# Effect of Kaolinite clay and different sand gradation mixture on Compaction parameters

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**Abstract.** In nature various types of soils distributed in such a way that they found together It is very much difficult to find clay, sand, silt, gravel in a pure condition. Also, these soils (clay, sand, silt, gravel) have different geotechnical properties. Although various researchers have focused on effect of clay particles on various geotechnical properties of Sand-Clay mixture. But, sand is available in different size and gradations. So, the effect of sand gradation and various particle size on geotechnical properties of Sand-Clay mixture is still not clear or very less information available about that. In this study effort have been made to understand the effect of clay particles (Kaolinite) on Compaction parameters (OMC, MDD) of various size and gradation of sand.

Experimental work involves the preparation of six samples of sand (i.e 3 Poorly or Uniformly graded and 3 Well graded) from procured materials. Poorly graded samples were obtained by following sand size. Coarse sand (>2mm), Medium sand (>0.425mm & <2mm), Fine sand (<0.425mm). For preparation of well graded samples efforts had been made by combining two or three types of sands i.e Coarse, Medium and Fine (C+M, M+F, C+M+F) Kaolinite clay was used as cohesive fine fraction. Different amounts of Kaolin clay were added in each of the sample i.e 0%, 5%, 10% and 15%. Preliminary tests were performed on all the three well graded, three poorly graded as well as on kaolinite clay in pure condition for finding out the physical properties of the soils. (i.e Atterberg's limits, Grain size distribution, Specific gravity). Relative density test was performed for finding out the density of all the sand samples at 0% Kaolin content ant 70% relative value was adopted. For all other sand-Kaolin mixture (5%, 10%, 15%) Standard Proctor tests were carried out.

Results indicated that among all the samples (Coarse+Medium+Fine+15%Kaolin) exhibits grater maximum dry density (MDD) and lesser optimum moisture content (OMC) while (Fine+5%Kaolinite) have lesser Maximum Dry Density and grater Optimum Moisture Content. So, from the results we can say for (C+M+F+15%) sample all the particles are well arranged so the gap between the particles are minimum so the MDD of the sample goes to increase.

**Keywords:** Kaolinite clay. Sand gradation. Optimum moisture content. Maximum dry density.

## 1 Introduction

Compaction of soil is a fundamental part of any construction procedure. It is utilized for support the structural entities such as foundation of the building, roads and railways, walkways, and Earthen dams, retaining structures are some examples. For a given soil type certain properties may consider it more or less desirable to perform adequately for a particular circumstance. Foundation soil should have satisfactory strength and should be relatively incompressible against the future settlement , volume change should be not occur with varying the water content and other environmental factors and also should be durable and safe against decline also the soil should have appropriate permeability.

Compaction of a soil is an important parameter for finding out the various geotechnical problems, such as building settlement seepage, and also control the stability of soil masses. Muni Budhu mentioned in his book that the maximum dry density basically depends on the soil type [1]. Well graded coarse-grained soils accomplish higher density and lower optimum moisture contents then fine-grained soils. Reason is fine particles have grater specific surface which require more water for lubrication. Type of the soil, particle-size distribution, shape of the soil particles, specific gravity of soil mass, quantity and type of the present clay minerals has a great effect on the maximum dry density and optimum moisture content.

