Process Equipment Design
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Lecture –44
Design of Packed Column-2

Hello everyone. I welcome you all in the 4th lecture of week 9 of the course Process Equipment Design and here we are discussing the packed column. And this topic we have started from the last lecture where we have defined the packed column, we have seen the applications of packed column, we have seen how to select packed column as well as plate column and further we have discussed the basic requirement based on that proper packing should be selected.

And here in this lecture we will specifically focus on types of packing. So, as far as type of packing is concerned that points we have also covered in the last lecture that basically we have two classes. First is the random packing and second is the structured packing. So, as far as this packing is concerned random packing as the name says that can be put randomly in the column.

We simply fill the column with these packings and as far as structured packing is concerned it means it is basically arrange in a proper structure or in the proper behavior or we can say the proper arrangement is done when this type of packing is used in the packed column. So, first of all we will focus on random packing.

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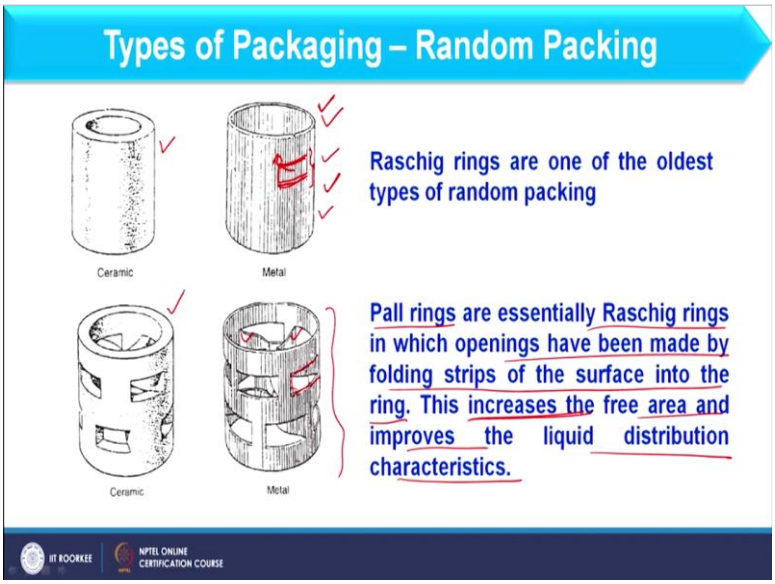

Let us see what are the different types of random packings available. The very common is basically the Raschig rings. So, as far as this type of packing is concerned it is the oldest type of random packing and if you see its structure it is basically like small cylinder and here we have the Raschig rings of the metal and here it is consider with ceramic. So, you can say ceramic has large thickness in comparison to metal to sustain same pressure conditions.

So, this type of packing are very small type of cylinder like if you have a small diameter tube and that you cut in a definite size. So, that is nothing, but the Raschig rings and that type of packing you must have considered while carrying out experiment in packed column in mass transfer course. So, being a chemical engineer you all have done that experiment. So, I hope that you all know this type of packing.

So, let us discuss few more packings. So, next packing we have is the Pall rings if you consider this is also with the shape of cylinder as we have discussed with the Raschig rings. So, these are basically Pall rings which are essentially the packing rings in which openings have been made by folding strips of the surface into the ring. So, what is done in this ring like if I am having this random packing that is the Raschig rings.

Here you basically open certain section. So, this section we cut, however, this particular section is attach with this Raschig rings. So, if I will cut this section and fold inside so here we can obtain the opening, but this strip is not disconnected from the ring that is already attach and it is folded inside as you can see here, you can see here like this. So, that is basically we can say the revised Raschig rings where internals are properly made.

And when we have this type of folding of the strip inside the ring we can have proper surface area or we can consider proper free area within the ring. So, in Pall rings free area is basically increased which improves the liquid distribution characteristics that you can understand that we have the opening and that metal strip is folded inside so we can have proper distribution within the ring also.

Whatever liquid is moving through the ring it will be properly distributed it will not accumulate inside the ring also. So, that we can have proper interaction of liquid as well as gas and similarly we can consider that design in ceramic rings also. So, these are basically Pall rings.

