 (2003) 183–194.

[9] Ng CWW, Fung WT, Cheuk CY, Zhang L. Zhang et al (2004) "Influence of stress ratio and stress path on behavior of loose decomposed granite", Journal of Geotechnical and Geo-environmental Engineering 130(1): 36-44.

[10] Georgiannou, V.N. (2006) "The un-drained response of sands with additions of particles of various shapes and sizes", Géotechnique 56(9): 639-649.

[11] Papadopoulou, A. and Tika, T. (2008) "The effect of fines on critical state and liquefaction resistance characteristics of non-plastic silty sands", Soils and Foundations 48(5): 713-725.

[12] Yamamuro, J.A., Wood, F.M. and Lade, P.V. (2008) "Effect of depositional method on the un-drained response of silty sand", Canadian Geotechnical Journal 45(11): 1525-1537.

[13] Yamamuro, J.A., Wood, F.M. and Lade, P.V. (2008) "Effect of depositional method on the micro-structure of silty sand", Canadian Geotechnical Journal 45(11): 1538-1555.

[14] Carraro, J.A.H., Prezzi, M. and Salgado, R. (2009) "Shear strength and stiffness of sands containing plastic or non-plastic fines", Journal of Geotechnical and Geo-environmental Engineering 135(9): 1167-1178.

[15] Hazirbaba, K. and Rathje, E.M.(2009) "Pore pressure generation of silty sands due to induced cyclic shear strains", Journal of Geotechnical and Geo-environmental Engineering 135(12): 1892-1905.

[16] Tsomokos, V. N. and Georgiannou (2010) "Effect of Grain Shape and Angularity On The Un-drained Response Of Fine Sands", Canadian Geotechnical Journal, 2010, 47:(5) 539-551, 10.1139/T09-121.

[17] Lupini, J.F., Skinner, A.E. and Vaughan, P.R. (2010) "The Drained Residual Strength Of Cohesive Soils", Géotechnique, Volume 31, Issue 2, pages 181 –213 , ISSN: 0016-8505, E-ISSN: 1751-7656.

[18] Monkul, M.M. and Yamamuro, J.A. (2011) "Influence of silt size and content on liquefaction behavior of sands", Canadian Geotechnical Journal, 2011, 48:(6) 931-942, 10.1139/t11-001.