Many factors like particle size and shape, void ratio, degree of saturation and water absorption capacity have greatly influence on soil compaction. Das said In nature it is quite difficult to found pure sand or pure clay but generally various soils found to gather [2]. Generally, all engineering methods and designs are for pure soils only, but in nature is always not possible various soils like aggregate, sand, silt, clay found to gather and it is also difficult to classify the properties of that soils. Dafalla concluded that Sandy soils found in different gradations and soil gradation is also affect on to the characteristics of soil hence, attempts are made by many researchers study the sand-clay mixture and apply them in practical application he also said that In sand- clay if the amount of clay content is small then also the mixture is classified anything other than sand and there is a stage at which the mixture is start as clay and clay domain the engineering property of the mixture [3]. Noor at al. had performed tests on various sand-bentonite mixtures and concluded that for 0 to 10% clay content maximum dry density increases and further increasing of cohesive fraction reduced the maximum dry density. Optimum moisture content increases with increasing clay content from 0 to 20% and clay contents are the reason for the increasing the moisture content [4]. Akyuli at al concluded that in sand-clay mixture it is problematic to established geotechnical characteristics of the mixture because this mixture contains both the properties of sand and clay also. He also established that Cohesion, compression index, plasticity index is increasing with clay content increasing while friction angle and initial void ratio decreases with increasing clay content [5]. Al-Shayayea had concluded that clay particles have domain influence on soil mass even they are available in very small amount he concluded that dry density of sand-clay mixture increases with increasing moisture content and also the clay content up to the certain limit after that it decrease he also concluded that dry density of sand-clay mixture increases with increasing moisture content and also the clay content up to the certain limit after that it decrease [6]. The soil type, shape and size of the soil particles, specific gravity of the soil grains and content, types of clay minerals present in soil - has a great influence on the maximum dry unit weight as well as optimum moisture content. Soil compaction is a useful parameter for increase shear strength bearing capacity of soil, to reduce the settlement and also to reduce the permeability. Pakbaz and Moquaddam state that in nature granular soil contain considerable amount of clay or silt and it is effect on the geotechnical properties of the soil [7]. Wasti and Alyanak worked on sand-clay mixture and conclude that when clay particles fill all the voids of sandy soil then sandy soil change its property sand to clay [8]. According to the ASTM when the percentage of material passing by the sieve no. 200 is grated than 50% it is classified as clay [9]. Khan et al. mixed natural clay with 20% and 40% sand and compaction strength parameters determine and concluded that Compression strength increasing by decreasing water content and decreasing by increasing sand content [10]. Dixo et al. concluded that addition sand content increases the compaction density [11]. Shafiee et al. concluded not only the characteristics of sand and clay but particle size of sand also influences on behaviour of sand-clay mixture [12]. Pakbaz and Moquddam worked on effect of sand-clay mixture and concluded that in sand-clay mixture with increasing sand gradation cohesion increase and angle of friction decrease [13]. American Association of State Highway and Transportation Officials suggested, the fine contents used for a reinforced soil retaining wall is necessary < 15%. However, some other factors also governing, like the accessibility of superior backfill materials and cost of the construction [14]. Elkady et al. mixed 0 to 60% clay with sandy soil and result shows with increasing clay content pore size structure changed [15]. Nagaraj concluded that sand gradation has a great influence on sand-clay mixture, his results shows that medium grained sandy soil and clay mixture have a greater strength as compare to all other sand grades [16]. Srikanth and Mishra made a mixture of 50-90% bentonite clay with fine and medium grained soil and concluded that Fine Sand-Bentonite mixture have higher OMC and lower MDD [17].

## 2 Materials and Methods for Experiments

For the present study work, experimental methodology includes sample procurement followed by preliminary laboratory testing and detailed laboratory testing methodologies. Two types of sample materials were used (i) Kaolinite Clay (ii) Ennore Sand of different gradation.

### 2.1 Following tests were carried out at geotechnical laboratory

- Atterberg limits – Liquid limit was determined by Casagrande apparatus, plastic limit and shrinkage limit were determined as per IS:1498 for the Kaolin clay [21].

- Specific Gravity tests were determined using 50-ml Density bottle for Kaolin Clay and Pycnometer used for different graded sands as per IS: 2720 – Part VI [20].
- Hydrometer tests were carried out as per IS code for finding out grain size distribution of Kaolin Clay as per IS: 2720 – Part IV [18].
- Sieve Analysis for different grade of sands as per IS: 2720 – Part IV [18].
- OMC-MDD tests were carried out using light compaction and 24 – hour soaking duration as per IS: 2720 – Part VII [19].

## 3 Experimental Methodology

The study being an experimental work requires following methodology. Collecting samples, analysis the collected samples, carrying out various experiments on that samples and arising conclusions from the results.

