A very warm welcome to all of you. I am Rajan Choudhary, a professor in the Department of Civil Engineering at the Indian Institute of Technology, Guwahati. Instructor for the NPTEL MOOC course, Pavement Construction and Technology, funded by the Ministry of Education, Government of India. Today's talk will continue our previous discussion under module 8, where we will discuss quality control and assurance-related aspects, and then we will focus on some important aspects related to the granular and earthwork courses. So, at the very beginning, I would like to acknowledge the use of text, information, graphs, and images sourced from various textbooks, codal standards, journal articles, reports, newsletters, and public domain searches. In the previous lecture where we discussed total quality management, we discussed key steps that are to be there.

So, the different key steps that were discussed included the selection of the class of quality assurance depending on the type of project. Then, the information regarding the personnel, specifically the manpower involved and the quality assurance plan, which is very important, was discussed in relation to the different aspects of the quality assurance plan. Then, the quality requirements for different kinds of works, products, finished products, or specialized items that need to be prepared. Laboratory setup to ensure the qualities of these products works both in the lab and in situ.

Then, we discussed the important aspect related to the calibration of inspection measuring and testing equipment, which is very important and therefore should be followed by inspection and testing. This information needs to be properly documented and communicated well. The information needs to be circulated as quickly as possible. Thereafter, the statistical analysis has to be done on the different results that have been obtained to arrive at a decision specifically in terms of acceptance, non-conformance, rectification, and a required third-party quality audit may also be done for the particular project. And we need to ensure the safety, health, and environment during any road construction project.

So, these were some of the things that were discussed as we continue our discussion specifically and as we discussed various terms. So, again, I'm just mentioning certain things briefly. So, the quality of a payment course or layer can be defined by its ability to meet and preferably exceed expectations. So, whatever minimum requirements are there, the target should not only be to reach the minimum targets, but definitely to exceed those minimum targets. So as to meet the expectations of the customer or the owner specifically.

So, in practical terms, this translates to ensuring that we are looking into the key attributes in terms of constructability during this course of time. The layer should be feasible to build with available resources, methods, and within the stipulated time. So, this needs to be taken care of. Second conformance to specifications includes whatever works and products that are fixed under the particular contract agreement. It must adhere to the prescribed standards and technical requirements that are in our standards and will also be mentioned in the contract document.

Performance assurance for the layer, whatever work needs to be done, should meet both structural and functional requirements, ensuring the durability and serviceability of the road project. So, during our discussion today, we will be looking into different codal specifications; some of them are presented here, while many more will be discussed during this particular course of talk. So, this is SP 11, MoRTH 2013 specifications for road and bridge works, SP 112, and SP 11 already amalgamated with the 1112 manual for quality control in roads and bridge works. We will look at some of the standard definitions which have been given. So, the two important aspects are quality control and quality assurance.

So, quality control refers to the tests that are required to control a product, or the product or work that we are trying to produce. So, the quality of that needs to be controlled. So, whatever exercises are specifically done by the concessioner or contractor are the quality control exercises. Then quality assurance, as we mentioned in the previous lecture, also takes care of the quality control and the acceptance part to a certain extent. So, it refers to those tests necessary to make a decision on the acceptance of a project work or a product.

Because finally, what product has been produced that needs to be ensured for acceptance again and helps to ensure that the product evaluated is indeed what the owner specified? So whatever work that has been produced is as per the specifications that were given at the beginning. A three-pillar system can be considered for it; one pillar is quality control, where the responsibility mainly lies with the contractor or the concessioner for achieving the final result. Independent assurance can be done by any agency specifically that does not involve the owner and the contractor. So, any independent agency can be there, as we mentioned that a third-party quality audit was present. So, any independent agency can be involved, and finally, on the basis of this, you have to make a decision on its acceptance.

So, that will rely with the owner of that particular one. Now, while doing this investigation specifically with road-related materials or road-related works, a variability is expected to exist. So is an inherent aspect of road construction activities just as it is in the case of any other manufacturer, because some amount of variability is expected in the product, specifically in road construction projects which are big projects involving a lot of different materials and a lot of different machinery. So, variability is expected to be there. So, the test results of a material or a mix that is produced largely depend upon the variability of its individual components.