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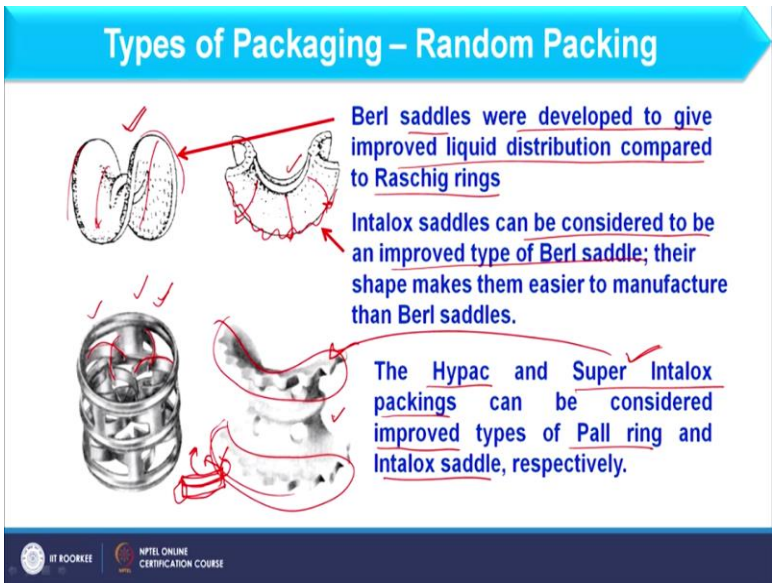

And next we have Berl saddle. So, this type of packing that is Berl saddles were developed to give improved liquid distribution compared to Raschig rings. So, you can consider this is basically the Berl saddle and how it is prepared when I am having the circular metal sheet and from two end we will fold like this and from two end we will fold like this. So, if you make flat of it is basically circular shape.

So, in this way we can consider the Berl saddles and because of this curved nature we can get proper distribution of the liquid in comparison to Raschig rings. And similarly we can have another type of packing and that we consider as intalox saddle. So, you can see here I am having the intalox saddles and these can be considered to an improve type of Berl saddle

because in Berl saddle here we have the curved structure and here we have the curved structure.

However, more uniform curved structure is available in this intalox saddle. So, you can simply consider this as a tube which is cut from the center so that we consider as the half tube and then you consider the small sections of that along the length and then we can fold that length in curved manner. So, that is basically the intalox saddle and after that we can have few more designs as far as this packing is concerned.

And these are very advanced type of packing which we call as Hypac and super intalox packing so this is basically the Hypac and if you consider here what will happen? This is the revised Pall ring. So here in Pall rings what happens we can have certain cut of the strip along the length of the packing. So, if I consider this as the total cut which we have to do we can simply consider half of this and half is basically cut from this side, this side and this side.

And second half we will cut from this side, this side and this side. So, first half will be connected with the ring from this side and second half will be connected with the ring from this side. So, from here I can fold this inside and this section I can further fold inside. So, in this way you can find this and this curve. You can find this curve as well as this curve. So, it is basically advanced Pall ring and we consider that as Hypac ring.

So, it basically offers more and more interaction of liquid and gas because of proper distribution of this, but as far as this design becomes complicated you can understand that cost of the packing will also keep on increasing. So, we have to be very careful about selecting the proper packing depending upon the cost as well as the operation we want and further if we have super intalox packing.

So, this is basically this packing which is of this shape, but with the curved sections as you can find here. So, curvatures are having zig-zag type of shape. So, these are basically considered as improved types of Pall ring I am discussing about the Hypac and the intalox saddle when I focus on the super intalox packing. So, in this way you can consider different types of random packing.

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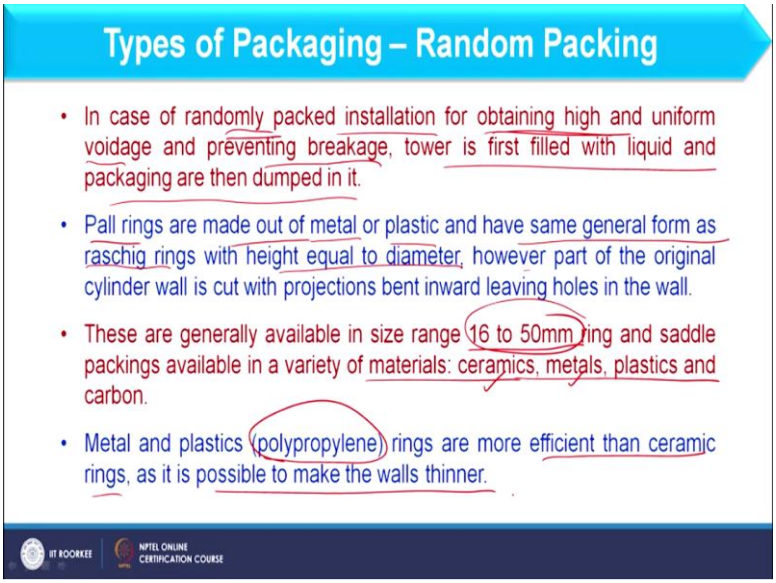