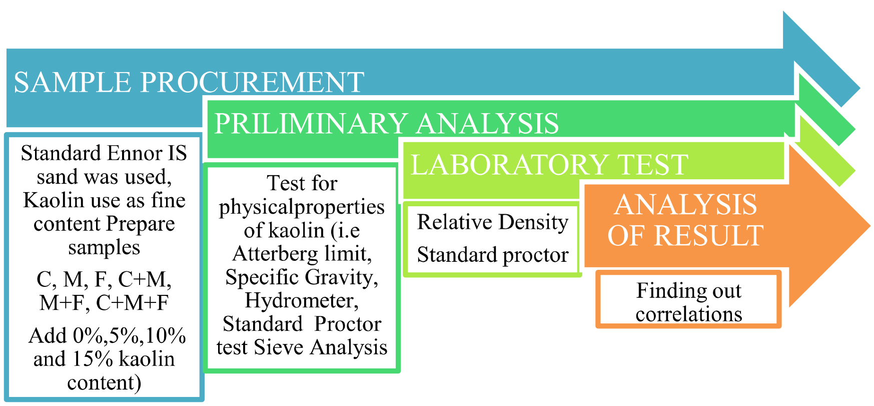


**Fig. 1.** Methods Adopted in the Project

### 3.1 Procurement of samples

In this research two different soil materials were used. Sand samples were procured from the locally available sand supplier. Grade of sand is I$^{st}$ Class & normal silica Ennore sand. They are fit to be used for various construction works & completely free from the cohesive material i.e. purely sandy samples. Kaolin clay was used as a cohesive fine fraction which is commercially available.

### 3.2 Preliminary analysis

Sieve analysis was performed for finding out gradation of sand and the proportions of course(2mm), medium (2mm-0.425mm) and fine (<0.425mm) sand in the sample were separate out; total six samples were prepared with different grades of sand particles. Specific gravity tests were performed for find out the specific gravity of different gradation of sand and kaolinite clay. Atterberg limit, Hydrometer tests were also performed to know the physical properties of kaolinite clay.

### 3.3 Laboratory test

From the procedure six sand samples were arranged with dissimilar gradations. On each set of samples (0%, 5%, 10%, 15%) kaolin would be added. Relative density test would have carried out for finding out the density of various grade of sand for (0% kaolin clay content) standard proctor test were performed for all other samples for find out the OMC-MDD.

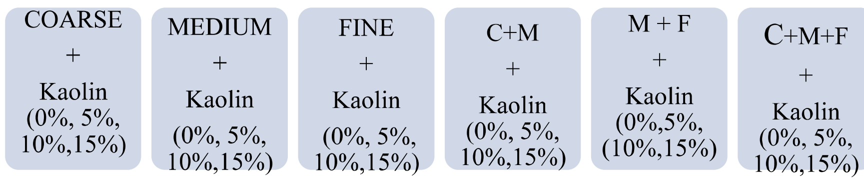


**Fig. 2.** Test Sample Distribution

## 4 Results and discussions

The physical properties of pure Kaolin clay and different gradation of sand will be find out before sand-clay mixing. On kaolin clay Grainsize distribution, Atterberg limits, Specific gravity, standard proctor compaction test was performed. For various grades of sand samples sieve analysis was carried out for making the three well graded and three poorly graded samples.

The results of various relative densities, Standard Proctor test for different grades of the cohesion less soil obtained were analyzed and experiential relations have been also recognized between sand gradation and Compaction.

**Table 1.** Details of laboratory test

| Sr. No | Experiment | Test no | IS reference |
|---|---|---|---|
| 1. | Grain size distribution (hydrometer + sieve analysis) | (01+06) | IS: 2720- Part IV |
| 2. | Specific gravity | 06 | IS: 2720- Part III |
| 3. | Relative density | 06 | IS: 2720-Part XIV |
| 4. | Standard proctor | 19 | IS: 2720-Part VII |

## 4.1 Sieve analysis

From the procedure six samples were prepared in which three samples were poorly graded (Coarse<2mm, Medium 2mm-0.425mm, Fine<0.425mm) and three well graded (Coarse + Medium, Medium + Fine, Coarse + Medium + Fine) samples were prepared. From the plot between percentage finer and particle size, the values of D10, D30, D60, Cu and Cc were determined. D10, D30 and D60 were found from the particle size gradation curve as per IS: 2720- Part-4 [18].