So, you may have variability; say a mix is produced. So, in the mix, the aggregates are there, the gradations are there, and different sources of aggregates are there. So, different contents offered are. So, individual component variability can lead to the variability of the final product. The equipment used, the production equipment, the compaction equipment, and even the equipment used for measurement also operate under different conditions.

So, these may introduce some variability into your test results. Projects with well-controlled processes are important; that is why it is essential to complete all exercises to ensure that the process for reaching that particular work or product is well controlled. So that we can produce materials with low variability. We will try to take all measures to ensure that there is less variability; if the control is not good, then we need to monitor it. If you are producing a mix from a wet mix plant, it needs to be controlled when it is laid by pavers.

It also has to be controlled when it is compacted, and the testing you are using to evaluate it needs to be uniform. So, if that control is good enough, you are able to reduce its variability. In addition, significant variation may arise from the sampling procedures and how you are sampling that particular one. So, the sampling also has to be done in a proper manner that can be accepted by all; it can be accepted by the owner as well, and it needs to be accepted by the contractor also. So, the sampling procedures and testing practices, as I mentioned, indicate that certain density gauges should have less variability in comparison to other density gauges.

So, your testing procedures also give some inherent variability to your results. Therefore, we need statistical analysis to become an essential tool for making informed acceptance decisions because we need to inform and we need that to be accepted by all the agencies that are involved. So, most of the characteristics or parameters considered in road construction, for example, may include properties we specifically look into regarding the materials or the work we do, which may be in terms of aggregate gradation, density of the layer, and if it is a bituminous mix, it may include air voids in the bituminous mix and binder content, as well as the stability of those mixes. These are some of the parameters that are worked out, but whenever these parameters are looked into, if we plot the results in terms of the frequency of those results, we usually get histograms in this particular bell-shaped pattern. So, we will have more values near the mean compared to the lesser frequencies at the edges.

So, most of the time we get a badly shaped pattern specifically for the products or materials that we use in road construction. So, the curve drawn through the upper points of such frequency diagrams resembles the normal distribution curve. So, this follows a pattern, specifically the pattern of a normal distribution curve. Recognizing this particular aspect, it is good to follow a normal distribution because it enables the use of a relatively larger sample size to work out the property characteristics of a big section from a smaller number

of samples. So, that is why if we are well aware of what kind of distribution can be there and what kind of variability can be there of that particular parameter, it will help us work out with a relatively small number of tests to reliably predict the characteristics of the entire population or lot.

Here, I mentioned the word "lot"; specifically, in road construction, we refer to lots. We will discuss lots and sub-lots in the upcoming slides as well. It is normally a one-day work which may be there, so in one day's work, a length of section may be constructed, so that we can consider it as one lot. So, in that particular lot, we may divide that job into smaller sections from which we can pick up the samples for our testing.

So, we can do the test. So, that will form our sub-lots. So, with a smaller number, we are able to reliably and confidently predict the characteristics of the entire lot. So, that is what is required by this statistical analysis. Now, certain parameters that are important for the statistical analysis of the results of the different tests we normally refer to specifically in road construction works. One is the variance, which measures how far a set of numbers is spread out; this is for the variance.

Then, we have the commonly used parameter, standard deviation, which is a measure to quantify the amount of variation or dispersion of a set of values; so this is what we have for standard deviation. Then we have the coefficient of variation; it is the ratio of standard deviation to the average of major test results. This is again referred to many times as this particular one. Then we have one more parameter, which is the standard error of the mean, specifically the sample mean. When we are looking for a small number of samples means, the sample mean may differ a bit from your true population mean, so we have the standard error of means.

So, these are certain parameters that are required in the statistical analysis of the results that we attempt for the road construction works. Now, if we have a normal distribution curve, two normal distribution curves are drawn here using the mean and standard deviation for, say, an example of 5 to 10 test results that have been done, so 5 to 10 samples have been tested for particular characteristics. And we plot this particular normal distribution curve. So, in that case, you can see that this particular one has a small dispersion of the data.

So, this is your mean. So, you can see the dispersion of the data is quite less compared to the other one, which is for the b. However, the mean in both cases is the same, but the dispersion, so I can say in one particular set where the control is not good, the dispersion of the results or the variability will be high compared to one particular project where the variability is less. I will always expect and look for a project that has good quality control so that the variability of my characteristic property is less. So, as shown in the figure, both

curves A and B share the same mean, but curve B has a larger standard deviation, indicating greater variability or scatter.