Now, let us focus on some points about the random packing such as in case of randomly packed installation for obtaining high and uniform voidage and preventing breakage tower is first filled with the liquid and packing are then dumped in. So, we can simply put the packing not in an empty column, but we can first fill the column through the water and then we put the packing into this.

So that packing can be dumped properly in the column and we can see the proper distribution of the liquid along the packing. If I consider Pall rings these are made out of metal or plastic and have same general form as Raschig rings with weight equal to the diameter. So, when I consider the size the size is basically L / D is 1 when I am considering a single ring and that is also followed in Pall ring.

So, as far as size of random packing is concerned these have a definite size such as 16 to 50 mm rings and saddle packing is also available in this size range in a variety of material such as ceramic, metal plastic and carbon. So, we have previously focused on ceramics as well as metal rings and metal and plastic that is made of polypropylene. These rings are more efficient in comparison to ceramic ring as it is possible to make wall thinner.

So, when you compare the metal ring as well as ceramic ring you have observed that ceramic ring have more thick wall. So, that we can reduce when we replace the ceramic material with plastic or metal, but ceramic material has also its advantage that it can sustain high temperature. So, according to the temperature we should choose proper packing, but if we

can have the choice we should choose the metal as well as plastic packing first in comparison to ceramic.

Further, we can consider Raschig rings if you consider its design it is very simple and so it is cheap also.

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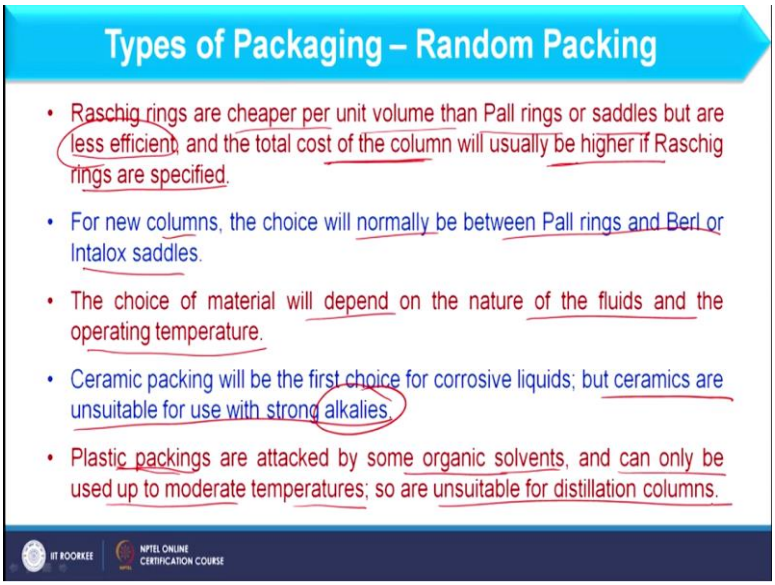

So, Raschig rings are cheaper per unit volume in comparison to Pall rings or saddle, but these are less efficient. So, if I am having the less cost that can be offset by less efficiency also because it does not have proper distribution of liquid inside the ring. It has a simple cylindrical wall and over that whatever interaction of liquid and gas occurs that can be considered.

However, that distribution cannot be improved until and unless I am not going to use Pall rings or saddle. So, the total cost of the column will usually be high if Raschig rings are considered. So, what is the point over here that Raschig rings are very cheap as far as cost is concerned, but because of less efficiency we have to provide more and more Raschig rings. So amount of Raschig rings in comparison to Pall rings or we can say the total material which is involved in Raschig rings that can be much high in comparison to Pall ring when I ensure same efficiency.