**Table 2.** Sieve Analysis & Specific Gravity Data for Sand Sample

| Sample No. | Coarse Sand (%) | Medium Sand (%) | Fine Sand (%) | $D_{60}$ (mm) | $D_{30}$ (mm) | $D_{10}$ (mm) | ($C_u$) | ($C_c$) | Specific Gravity |
|---|---|---|---|---|---|---|---|---|---|
| 1. | 100 | - | - | - | - | -- | - | - | 2.72 |
| 2. | - | 100 | - | - | - | - | - | - | 2.64 |
| 3. | - | - | 100 | - | - | - | - | - | 2.58 |
| 4. | 50 | 50 | - | 0.6 | 0.45 | 0.3 | 6.2 | 1.02 | 2.68 |
| 5. | - | 50 | 50 | 0.55 | 0.35 | 0.13 | 6.33 | 1.4 | 2.614 |
| 6. | 33.33 | 33.33 | 33.33 | 1.00 | 0.4 | 0.21 | 6.5 | 1.18 | 2.61 |

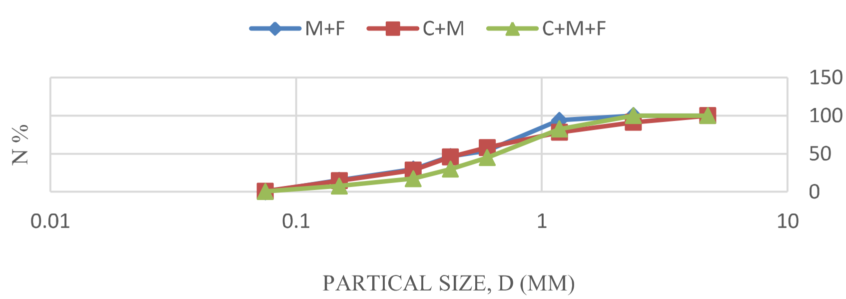


**Fig. 3.** Partial Size Distribution Curves for Well Graded Sand

$$C_c = D_{30}^2 / (D_{10} . D_{60}) \;, C_u = D_{60} / D_{10}$$

Table 2 gives the grain size distribution of various gradation of sand and Specific gravity of various gradation of Ennor sand. for sample 4, 5 & 6; Cu>6 and 1<Cc<3 implying that these are well-graded samples and others samples are uniformly graded samples or poorly graded samples. The specific gravity for fine sand in minimum and it is 2.58 while specific gravity for coarse sand is maximum and it is 2.72. from the above results we can say that as the gain. size goes to increase the Specific density of the soil sample also goes to increase and for the (M+F) and (C+M+F) samples the specific gravity is almost same.

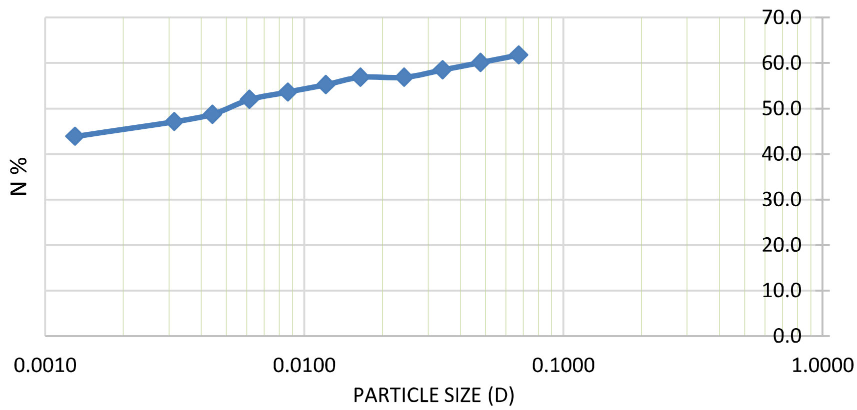


**Fig. 4.** Hydrometer graph for Kaolinite Clay

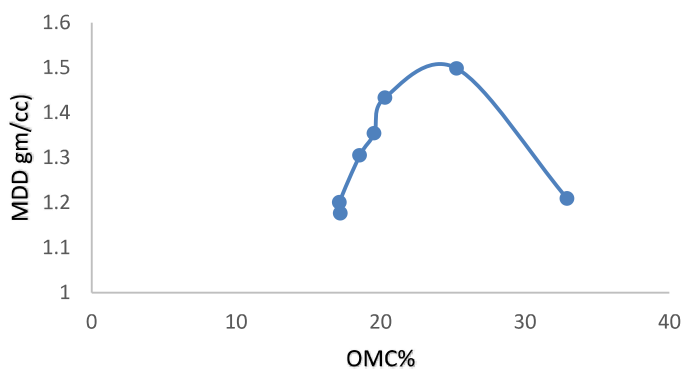


**Fig. 5.** Compaction curve for Kaolinite Clay

As shown in above graph for the Kaolinite clay the total clay percent for the Kaolin clay heaving the clay content of 45%. The specific gravity of the sample is 2.597 Liquid limit of Kaolin is 66.4 while (Ip) of Kaolin is 33.06 so as per the soil classification the soil is classify as CH (Clay of High Compressibility) as per IS:1498–(1970) group [21]. Standard Proctor test had been carried out on the pure Kaolinite clay sample.