So, that is not preferred. So, the balanced normal distribution curve is symmetric about its vertical axis, with the midpoint representing the mean. Now, if we have the probability density function, then the total area under this particular one will be equal to 1. So, this is the standard characteristic of a normal distribution curve, the normal distribution probability density curve. Now, further if you look into it, any value x can lie to the left; any value can be there. So, we have seen that this is the normal distribution; we can see how much the value varies with respect to the mean on the lower side and how much it can vary with respect to the mean on the upper side.

So, lower, and I can say the right-hand side and the left-hand side. So, any value x can lie to the left (negative) or right (positive) of the mean, and its distance from the mean is measured with respect to the standard deviation. So, it can be measured with respect to the standard deviation, and that particular parameter is important specifically; we call it the standard normal deviate Z. Z is determined, which gives you an idea about the variation from the mean with respect to the standard deviation. So, this is the Z-standard normal deviate, which is calculated in this particular manner.

It gives the idea of how much variation there is from the mean with respect to the standard deviation. Now, these standard deviations are specifically used for the standard probability density curves, specifically for probability distributions of the normal distribution curve, and from there, we can work out the area under these curves. So, the area in the tail beyond a value indicates the probability that the variable will not exceed it on the positive side or fall below it on the negative side. So, for this once you have these standard normal deviates, we will make use of the standard probability tables for normal distribution curves. And here you can see that from this we can work out, say, for a value of z of this one.

What is the area specifically in this one? So that gives us the probability density, specifically how much probability there is that the result is lying in this range and how much probability there is that it exceeds this particular one. So, this help us to get an idea about whether where our results will be is expected to lie. So, this normal standard deviation, which is your Z statistic defined as the deviation from the mean with respect to standard deviation, indicates how far a value deviates from the mean in terms of standard deviation. Now, we use these standard statistical tables specifically for the corresponding area. So, here you can see this is the probability distribution curve, and it can be for any characteristic; if I mention it here, it may be for density, or it may be, say, for air void content.

So, here if the Z has a value of 1, it says that whatever the area under this particular curve less than this one is equals to around 0.8413, and whatever exceeds towards the tail on the

right-hand side will be 1 minus 0.1587. So, for example, it says that at z equals 1, the cumulative area is 0.813 up to this particular point from here to here.

Meaning that there is an 84.13 percent probability that the variable will not exceed this value. So, whatever the case, if we have this Z statistic or standard normal deviate value of 1, it gives an idea that there will not be results which are at least 84.13; results will be there that will not exceed this value of 1. The probability that the variable will not exceed this value is 15.87, so we are getting an idea of this. And similarly, if it is on the negative side, it can be said that depending on it, the variation here is on the right-hand side; if the variation is on the negative side, then similarly we can say that there is an 84.13% probability that the variable will not fall below this value. And whatever is in this particular tail will be there, so that will be again 15.87. So, now if I need to look into what exactly these two limits are to be ensured, then I am trying to see with the probability that my results are in this particular range.

So, it says the probability of a value lying between z minus 1 and z plus 1 is, therefore, 1 minus how much it is exceeding on both ends. So, then there are 68.26. So, if I have a value, a characteristic quantity, or a property that has a Z statistic value of 1. So, there in that particular case, I can ensure that around 68.26 percent will be lying in this variation with respect to the mean and the standard deviation. So, and 68.26 percent will be the results are expected to lie in this range. So, IRC SP 112, in a similar fashion, explains that if we have a value of the standard normal deviate of plus 1, then it indicates an 84 percent probability that x will not exceed the mean plus your standard deviation, and a 16 percent probability that it can go as low as 15.87, rounded off to 16 percent; therefore, there is a 68 percent probability that it is within this particular range.

So, this is on the basis of a standard normal deviate of plus 1; similarly, if I have a minus 1, in that particular case, z plus 1 minus 1 will give me an allowance of 68 percent. Similarly, if this z value is plus or minus 1.64, then I can say that there is a 90 percent probability that it will lie within this particular range. Depending upon this variation, I can work out how much of my data is specifically lying between this particular range. So, this determines how much confidence there is, which is 90 percent in this particular case.