So, sometimes cost of column become higher when I choose Raschig rings even though the cost of ring is very less. So, for new column the choice will normally be between Pall rings and Berl or intalox saddle. Choice of the material will depend on the nature of the fluids and

the operating temperature. As I have already told that ceramic kind of material can sustain high temperature which is not possible for metal as well as plastics.

And as far as corrosive nature of the packing is concerned so that we should keep in mind that packing should not be corroded while doing the operation. So, in that case if fluid is having corrosive nature because you cannot change the fluid whatever mass transfer is occurring between gas to liquid and the type of fluid that you have to consider. So, if fluid is having corrosiveness nature we should select packing properly.

And what is the proper packing that should be of ceramic. So, instead of metal and ceramic in that case we should consider ceramic as a material of construction for such packing. On the other hand ceramics are basically unsuitable for use with strong alkalies. So that also we should keep in mind. So, everything will depend on the fluid which you are dealing in packed column.

Further, we should consider that plastic packings are attacked by some organic solvents and can only be used up to moderate temperature so are unsuitable for distillation column. So, when I consider the distillation column I should not choose plastic as a material because distillation column usually consider at high temperature when we consider the lower section of distillation column where reboiler is available. So, packing should be chosen properly.

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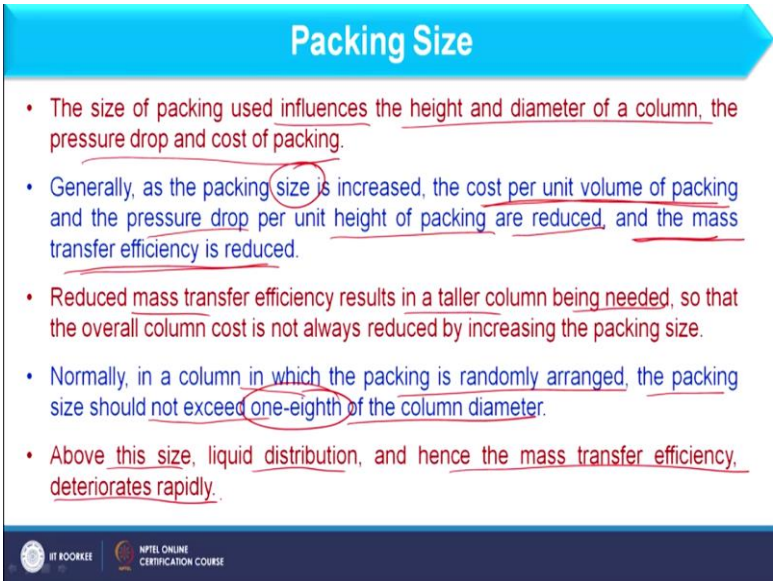

Now we will discuss that how the packing size should be selected? So, the size of packing used influences the height and diameter of the column and the pressure drop and cost of the

packing. So, size is very important. So, when we consider the size of the packing as the size of the packing increases the cost per unit volume of packing and the pressure drop per unit height of the packing are reduced.

So, if you consider the lesser size we can have more friction when the fluid is passing through the column and so we can have more pressure drop and in that case we can have more cost of ring per unit volume of the packing. So, that we have to consider while selecting the proper size of the packing. Further, the mass transfer efficiency is reduced when I consider larger size of the packing.

And reduce mass transfer efficiency results in taller column being needed. If I consider the same separation because mass transfer efficiency is less. So, we should put more and more packing and so the height of the column will be increased. So, what we can observe over here when I increase the size of the packing obviously the cost will reduce, cost of the packing will reduce.

But to meet same separation efficiency we have to consider more and more packing, more and more height of the packed column and so the overall cost of the packed column will increase even I am considering larger size packing which has lower cost. So, you can consider all these points while selecting the proper size of the packing. Normally in a column in which packing is randomly arrange the packing size should not exceed one-eighth of the column diameter.

So, here I am having the guideline because based on the packing size we can directly calculate the cost of the packed column. And further we should consider that above this size liquid distributor and hence the mass transfer efficiency deteriorates rapidly. Above this size means when size of the packing exceeds one-eighth of the column diameter. So, in that case we should choose the proper size which should follow this guideline.

And what should be the proper size depending upon the column diameter it also has some definite guideline that we will discuss in subsequent slides.