Maximum dry density and optimum moisture content had been finding out for the pure kaolinite sample. For the pure kaolinite clay MDD is 1.510 gm/cc while OMC is 24.15%.

**Table 3.** Physical Properties of Kaolinite Clay

| Property | Value |
|---|---|
| Liquid Limit (LL) | 66.4% |
| Plasticity Index (Ip) | 33.06% |
| MDD | 1.510 gm/cc |
| OMC | 24.15 % |
| Specific Gravity | 2.597 |
| Percentage of Clay | 45% |
| Soil Type | CH |

### 4.2 Procurement of samples

Relative density test was performed for finding out the maximum and minimum density of all of the six samples at 0% Kaolin content. This test gives us the maximum and minimum density which is used to find the relative density for the six samples prepared and tested for the relative Density Test.
The maximum and minimum dry densities and void ratios are calculated as follows-

$$D_r = \left(\frac{\rho d - \rho min}{\rho max - \rho min}\right) * \frac{\rho max}{\rho d}$$

$\rho$min = Mass of Sand before vibration / Volume of Sand in mould

$\rho$max = Mass of Sand after vibration / Volume of Sand in mould

$\rho$d = Dry Density in Natural State

**Table 4.** Relative Density data of the prepared samples

| **Sample No.** | **Sample Type** | **$\rho_{min}$ gm/c** | **$\rho_{max}$ gm/** | **$\rho_d$ gm/c** |
|---|---|---|---|---|
| 1. | Coarse Sand | 1.55 | 1.92 | 1.79 |
| 2. | Medium Sand | 1.53 | 1.89 | 1.74 |
| 3. | Fine Sand | 1.5 | 1.88 | 1.72 |
| 4. | Coarse + Medium Sand | 1.65 | 2.06 | 1.94 |
| 5. | Medium + Fine Sand | 1.7 | 2.09 | 1.73 |
| 6. | Coarse + Medium + Fine | 1.7 | 2.07 | 1.86 |

Relative density tests were performed for finding out the density of pure sand for all the six samples (C, M, F, C+M, M+F, C+M+F) and from all of that 70% relative value was selected for all of the six samples. From all above the six samples the relative density for (Medium +Fine) grained soil is maximum while the value for fine grained sand in minimum.

### 4.3 Compaction

Standard Compaction Test was carried for finding out the Optimum moisture content and Maximum dry density of all of the six samples for (5%, 10% and 15%) kaolin content. The results of Maximum dry density and Optimum moisture content are given in below table and relationship for various kaolinite content with the different sand gradations are shown below graphs.

**Table 5.** Compaction test Results

| Sample No. | Clay Percentage | OMC (%) | MDD (gm/cc) |
|---|---|---|---|
| 1. | Coarse +5%Kaolinite | 11.41 | 1.845 |
| | Coarse +10%Kaolinite | 10.82 | 1.873 |
| | Coarse +15%Kaolinite | 10.34 | 1.911 |
| 2. | Medium+5%Kaolinite | 12.14 | 1.78 |
| | Medium+10%Kaolinite | 11.85 | 1.881 |
| | Medium+15%Kaolinite | 10.94 | 1.907 |
| 3. | Fine+5%Kaolinite | 12.29 | 1.748 |
| | Fine+10%Kaolinite | 11.70 | 1.801 |
| | Fine+15%Kaolinite | 11.29 | 1.865 |
| 4. | Coarse+Medium +5%Kaolinite | 10.91 | 1.946 |
| | Coarse+Medium +10%Kaolinite | 10.53 | 1.952 |
| | Coarse+Medium +15%Kaolinite | 10.46 | 1.976 |
| 5. | Medium +Fine+5%Kaolinite | 12.14 | 1.745 |
| | Medium +Fine+10%Kaolinite | 11.85 | 1.831 |
| | Medium +Fine+15%Kaolinite | 10.99 | 1.871 |
| 6. | Coarse+Medium+Fine+5%Kaolin | 10.66 | 1.93 |
| | Coarse+Medium+Fine+10%Kaolin | 10.41 | 1.951 |
| | Coarse+Medium+Fine+15%Kaolin | 10.20 | 1.997 |