If this is a single limit, and if it works out, then it indicates that I may have a requirement where it can be a lower limit as well as an upper limit. Lower limit says density; I specifically mention that the density should not be less than this one. So, this is called a lower limit. For certain other characteristics, I can mention that the moisture content should not be more than this particular percent, or any other percentages of voids in mineral aggregates, or air void content should not be more than 6 percent.

So that is on the upper end. So, similarly, this is a standard normal deviate for 1.96; it says that in this particular case, you get a 95 percent probability that it is in this particular range.

So, similarly for values of the standard normal deviate of plus 2 and plus 3 as taken from the standard probability tables of normal distribution. So, once we have this particular information, as I mentioned, we need to pick up the sections or the quantum of work for making this exercise. So, for the acceptance of a production of a work under road construction, it is quite often that we need to divide the work into lots and sub-lots, as I mentioned.

So, for that one, a lot is a quantity of material produced from a single source, specifically. So, that means a single source means the variability is one day when we are running a wet mix plant and one day when we are running a hot mix plant. So, we are expecting that there is uniformity in that particular process from that one day's work. So, under uniform conditions, for example, a section of a pavement layer constructed on the same day using the same materials. But yes, there may be chances that in due course, within one day's work, if some variability exists, a major variability exists which is known to you.

Then, we can further consider it as two lots; otherwise, normally in practice, one day's work is considered as one lot. So, a sublot is a division of a lot, specifically used for sampling purposes. So, how can I reduce it to a sub lot, so that I can do some sampling there? So, similarly depending on different kinds of characteristics, we may have to work out around 6 to 10 samples, and that will again depend on how much frequency is stated in our coder specifications or contract agreement for specific characteristics. So, certain characteristics required a greater number of tests compared to the others. So, typically, for example, 6 to 10 sub-lots are considered within a lot, and samples from each lot are tested for properties, which can include density, binder content, or aggregate gradation.

So, the material can be picked up and tested. And, within these sub-lots, it is also important to see that it is mentioned that is why we do not want to put all our sample testing in one place. So, it has to be distributed along the entire lot work, and within those particular sub-lots, the locations also have to be picked up in a random manner. This is another concern that it should not be near the center line, the middle of the lane, or the edges. So, in a random manner, using the table of random numbers, we can decide on the x and y coordinates for our different sample locations. And then the second specific requirement, as I mentioned, there may be certain characteristics where you may require only one limit.

So, for the density part, I am just trying to ensure that the density should be more than, say, the effort required for subgrade construction or granular course construction; my requirement may be, say, 97 percent of the maximum dry density or 98 percent of the laboratory-derived maximum dry density. So, these specifications limit the allowable values set around a target for quality. So, we set certain targets specifically based on characteristics. A limit may be a single specification, and a single specification may be either a lower limit or an upper limit; that upper limit, if an aggregate, is where I pick up a particular sieve where a material has a certain percentage passing or any particular

characteristics, which may be in terms of shape. So, should I mention that the shape of the aggregate should have a combined flakiness and elongation index value of 35 percent? So, it should not go beyond 35 percent.

So, this is my upper specification limit, and there may be certain requirements; similarly, it is for impact also. It may be 24 percent, 27 percent, and there are certain requirements where it should not fall below a certain limit, which may be in terms of binder content and density as well. So a limit may be a single specification limit, either an upper specification limit or a lower specification limit, and there may be certain characteristics that have an upper specification limit and a lower specification limit, as we have in the case of air void content. Say, for bituminous mixes, the air void content may be in the range of 3 to 5 percent. So, there is a lower specification limit, and there is an upper specification limit as well.

So, I need to ensure that it lies within both the upper and lower specification limits. So, this is a quality measure. Now, on the basis of that, we need to work out what the quality of the work is. So, a quality measure evaluates a material, layer, or component against a specific quality. So, we can measure the quality of a particular work in terms of different attributes or characteristics.

It may be meeting one characteristic but may not be meeting the other characteristics. So, you should be well aware that one particular work needs to be ensured in terms of what characteristics. And finally, we need to go for statistical acceptance. So, the common measures include percent defective and percent within limits. So how much quantum of work is there that is outside the limits, and how much quantum of work or how much of your results is within the acceptable limits? So, we have the percentage defective and the percent within limits.