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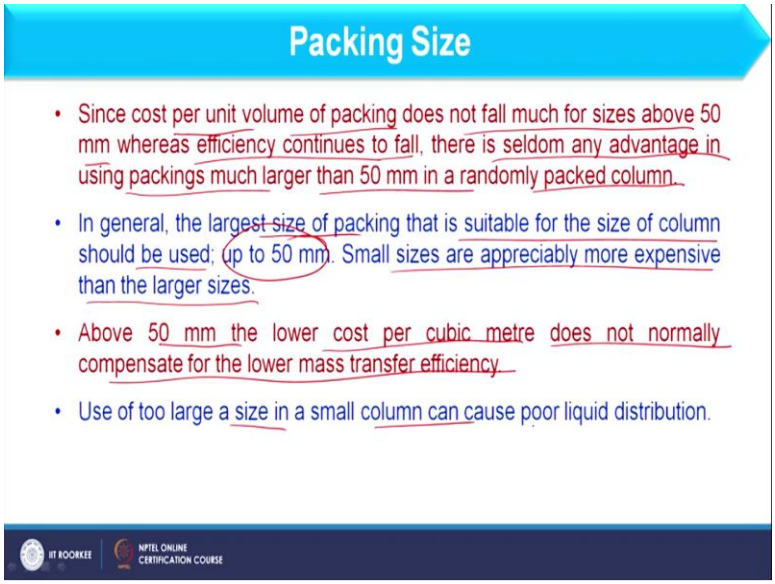

Further, since cost per unit volume of the packing does not fall much for sizes above 50 mm whereas efficiency continues to fall. There is seldom any advantage in using packing much larger than 50 mm in randomly packed column. So, here you should have the guideline that packing should be less than 50 mm because above that cost will not affect much however efficiency of the column reduces significantly.

So, that we consider while selecting the size of the packing. Larger size of the packing that is suitable for the size of column should be used and that is up to 50 mm. Small sizes are appreciably more expensive than the larger sizes. However, we can have more efficiency also when I consider small size packing. Above 50 mm the lower cost per cubic meter does not normally compensate the lower mass transfer efficiency.

So that point we have already discussed. Further, use of too large in small column can cause poor liquid distribution. So, that is basically disadvantage for packed column because we should consider proper distribution of liquid and so we can have proper mass transfer between gas and liquid and which we cannot find when I consider large size packing in a small column.

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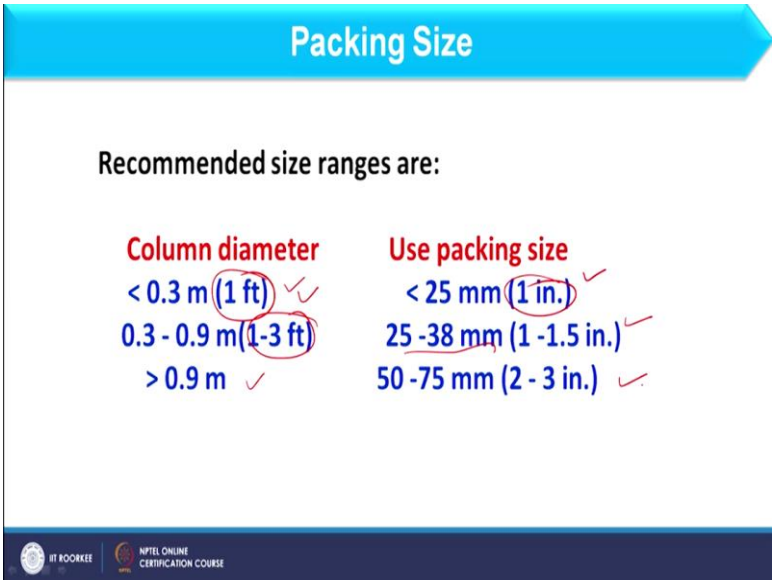

So, based on these guidelines I am having some recommendation for the size of the packing depending upon the column diameter. If column diameter is less than 0.3 meter that is one feet we should choose packing which is less than 25 mm in size and that will be close to one inch. From 0.3 to 0.9 meter that is 0.1 to 3 feet we can choose packing between 25 to 38 mm and beyond that is 0.9 meter above we can consider 50 to 75 mm packing.