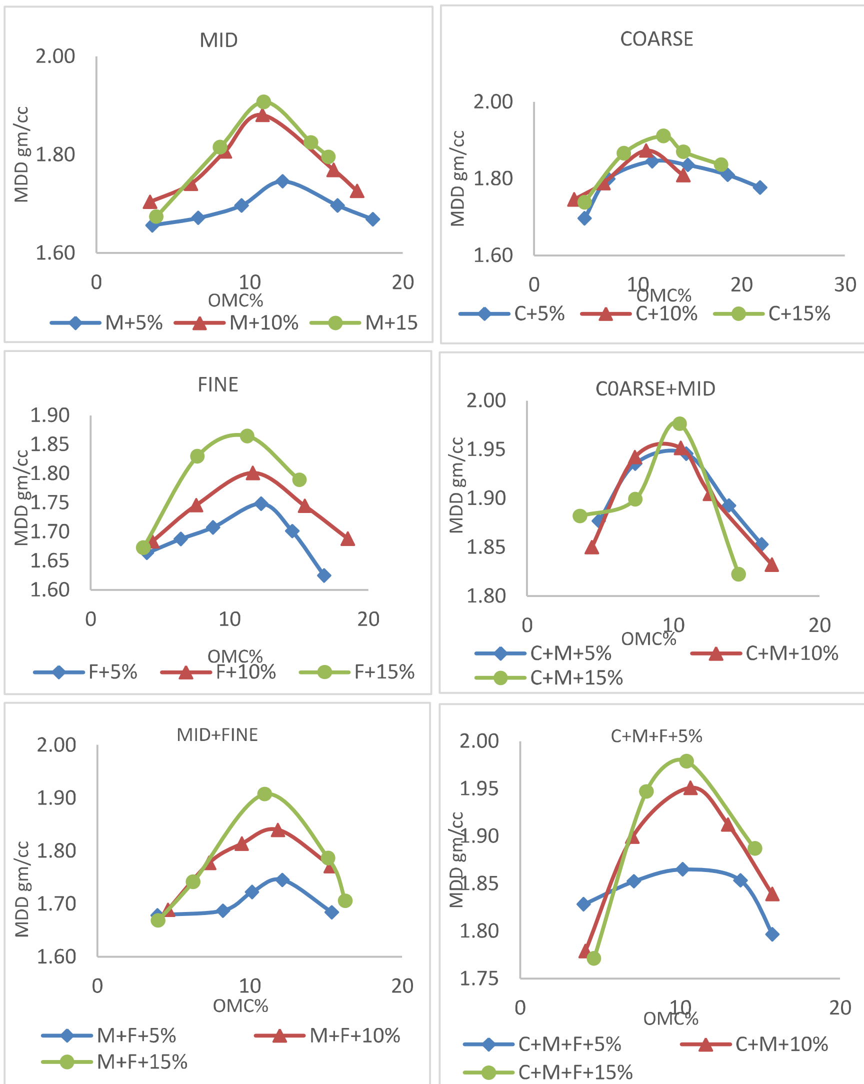


**Fig. 6.** Compaction curves for various sand-clay mixtures

Relative density for cohesion less Coarse-grained soil at 70% relative value is 1.79gm/cc and when the cohesive fine content added to the soil dry density of soil increase up to 1.85 gm/cc by further increasing the clay content again MDD increase.