These are the two terms that are very commonly used. So, these measures are quite preferred as they efficiently capture both the average level and the variability of the characteristics, which I can show you. So, the first one is percentage within limit. So, now you can see in this particular distribution of the results, the normal distribution of the results; you can see if I put up the lower limit and the upper limit here. So, the percentage within limit is the percentage of the lot falling above the lower specification limit. So, what I require is that if there is a requirement of 3 to 5 percent air void content, then I will put up this, even if this may be for any other volumetric parameter in the case of bituminous mixes, like we have the voids filled with bitumen, where we say that the voids filled with bitumen should be in the range of 65 to 75 percent.

So, we have both the lower specification limit and the upper specification limit. So, whatever percentage falls outside of it is the percentage defective, and whatever results lie in this particular one will be your percent within limits. So, percent within limits is the

percentage of the lot falling above the lower specification limit and beneath the upper specification limit; that is the range between the lower specification limit and the upper specification limit. It is similar to determining the area under the normal probability density curve, where the normal curve is bounded by the lower and upper specification limits, and we work out what percentage of the area falls outside of those specification limits. So, the percentage within limits is estimated using the sample mean and the population standard deviation; this is what we work out in a similar fashion as we explained in the previous slides.

So, the percentage within the limit indicates that if it is a single limit, it can be 100 minus the percentage defective, and this defective can be on the upper side as well as on the lower side. So, this can be the percentage defective if it is a single limit. So, percentage defective on the lower side or percentage defective. So, whatever goes beyond it or whatever goes lesser than this particular one. So, that is the case when single limit criteria are present and percent within limit if you have both the criteria for the upper specification limit and lower specification limit.

So, then you have this one. Now, on the basis of this particular one, we get the percentage of defective items. So, now what is the percentage that lies outside indicates the percentage of the lot falling outside the specification limits. So, you can fix it so that I require only 5 percent of my results to fall outside my specification limits; only 5 percent of results are allowed to fall outside of it. So, we need to ensure in our specifications for this particular one that only 5 percent of results can be, and depending on the requirement, if it is only one limit, we can mention that only 5 percent of the results can be lower than this particular value, or 5 percent of results can be more than this particular value. Now, percent within limits indicates the percentages of the lot conforming to the specification limits, and many times on the basis of this percent within limits, we introduce a pay factor; also, if the percentage within limits is ensured well, on the basis of that percent within limits, we can release the payment for a particular work.

So, this is also practiced in different countries, specifically based on how good the quality control is; on that basis, we can release the payment or even give a bonus if we find that the quality control is good enough. So, in respect of the following materials, a statistical analysis procedure is adopted for quality control, specifically what it says for the works related to earthwork. So, now as I mentioned, it depends on how many samples have to be tested. So, as per the requirement of SP 112, it states that for earthwork for embankment, the quality characteristic that is usually ensured is compaction.

So, we ensure for compaction. And what is a typical lot size? So, it says around 3000 square meters, but is limited to a single day's production work. So, if the single day's production work is less than that, we will consider that as a lot; we will not accumulate 2 days' work to form 3000 square meters. And then how many sub-lots can there be? So that we at least

get 10 samples to ensure the compaction quality. Similarly, it applies to subgrade. We need to go for a smaller area that is 2000 square meters, but if we are not able to produce any work that is less than 2000 in one day, the lesser amount will be considered.

Again, sample numbers are to be done. So, we conduct the compaction test and ensure it. And how the information is recorded is very, very important; you can see this is a format that has been taken from SP 112, which mentions the source and location of the lab, as well as the material sources and records from the bore area where the sample has been taken, optimum moisture content, maximum dry density that is to be ensured, and the date on which this particular test is conducted. At what chainage has this test been conducted, and on which layer are we doing this particular one? What is needed during the sand replacement procedure is specifically the standard sand. So, what is the bulk density of the sand that has been used? So that we are able to look into its variability. As I mentioned, the testing procedures' variability can also introduce variability in your test.

Weight of sand in the cone, so if the setup is a bit changed, what you have used in one particular location has changed with respect to the other one. And then we finally record the individual observations, and it has been. Who has prepared this particular one, and who has ensured this one? So, all this is how the information must be recorded in a proper manner. Now, similarly, these quality characteristics are to be ensured for granular courses as well, and where it states that if I am using a material, say for granular sub-base course, then the compaction, again, what specific characteristics are ensured is field density to give the acceptance, rejection, or any rework that is allowed, and here it is mentioned again that 2000 square meters is good enough, and we can go for 5 samples in that case. When it is for the wet mix mechanism typically used for base courses, this particular one is in terms of compaction density, and we usually go for an area of 2000 square meters limited to a single day's work with 6 samples.