But in that case 50 mm should be the desirable size, but everything will depend on the operation you are performing in packed column and so you can select the proper size. However, what are the basis of selection of that we have already discussed.

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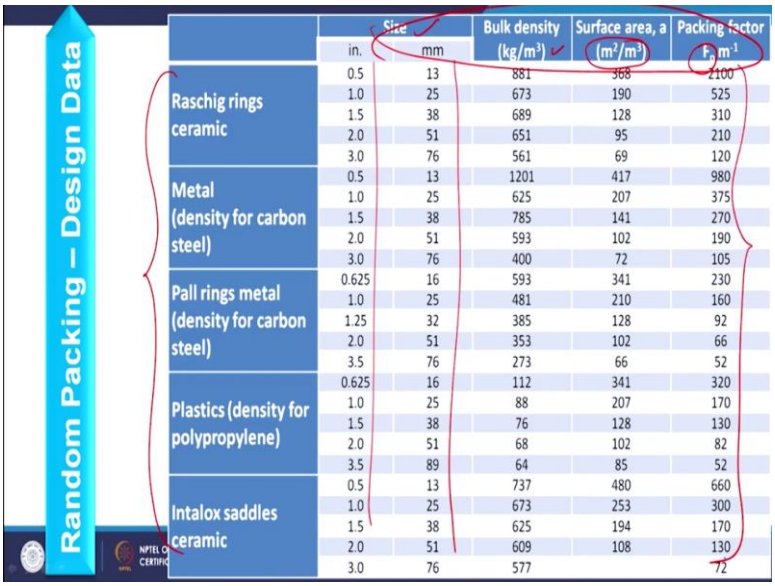

	Size		Bulk density	Surface area, a	Packing factor
	in.	mm	(kg/m³)	(m²/m³)	F_p m^{-1}
Raschig rings ceramic	0.5	13	881	368	2100
	1.0	25	673	190	525
	1.5	38	689	128	310
	2.0	51	651	95	210
	3.0	76	561	69	120
Metal (density for carbon steel)	0.5	13	1201	417	980
	1.0	25	625	207	375
	1.5	38	785	141	270
	2.0	51	593	102	190
	3.0	76	400	72	105
Pall rings metal (density for carbon steel)	0.625	16	593	341	230
	1.0	25	481	210	160
	1.25	32	385	128	92
	2.0	51	353	102	66
	3.5	76	273	66	52
Plastics (density for polypropylene)	0.625	16	112	341	320
	1.0	25	88	207	170
	1.5	38	76	128	130
	2.0	51	68	102	82
	3.5	89	64	85	52
Intalox saddles ceramic	0.5	13	737	480	660
	1.0	25	673	253	300
	1.5	38	625	194	170
	2.0	51	609	108	130
	3.0	76	577		72

And here we have some data for the random packing and this data we call as the design data and you see here I am having different types of packing and here we have some of the

properties like size. So, that size is given in inches as well as in mm. So, what is this size this size is basically the height of the ring. When we consider the Berl saddle size is basically it is diameter when I consider intalox size is basically the length of the one packing.

We can have bulk density of the packing, surface area that is basically the interfacial surface area that is meter square per unit volume of the packing and next we have the packing factor which we consider while designing the packed column and you can choose the value accordingly depending upon the size as well as type of packing.

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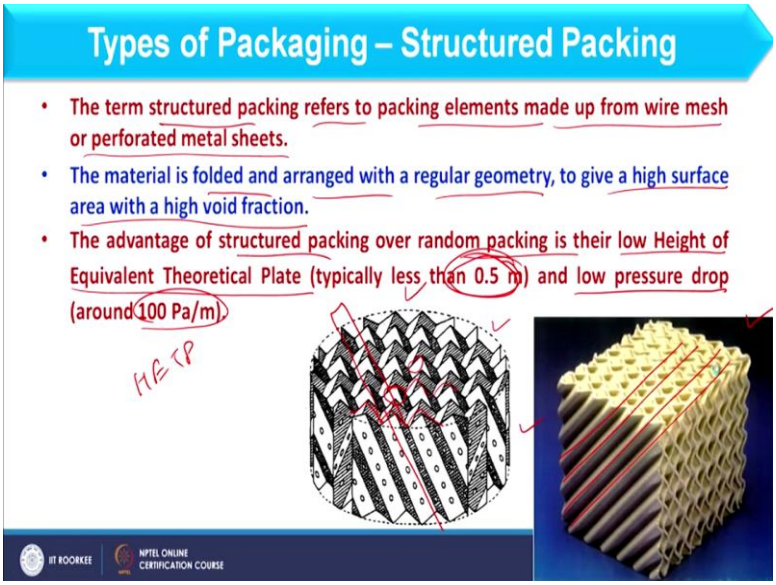