For Medium-grained cohesion less soil relative density at 70% relative value is 1.746 gm/cc and when cohesive fine content added to the soil dry density of soil goes to increases up to 1.78 gm/cc by further increasing the clay content MDD also increase. For fine grained soil graph also the relative density at 70% relative value is laser than the MDD for (Fine+5%) but as the clay content increases the MDD also increases. For (Coarse+ Medium) grained soil relative density for 0% Kaolin content at 70% relative value is 1.732 and further increasing the clay content MDD of the sample again increases. For (Medium + Fine) grained soil relative density at 70% for the 0% Kaolinite clay is 1.94 gm/cc while MDD for (M+F+5%) sample is 1.745 gm/cc which is much lesser then the relative density of the same sample.  For (C+M+F) grained sample also the relative density of pure clay sample is lesser then the MDD of the (C+M+F+5 kaolinite%) sample. lesser then the MDD at 5% kaolinite of the same samples. While for the samples 2, 3 & 5 relative density at 70% for the 0% kaolinite content is more than MDD for the 5% kaolinite of the same samples. So, from the results we can say that for the coarse-grained sand-Kaolin have grater MDD then the medium and fine grains sand mixture with kaolin for the same So from the above cases we can say that for samples 1, 4 & 6 Relative density at 0% kaolinite clay is proportion of bentonite but from all the six samples (C+M+F+Kaolin) sample have maximum MDD for all the clay contents (5%,10%,15%,20) and the reason is fine particles well arranged in the gap between the coarse particles and so for the well-graded samples formed Hence, MDD for this sample is grater then all other samples. While fine sand has lesser MDD then all other samples.

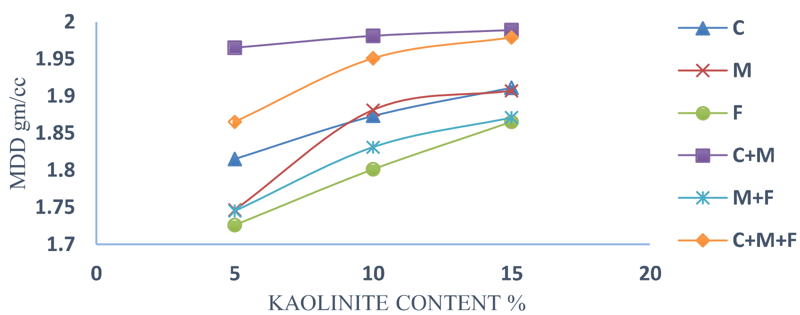


**Fig. 7.** Influence of Kaolin content on Maximum dry unit Weight

### 4.4 Influence of Kaolin content on Maximum dry unit weight

Above graph shows the effect of various Kaolinite content on MDD of various sand gradation. Maximum dry density increases with increasing the clay content from 5% to 15% the reason for the increasing the MDD is kaolin particles fill the gap between the sand particles and increase the MDD.

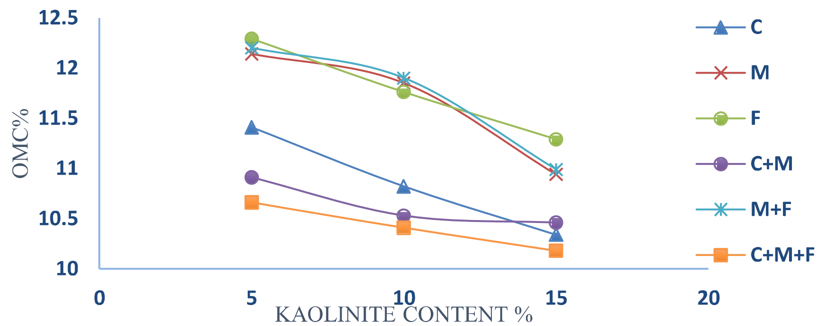


**Fig. 8.** Influence of Kaolin content on Optimum Moisture content

## 5 Conclusion

Compaction is a key parameter to understand nature of any soil. Certain conclusions are arrived that will help in understanding the effect of clay content and particle size distribution on Moisture Content and Dry density. The summary of the findings are as follows:

- Cohesive fine particles have falling effect on OMC & MDD and this effect depends on amount of clay particles.
- Optimum moisture content has been decreases with increasing the Plastic fine fraction for all cases.
- For all the cases Maximum dry density increases with increasing the Plastic fine fractions.
- Among all the cases (F+5%Kaolin) soil has grater OMC while, (C+M+F+15%Kaolin) soil have lesser OMC.
- Among all the cases (C+M+F+15%Kaolin) grained soil has grater MDD and the reason is in this sample all the soil particles are well arranged while (F+5%Kaolin) soil have lesser OMC.
- From Fig.7 we can conclude that for the grater Kaolinite content we have grater MDD so the soil has grater Shear Strength.

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