As I mentioned earlier, these are tentative; these are some guidelines in terms of the number of samples you require. Depending on the actual variability that is occurring, if you find that a certain section has more variability, you can opt for a larger number of samples in that particular case. Now once those quality characteristics are present, as the compaction density has been in the granular courses and the subgrade. Thereafter, we try to ensure the acceptance; the acceptance is in this particular manner as this is for a 95 percent confidence level when we are looking specifically for single limits because here, we are trying to ensure the density part. So, this acceptance criteria have been that if the mean of the values of all test results of the sample is more than the specified value, it is considered acceptable; otherwise, it is less than the specified value.

These are the two cases: specifically, there can be an upper specification limit and a lower specification limit. Specifically, if we are checking for the compaction density, it will be the lower specification limits only. Now, it says that in that particular case, the mean should not be less than the specified amount, plus this particular one. But if there is some upper specification limit, then it should not be more than the specified limit minus this particular one standard deviation. So, here it says this is specifically when we use more than, more than, and positive if lower specification, if I have a requirement that my density should be for my compaction density.

So, my mean density should be more than the specified one, which may be said to be 97 percent of your MDD plus this into the standard deviation. If there is a certain requirement, as I mentioned, it can be in terms of the air void content or in terms of any particular aggregate gradation characteristics; then it states that this should be less than the specified value minus this particular one times the standard deviation. So, the number of samples has already specified how many samples you have to pick for it. Now, once you have this particular one, you are able to work out the number of the lot you have decided, the sub-lots you have decided, you have done the testing, you have verified whether it is meeting the requirements, and as I mentioned, if it falls within certain sections, what actions have to be taken if it is not meeting the requirements. So, one possibility is that your contract document will mention that certain elements may be present or works may be available that can be reworked; specifically, as I mentioned, if some aggregate gradation is not working out, then I can rework that material with some additional material to reach the desired gradation.

If density is not working out for a subgrade course, I may open it up, add water to it, and recompact it to meet the specified requirements, but this should be specified in the course. So, for example, an aggregate stockpile filling gradation requirement for a particular work may be mixed with aggregates of suitable sizes so that now the blended aggregates meet the requirement. So, this can be one way of doing the acceptance if something is falling out of it. Second is accepted with a reduced pay factor. As I mentioned, if the percent defective is more than a certain percentage, then, if the clause permits, there can be a particular job that can be accepted, but only up to a certain limit and with a reduced pay factor; that means whatever the earlier price or cost that has been fixed for it will be reduced specifically.

So, all these that have to be already there should be mentioned in your contract document; then only can these be exercised. The third possible option can be regraded for alternatives, whatever material you have. You may find it unsuitable for a particular course if you have a granular course gradation that you do not find good enough. If you find a particular soil not good enough for one task, you can explore it for some other tasks. If it is not suitable for subgrade construction, you can explore it at certain locations where some embankment construction is present to determine whether it can be used at that particular location.

So, it can be explored in that way. And if there are certain jobs that cannot be considered under the previous three categories, then they need to be rejected, and they must be reworked or replaced. The work has to be removed and reconstructed. So, if none of the above options normally work, this has to go in this particular manner. Now, as I mentioned, the applicability of a particular option to a particular material, other than one, is a typical exercise where we especially work, which is a common exercise that may not be possible with all different courses. But usually, for subgrade granular courses, the one common exercise that is worked out, other than options 1 and 4, shall specifically be when we are looking into 4, which is a complete rejection; you are not accepting that particular course, and it has to be removed.

First, you are doing a small amount of exercise to bring it to the required specification. But these two, what is in between that can be used for some other use or a reduced pay factor should be in accordance with the conditions of the contract specifically mentioned therein. So that should have been specifically mentioned already. So, this is where we discuss some of the aspects related to the statistical analysis tools that we employ to judge the variability of the materials used in road construction, and we discuss some of the characteristic properties that we need to look for, specifically in earthwork and granular courses. In the next lecture, we will look again at the characteristics of bituminous mixes to ensure their quality. Thank you so much.