And now we have another class of the packing that is the structured packing. So, that you can understand structured packing are basically when we arrange the packing in a proper or in a definite manner. So, what these packings are? The term structured packing refers to packing elements made up from wire mesh or the perforated metal sheets. As you can see here we can have proper arrangement of the wire as well as metal sheet.

And you can see this type of arrangement and throughout you can find this type of arrangement. So, whatever next block of this packing will be available that should be fitted properly over this. So, whatever openings are there this opening should continue above as well. So in that way you can consider the structured packing. So, in this type of packing material is folded and arranged with the regular geometry to give high surface area with high void fraction because whenever I am considering these opening these are basically void.

So, this void that is the void fraction is high in structured packing in comparison to random packing. So, advantage of structure packing over random packing is there low height of equivalent theoretical plate. So, this is basically HETP and that is less in structured packing and that we consider usually as less than 0.5 and it has low pressure drop that is 100 pascal per meter.

So, when I consider the random packing because of the randomness more friction is created and so we can have more pressure drop along the length. However, in structured packing the arrangement is so definite that we can have less pressure drop and high efficiency. So, height of equivalent theoretical plate means what? It means that whatever convergence or whatever separation we are obtaining on a single plate that convergence or that separation can be obtained in how much height in the packing that we consider as height of equivalent theoretical plate and that is very less in structured packing that is less than 0.5 meter.

So, this figure you can consider as another type of structured packing. So, here you can observe the holes properly and the next block of this structured packing can be arranged just over this so that this void should be uniform. So, void should not break when I consider the arrangement of the packing. So, you can consider that in random packing we can have more pressure drop as well as more HETP value.

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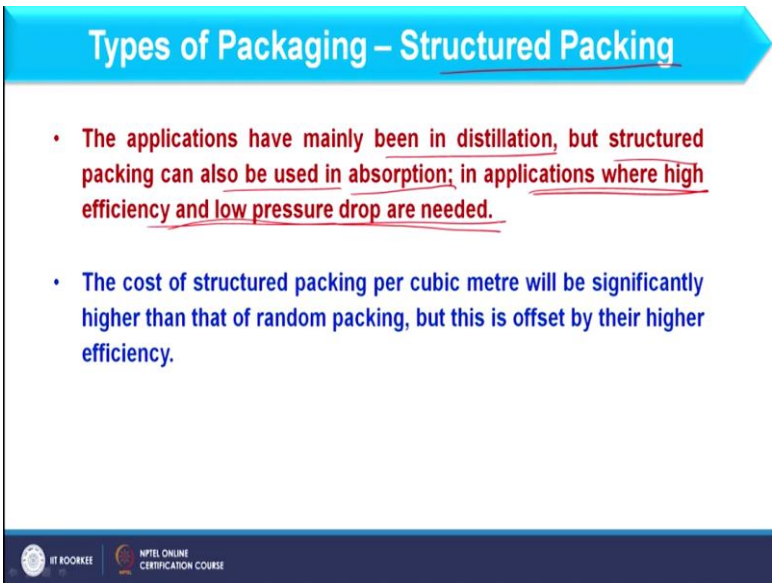

Further, as far as application of structured packing is concerned these are mainly used in distillation. However, structured packing can also be used in absorption in applications where high efficiency and low pressure drop are required. So, in this way you can select the proper

packing among the class of packing that is random packing and structured packing. However, as far as cost of structured packing is concerned because of definite shape of it as well as definite arrangement of this the cost per unit volume of the structured packing is very high in comparison to random packing.

However, that can be offset by high efficiency which we can obtain in random packing. So, you can select the proper packing accordingly. So, here we have discussed different types of packing and these types of packing we have further consider in each class that is random as well as structured. In structured packing, the shape are not varying much however more shapes are available in random packing.

So, all these points you can consider while selecting the proper packing and in this lecture we are considering this part only. So, that is all for now. Thank you.